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Determination of color parameters of gamma irradiated fresh and dried mushrooms during storage

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Abstract

The visual appearance of mushrooms is one of the first quality determinants made by the Ghanaian consumer. Color parameters were measured for fresh mushrooms (Pleurotus ostreatus) irradiated at 0, 1, 2 and 3 kGy at a dose rate of 1.7 kGy hr-1 after harvest (0 day) and then measured after storage (5 days). Dried mushrooms were exposed to gamma radiation at 0, 0.5, 1, 1.5 and 2kGy at the same dose rate and stored in polythene and polypropylene packaging materials and stored for a period of 12 months. The effect of gamma radiation on colour was monitored at 0, 3, 6 and 12 months. The colour parameters for the colour change were quantified by the Hunter L (whiteness/darkness), a (redness/greenness) and b (yellowness/blueness) system. These values were also used for calculation of the total colour change (ΔE), chroma (C), hue angle (H) and browning index (B.I). There were significant differences (P< 0.05) for L, a*, b*, chroma, hue angle, browning index and overall colour change of fresh and dried mushrooms over the storage periods. There was an increase in a*-values while L*, b*, C and H values decreased. This study investigates the effect of ionizing radiations on the colour quality of oyster mushrooms during storage showing its suitability of usage in food preservation.*

Keywords: *Gamma radiation, mushrooms, color, chroma, hue angle, colorimeter.L*a*b**

1. Introduction

Colour attribute of a product is of prime importance to the consumer as a product quality criterion, since consumers associate it with freshness and is critical in the acceptance of a particular product among others (Campbell et al., 2004). Producers strive to prevent products with defective colorations from reaching the market (Pedreschi, et al., 2000; Abdullah et al., 2004; Hatcher et al., 2004) because when they do not, their prices are significantly affected (Cui et al., 2004) or are rejected by the consumer (Lopez et al., 1997; Waliszewski et al., 1999) . When an object is visually assessed; three physical factors must be present. There must be a source of light, the object, and a light receptor mechanism (Vidal et al., 2010). The colorimeter generates a composite three parameter L*a*b* number. The CIE 1976 L*a*b* is an approximately uniform colour scale (Hunterslab Technical Manual, 2008). It is used extensively in many industries throughout the world which is sometimes referred to as the CIELAB color difference metric.

Mushrooms are one of the useful, delicious and mysterious members of the biosphere (Saifullah, 2012). Oyster mushrooms (*Pleurotus* spp.) are consumed in many parts of the world owing to their characteristic taste and flavour (Obodai et al., 2003; Dundar et al., 2008; Zawirska-Wojtasiak et al., 2009; Somashekar, et al., 2010; Guillamon et al., 2010; Wan-Rosli and Aisha, 2013). They have nutritional as well as medicinal properties (Kortei, 2011; Mahmood, et al., 2011). They are low in calories, fats, sodium, carbohydrates and cholesterol, while being rich in proteins, minerals, vitamins and fibers (Kortei, 2011; Gupta, et al., 2011). Antioxidant and antitumor activities of *Pleurotus sp*. have also been reported (Lindequist et al., 2010; Singh et al., 2012; Oyetayo and Ariyo, 2013).The highly perishable nature of mushrooms remains a problem for the progress of this industry in Ghana. In fact, fresh mushrooms can only be stored for a few days until they lose freshness and quality. There are many methods to extend the shelf-life of mushrooms. Among the various methods employed for preservation, drying is one of the common methods used for mushrooms (Kar et al., 2004; Walde et al., 2006; Kotwaliwale et al., 2007; Argyropoulos et al., 2011; Kumar et al., 2013).

A potentially attractive alternative is exposure to ionizing radiation, and previous work have suggested this method is highly effective in inhibiting physical changes associated with postharvest deterioration and maintaining a fresh product appearance (Kader, 1986; CAST, 1996; IAEA, 1992; ASTM, 1998; Adu-Gyamfi and Appiah, 2012). Food processing by employing radiation is well established as a physical, non-thermal mode of food preservation (cold-pasteurization) that processes foods at or nearly at ambient temperature. Irradiation of food products causes minimal modification in the flavor, color, nutrients, taste, and other quality attributes of food. However, the levels of modification (in flavor, color nutrients, taste etc.) might vary depending on the basic raw material used, irradiation dose delivered, and on the type of radiation source employed (gamma, X-ray, UV, electron beam) (Bhat et al., 2007; Bhat and Sridhar, 2008; Mexis et al., 2009).

The objective of this study was to evaluate the effect of gamma radiation on the color parameters of fresh and dried mushrooms stored in packaging materials.

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2. Materials and methods

2.1 Mushroom species used and growth parameters

Pleurotus ostreatus originally from Mauritius, were cultivated on *Triplochiton scleroxylon* sawdust composted for 28 days, supplemented with 1% $CaCO_3$ and 10% rice bran as described by Obodai et al., 2003**.** This was carried out at the Mushroom Unit of CSIR- Food Research Institute, Accra, Ghana. Growth and harvesting of mushrooms was from the period of September to December, 2013. The collected fresh mushroom material were kept in polythene and polypropylene containers and stored. Some fresh was solar-dried at temperature range of (50- 60°C) to a moisture content of about 12±1%. Dried mushroom parts were cut up and stored in tight-seal polythene and polypropylene containers at room temperature until needed.

2.2 Irradiation of Mushroom Materials

Forty (40) grams of dried mushrooms (*Pleurotus ostreatus)* were packed into polythene and polypropylene containers and irradiated at doses of 0, 0.5, 1, 1.5 and 2 kGy while sixty (60) grams of fresh mushrooms were also stored in same containers and irradiated at 0, 1, 2, and 3 kGy at a dose rate of 1.7 kGy per hour in air from a cobalt- 60 source (SLL 515, Hungary). Radiations absorbed were confirmed using the ethanol-chlorobenzene (ECB) dosimetry system at the Radiation Technology Centre of the Ghana Atomic Energy Commission, Accra, Ghana.

2.3 Determination of Colour

In the CIE L*a*b* uniform color space, the color coordinates are: L*—the lightness coordinate; a*—the red/green coordinate, with +a* indicating red, and -a* indicating green; and b*—the yellow/blue coordinate, with +b* indicating yellow, and -b* indicating blue. The L*, a*, and b*coordinate axis defines the three dimensional CIE color space. Thus, if the L*, a*, and b* coordinates are known, then the color is not only described, but also located in a quadrant (Schnell et al, 2005).

The colors of irradiated fresh mushrooms were measured immediately after harvest (0 day) and after storage period (5 day) at room temperature and in polythene and polypropylene containers. Also irradiated dried mushrooms were measured after drying (0 month) and during the storage period (3, 6, and 12 months) with a Minolta CR-310 (Minolta Camera Co. Ltd, Osaka, Japan) colorimeter. The colorimeter has a beam diameter of 8 mm, three response detectors set at 0 viewing angle and a CIE standard illuminant C with diffuse illumination. This illuminant is accepted as having a spectral radiant power distribution closest to reflected diffuse daylight.

The machine was calibrated with a reference white porcelain tile (L_o=97.63; a_o=0.31 and b_o=4.63), before the determinations. The colour space parameters L (lightness, ranging from zero (black) to 100 (white), a* (ranging from +60 (red) to -60 (green) and b* (ranging from +60 (yellow) to –60 (blue) were measured in triplicate and means reported.

Chroma (C) measures color saturation or intensity and the hue angle (H°) describes the relative amounts of redness and yellowness where 0 °/360 ° is defined for red/magenta, 90 ° for yellow, 180 ° for green and 270° for blue color or purple, or intermediate colors between adjacent pairs of these basic colors (McGuire, 1992; Voss, 1992; Schnell et al., 2005; Pedisic et al., 2009). A lower hue value indicates a redder product. Hue angle and chroma were calculated from a* and b* values according to the following formulae (Wrolstad and Smith, 2010):

$$\text{Hue angle } (^\circ) = \arctan (b^*/a^*) \quad (1)$$
$$\text{Chroma} = \sqrt{(a^{*2} + b^{*2})} \quad (2)$$

The color difference if pretreated samples, ΔE, was calculated in relation to the control sample (Saricoban and Yilmaz, 2010) as follows;

$$\Delta E = [(L_0-L^*)^2+ (a_0-a^*)^2 + (b_0-b^*)^2]^{1/2} \quad (3)$$

where L_0, a_0 and b_0 are values for initial. L*, a* and b* are values for the final/pretreated sample.

The browning index was calculated using L*, a*, b* according to Mohammadi et al., (2008);

$$\text{Browning Index (B.I)} = \frac{[100\,(x- 0.31)]}{0.17} \quad (4)$$

where:

$$X = \frac{(a^* + 1.75\,L^*)}{(5.645\,L^* + a^* - 3.012\,b^*)}$$

$$\Delta C = L^* \text{ control} - L^* \text{ sample} \quad (5)$$
$$\Delta H = H^\circ \text{ control} - H^\circ \text{ sample} \quad (6)$$

Browning index (BI) represents the purity of brown colour and is considered as an important parameter associated with browning (Lopez-Malo, 1998).

3. Results and discussions

Color parameter results obtained for fresh mushrooms irradiated at 0, 1, 2 and 3 kGy for storage on 0 day showed that whiteness (L*-value) of irradiated fresh mushrooms ranged between 60.46- 61.30, while a-value (red/green) and b-values (yellow/blue) ranged 3.47- 3.91 and 18.13- 19.39 respectively. There was no significant difference in the initial parameters of L*, a* and b* with respect to the variation in doses of gamma radiations. The values obtained were within range for findings of some researchers (Kotwaliwali et al., 2010; Wan- Rosli, 2011) who investigated changes in textural and optical properties of oyster mushroom (*Pleurotus spp.*) during hot air drying and colour, textural properties, cooking characteristics and fibre content of chicken patty added with oyster mushroom (*Pleurotus sajor-caju*) respectively. However, Mami et al., (2012) recorded higher values for effect of gamma radiation on color of *Agaricus bisporus* during storage. The metric chroma (C), hue angle (H) and browning index (B.I) were in values of ranges from 18.53- 19.70, 77.92- 79.85 and 35.3- 41.2 respectively.

After five (5) days of storage, there was a general decrease in luminosity (L*-values), which ranged between 59.86- 61.18 but showed no significant difference (P>0.05).The red/green (a*-values) increased and ranged between 3.54- 3.98 and showed no significant difference (P>0.05). The yellow/blue (b*-values) decreased and ranged between 18.09- 19.27 and showed no significant difference (P>0.05). According to Aktas et al., (2011), decreasing of the L* values in these applications supported the decreasing of b* values namely occurring of slight browning which is attributed to non enzymatic browning (Kotwaliwale et al., 2010). Whiteness is known to be affected by physico-chemical properties and pretreatments (Matser et al., 2000).

The observed metric chroma (C), hue angle (H) and browning index (B.I) at the end of the storage period were of the range 18.51- 19.59, 77.76- 79.59 and 35.3- 41.2 respectively. There was a general decrease in (C) values. Goncalves et al., (2007) reported that lower (C) value indicates an increase in tonality of the mushroom color. This observation was in disagreement with work of Sasnauska et al., (2011) who reported an increase in metric chroma values of apples during storage. The hue angle range was within the 90^{o} region which suggests an apparent reddish yellow color (Pedisic et al., 2009). Browning index was also low which gives an indication of a slow rate of occurrence of enzymatic browning.

The total differences of the color parameters of fresh mushrooms after five (5) days are presented in Table 1. The total color change (ΔE) during the storage period for fresh mushrooms was in the range 0.13- 0.61. Total change in luminosity (ΔL*) ranged from 0.07- 0.6, change in redness/greenness (Δa*-values) ranged between -0.01- 0.03, change in yellowness/blueness (Δb*-values) ranged between 0.03- 0.13, change in metric chroma ranged between 0.04- 0.11 while change in hue angle ranged -0.07- 0.29.

Table 1: *Total colour change of fresh mushrooms due to effect of gamma radiation after 5 days of storage*

Dose (kGy)	Δ L*	Δ a*	Δ b*	Δ C	Δ Hue Angle	Δ E
0	0.6	-0.07	0.12	0.11	0.26	0.61
1	0.07	-0.07	0.13	0.11	0.29	0.13
2	0.19	-0.01	0.08	0.07	-5.08	0.21
3	0.12	0.03	0.03	0.04	-0.07	0.13

The results of color parameters of dried and irradiated mushrooms during the twelve (12) months period of storage are presented in Table 4. There was a decrease in luminosity (L-values) of the fresh and irradiated of 5 day storage which ranged from 59 - 61 to a range of 56- 59 which occurred for 0 month of irradiated and dried of both storage packs (polythene and polypropylene). This represents the transition from fresh to dry. Statistically, there were significant differences (P< 0.05) between all the L*, a*, b* parameters.

For the 0 and 3 months, there was a gradual change in the color parameters. The L* values decreased gradually and ranged between 51.30- 59.85. For the first month of storage, gamma ionizing radiation doses and storage packs interactions caused significant changes (P<0.05) (Table 4). However, the 3rd month resulted in apparent minimal effect of doses on L* values causing no significant change (P>0.05) for mushrooms in polythene packs (Table 2). The a* values increased slightly and ranged between 4.15-5.30 which caused significant changes (P<0.05). The b* values decreased generally and ranged between 11.00- 15.73 and caused significant changes (P<0.05).

The metric chroma, hue angle and browning indices for dried and irradiated mushrooms stored in the storage packs are

Table 2: *Colour parameters of dried mushrooms due to irradiation and storage (period 0 - 3 months)*

Time	Package	Dose(kGy)	L*	a *	b *	Chroma	Hue	B.I
0 month	Polythene	0	58.92^{c}	4.18^{a}	14.57^{e}	15.16^{e}	73.99^{d}	35.3
		0.5	56.66^{b}	4.64^{c}	12.65^{b}	13.47^{b}	69.86^{b}	29.4
		1	56.83^{b}	4.15^{a}	13.00^{c}	13.65^{c}	72.30^{d}	29.4
		1.5	58.09^{b}	4.17^{a}	13.82^{cd}	14.43^{cd}	73.20^{d}	29.4
		2	59.04^{c}	4.38^{b}	14.23^{d}	14.89^{e}	72.89^{d}	35.3
	Polypropylene	0	58.27^{bc}	4.64^{c}	14.22^{d}	14.96^{e}	71.93^{bc}	35.3
		0.5	53.29^{a}	4.88^{cd}	11.00^{a}	12.03^{a}	66.08^{a}	29.4
		1	58.64^{bc}	5.00^{d}	14.95^{e}	15.76^{f}	71.51^{bc}	35.3
		1.5	56.95^{b}	4.73^{c}	14.08^{d}	14.85^{e}	71.43^{bc}	35.3
		2	59.85^{c}	4.59^{c}	15.54^{ef}	6.20^{fg}	73.54^{d}	35.3
3 month	Polythene	0	56.93^{b}	4.19^{a}	14.58^{e}	15.17^{e}	73.97^{d}	35.3
		0.5	55.72^{b}	4.61^{c}	12.92^{c}	3.72^{c}	70.26^{b}	29.4
		1	55.40^{b}	4.19^{a}	12.88^{c}	13.54^{b}	71.98^{bc}	29.4
		1.5	57.03^{b}	4.17^{a}	13.82^{cd}	14.42^{cd}	73.20^{d}	35.3
		2	57.90^{b}	4.40^{b}	13.98^{d}	14.66^{e}	72.53^{d}	35.3
	Polypropylene	0	56.37^{b}	4.68^{c}	14.52^{e}	15.26^{e}	72.14^{d}	35.3
		0.5	51.30^{a}	4.94^{d}	11.69^{ab}	12.69^{ab}	67.09^{a}	35.3
		1	57.29^{b}	5.30^{ed}	15.08^{e}	15.98^{f}	70.63^{b}	47.1
		1.5	56.41^{b}	4.79^{c}	14.24^{d}	15.02^{e}	71.40^{bc}	35.3
		2	58.28^{bc}	4.61^{c}	15.73^{ef}	16.39^{fg}	73.66^{d}	35.3

Means with same letters in a column are not significantly different (P> 0.05)

***Table 3**: Colour parameters of dried mushrooms due to irradiation and storage (period 6 - 12 months)*

Time	Package	Dose(kGy)	L*	a*	b*	Chroma	Hue	B.I
6 month	Polythene	0	56.81[b]	5.19[d]	13.58[cd]	14.54[cd]	69.08[b]	35.3
		0.5	54.69[a]	5.61[f]	12.92[c]	14.09[c]	66.53[a]	35.3
		1	55.32[b]	4.19[a]	12.88[c]	13.54[b]	71.98[bc]	29.4
		1.5	56.03[b]	5.17[d]	13.82[cd]	14.76[e]	69.48[b]	35.3
		2	56.48[b]	4.40[b]	12.98[c]	13.71[c]	71.27[bc]	29.4
	Polypropylene	0	55.16[b]	5.68[f]	14.52[e]	15.59[f]	68.63[b]	35.3
		0.5	51.26[a]	4.94[d]	11.69[ab]	12.69[ab]	67.09[b]	35.3
		1	56.19[b]	5.30[ed]	14.08[d]	15.04[e]	69.37[b]	35.3
		1.5	56.28[b]	5.79[g]	13.24[c]	14.45[cd]	66.38[a]	35.3
		2	57.17[b]	4.61[c]	15.73[ef]	16.39[fg]	73.67[d]	35.3
12 month	Polythene	0	55.42[b]	5.37[ed]	13.26[c]	14.31[cd]	67.95[b]	35.3
		0.5	53.19[a]	5.68[g]	12.52[b]	13.73[b]	65.59[a]	47.1
		1	54.22[a]	4.19[a]	12.48[b]	13.16[b]	71.44[bc]	29.4
		1.5	55.09[b]	5.17[d]	13.52[cd]	14.47[cd]	69.07[b]	35.3
		2	55.40[b]	5.40[ed]	12.98[c]	14.05[c]	67.41[b]	35.3
	Polypropylene	0	54.16[a]	5.68[f]	14.52[e]	15.59[f]	68.63[b]	35.3
		0.5	51.26[ab]	5.94[gh]	11.69[ab]	13.11[b]	63.06[a]	35.3
		1	55.19[b]	5.80[g]	14.08[d]	15.23[e]	67.61[b]	35.3
		1.5	55.33[b]	5.59[f]	13.24[c]	14.37[cd]	67.11[b]	35.3
		2	56.70[b]	5.18[d]	14.73[e]	15.61[f]	70.63[b]	29.4

Means with same letters in a column are not significantly different (P> 0.05)

presented in Table 2. The 0- 3 months period of storage resulted in values ranging from 12.03- 16.39, 66.08- 73.99 and 29.4- 47.1 for metric chroma, hue angle and the browning index respectively. The mushroom samples according to the values expressed a color close to the red/orange range.

For the 6 and 12 months, a similar trend was observed which resulted in L*-values ranging from 51.26- 57.17 and caused significant difference ($P<0.05$). The a*- values ranged between 4.19- 5.94 with significant difference ($P<0.05$) and b*-values also ranged 11.69- 15.73 and caused significant ($P<0.05$) changes (Table 3).

For 6- 12 months period of storage, values ranged from 12.69- 15.61, 63.38- 73.67 and 29.4- 47.1 respectively for metric chroma, hue angle and the browning index respectively (Table 3). At the end of 12 month, hue angle reduced to lower values which implied a resultant redder product than the values expressed in 0- 3 month.

The overall color change from 0 month- 12 months are presented in Table 4. Generally, an interaction of gamma radiations and the various storage packs caused a decrease in lightness and caused browning of dried mushroom samples. The ΔL* values ranged from 1.6- 4.1 and so became less white, Δb* values ranged from -0.3- 1.31 which implied fluctuation from yellow to blue while the Δa* values ranged from -0.04- -1.19 which implied a change to green. The ΔC which refers to change in color saturation values ranged from -0.26- 0.85. The overall change of saturation was insignificant ($P>0.05$).

Total color difference ΔE, which is a combination of parameters L*, a* and b* values, is a colorimetric parameter extensively used to characterize the variation of colours depending on processing conditions (Maskan, 2001). In this study, ΔE values were calculated in relation to the initial 0 month period of storage (control mushroom). A larger ΔE indicates greater colour change from the reference mushroom sample (Sarico-

***Table 4**: Total colour change due to irradiation and storage (12 months)*

Package	Dose(kGy)	Δ L*	Δa*	Δ b*	Δ Chroma	Δ Hue	ΔE
Polythene	0	3.5	-1.19	1.31	0.85	6.04	3.54
	0.5	3.7	-1.04	0.13	-0.26	4.27	3.43
	1	2.6	-0.04	0.52	0.49	0.86	2.65
	1.5	3.0	-1.00	0.30	0.04	4.14	2.84
	2	3.6	-1.02	1.25	0.84	5.48	3.71
Polypropylene	0	4.1	-1.04	-0.30	-0.63	3.30	3.95
	0.5	2.1	-0.92	-0.69	-1.08	3.02	1.75
	1	3.5	-0.80	0.87	0.53	3.90	3.52
	1.5	1.6	-0.86	0.84	0.48	4.32	1.59
	2	3.2	-0.59	0.81	0.59	2.91	3.20

ban and Yilmaz, 2010). Generally, lower values of ΔE ranging 1.53- 3.95 were recorded as the overall color difference and this could be due to the absence of water in the capillary voids of the dried mushrooms which usually transport the enzymes to catalyze the oxidation of phenolic substrates into quinines (Jolivet, 1998). These products then undergo subsequent reactions leading to the formation of dark pigment melanin (Weijn et al., 2011). These values were lower than work of Aktas et al. (2011) who reported higher ΔE values when he studied the influence of pretreatments and different drying methods on color parameters and lycopene content of dried tomato.

4. Conclusion

In conclusion, although the presented results show that color loss due to irradiation was significant ($P<0.05$), to the application of low-dose gamma radiation by the local food industry would improve the hygienic quality and extend shelf-life of fresh and dried mushrooms enhance their competitiveness in domestic and export markets.

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