CORRELATION BETWEEN HUE-ANGLE AND COLOUR LIGHTNESS OF GAMMA IRRADIATED MUSHROOMS

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Abstract
*The colour of a food product is conceivably the most important acceptability or sensory attribute which ultimately affects its marketability. Colour parameters were measured using CIE L*a*b* and H*C* color coordinate systems.Fresh mushrooms (Pleurotus ostreatus)were gamma irradiated at doses 0, 1, 2 and 3 kGy after harvest (0 day) and after storage (5 days). Dried mushrooms were also measured at beginning of storage (0 month) and at the end of storage period (3 month) after subjecting to irradiation doses of 0, 1, 2 and 3 kGy at a dose rate of 1.712 kGy hr^{-1} in air from a Cobalt- 60 source (SLL 515, Hungary). A range of colors from red to yellow as well as intermediates were created by the interaction of gamma radiation dose and storage period. Good linear correlations were established between the hue angle and the lightness for fresh mushrooms (r^2=0.54 and r^2= 0.657) and dried mushrooms (r^2= 0.74 and r^2= 0.624). This correlation gives the possibility to follow only the whiteness (L*) color parameter after pretreatment(gamma irradiation, steaming, blanching etc.) and storage. Gamma radiations had no adverse effect on the product quality and so could be used as a preservation method since it aids prolong shelf-life by destroying larvae of insects and insects that cause post harvest losses.*

Key words- Hue angle, whiteness (L*), gamma, irradiation, *Pleurotus ostreatus*

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1. INTRODUCTION

Mushrooms are cherished for their nutritive (Oyetayo and Ariyo, 2013; Kortei, 2011; La Guardia et al., 2012; Kortei et al, 2014a) and medicinal (Lindequist et al, 2005; Singh, 2012; Kortei et al, 2014b) attributes. However, after harvest, mushrooms like all fruits remain physiologically active, and hence continue with maturation, changing their physicochemical, textural and sensory properties. Fresh mushrooms have been reported by Mahajan *et al*., (2008)to store between 1-3 days at ambient conditions because of their high moisture content and transpiration rate. Therefore, it is necessary that they are marketed soon after harvest, or preserved with special care to maintain its wholesomeness.
Numerous processing techniques have been developed to control food spoilage and raise safety. The traditional methods have been supplemented with pasteurization (by heat), canning, freezing, refrigeration and chemical preservatives (Morstafavi et al, 2012). Another technology that can be added to this list is irradiation. Food irradiation is the process of exposing amount of energy in the form of speed particles or rays for improving food safety, eliminating and reducing organisms that destroy the food products.
Consumer demands have increased for processed products that keep more of their sensory properties and their nutritional value, so that it has become necessary to optimize drying conditions in order to achieve certain characteristics related to color, texture, water content, etc. (Heredia et al., 2007). Drying conditions, including high temperature, light, and oxygen exposure, may cause degradation of the food product and thereby affect the attractive color and nutritive value of the final products (Shi, 2000).Essentiallycolor retention influences its preference, prices, and ultimately acceptability (Cui et al., 2004; Meullenet,

2009).Therefore, color is regarded as a basis for the assessment of quality both for its aesthetic role and for its nutrition (Cui et al., 2004).
When an object is visually observed, three physical factors must be present; a source of light, the object, and a light receptor mechanism (Wrolstad and Smith, 2010).Standard sources of light used in colorimetric tests vary. However, the most widely used in colour measurement of food is the standard D65 (Noburu and Robertson, 2005) which corresponds to the spectral distribution of mid-day sun which is recommended as the standard daylight illuminant by CIE (Gilabert, 2002). The light receptor mechanism normally converts the light stimulus into electrical signals that are later interpreted like the numerical description of the response to the colour perceived by the human eye.
Colorimeters are electronic devices for colour measurement that express colours in numerical coordinates and have been widely used in numerous published research articles (Mitsui 2004; Aktas et al, 2011; Mohamadi et al, 2008; Kortei et al, 2014 in press) due to its objectiveness.Some parameters including lightness (L*), TCI (Transmittance Color Index), and Hue angle are used to evaluate the color quality (Yildiz and Baysal, 2007).In color theory according to Conway (2007, 2009),hue refers to a pure color: one without tint or shade (added white or black pigment, respectively). A hue is an element of the color wheel and is first processed in the brain in areas in the extended area known asglobs. Lightness (L*) also describes the degree of whiteness of a product (Fairchild, 1995).Correlations could be established between the co-ordinates which would simplify the color measurement.
The objective of this study is to establish a correlation between the hue angle and lightness as a result of the interaction of gamma radiation and storage period.

2. MATERIALS AND METHODS

Mushroom material

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 outat 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 mushroom material was solar-dried at temperature range of (50- 60^{o}C) to a moisture content of about 12±1%. Dried mushroom parts were cut up and stored in tight-sealed transparent polythene containers at room temperature until needed.

2.2 Irradiation of Mushroom Materials

Forty (40) grams of fresh and dried mushrooms (*Pleurotus ostreatus)* were packed into transparent polythene bags and irradiated at doses of 0, 1, 2 and 3 kGy at a dose rate of 1.7 kGy per hour in air from a cobalt- 60source (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

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 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.

The hue angle (H^o) 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 was calculated from a* and b* values according to the following formulae (Wrolstad and Smith, 2010):

Hue angle (°) = arctan (b*/a*) (1)

3. RESULTS AND DISCUSSIONS

The colour hue of both irradiated fresh and dried mushrooms were between 0° and 90°. where 0° represents the red colour and 90° represents the yellow colour. The full intensity range of lightness is 0-100 units, where 0 represents the total dark followed by grey up to bright white (100 units).The correlation between lightness and colour hue the results are presented in Figs. 1-4.

The linear regression equations and the coefficients of determination of gamma irradiated fresh mushrooms stored for 0 and 5 days were calculated from the standard curves (y= -1.934x + 196.2 and y= -1.259x + 154.6) showed a strong correlation (r^2=0.54 and r^2=0.66 respectively). Also, calculated values of irradiated dried mushrooms stored for 0 and 3 months were obtained from the standard curves (y= 1.435x – 10.38 and y= 1.537x – 14.16) which also showed stronger correlation (r^2= 0.740 and r^2= 0.624 respectively).

The linearity between lightness and colour hue was heightened when dried mushrooms were gamma irradiated prior to storage (0 month).

The linear correlation gives a possibility to follow the colour change during gamma irradiation and storage by measuring only the lightness. This result represents the main impact of this study. Because the lightness depends only on the Y colour component it can be measured by a proper colour filter too, avoiding the use of an expensive colorimeter.

Although published data on this correlation exist, it is very scanty. Results obtained in this study, corroborate with results of Tolvaj and Nemeth (2008) when they studied the correlation between hue angle and color lightness of steamed black locust wood. Again, Camelo and Gomez (2004) made similar observations in comparison of color indexes in tomato ripening.

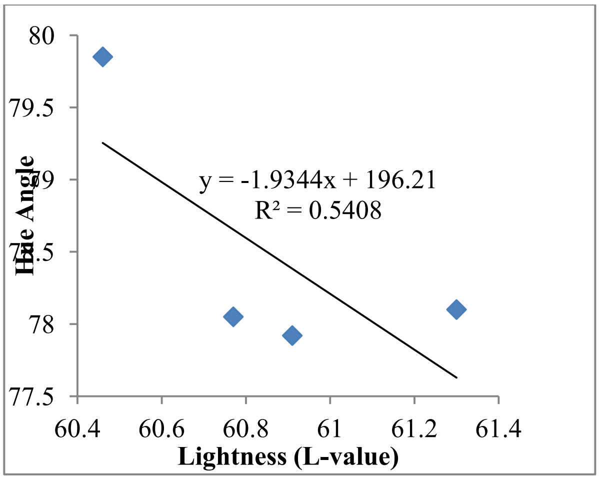

Fig.1. Relationship curve of Lightness and Hue angle of irradiated fresh mushroom (0 day)

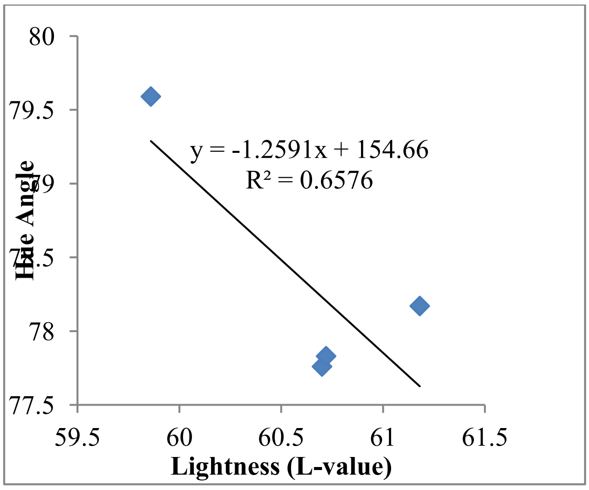

Fig.2. Relationship curve of Lightness and Hue angle of irradiated fresh mushroom (5 day)

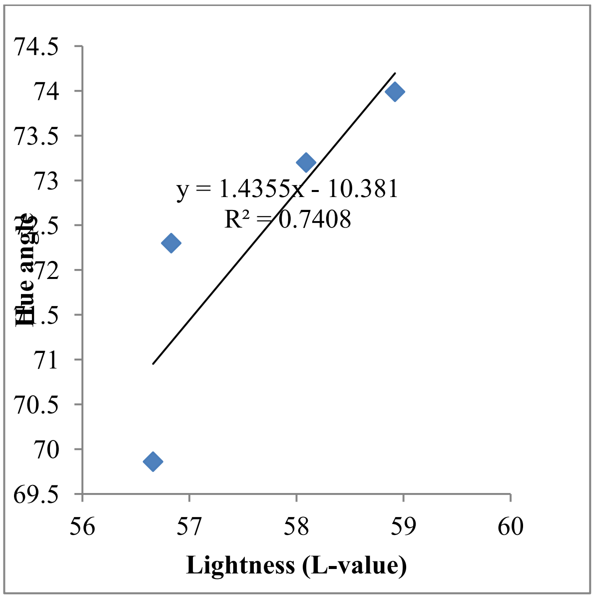

Fig.3. Relationship curve of Lightness and Hue angle of irradiated dried mushroom (0 month)

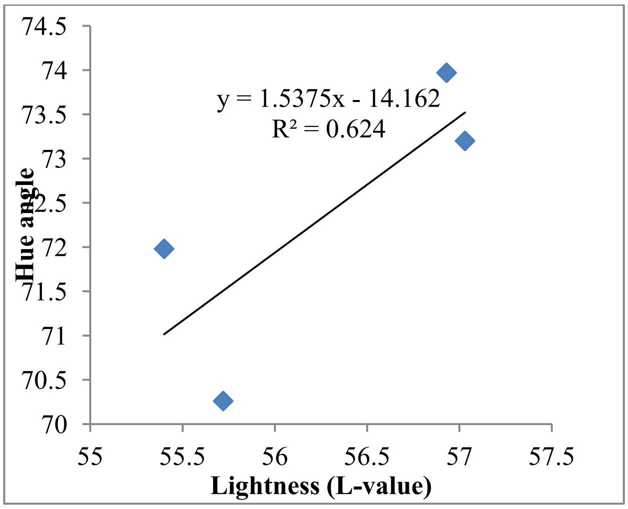

Fig.4. Relationship curve of Lightness and Hue angle of irradiated dried mushroom (3 month)

The effect of gamma radiation and storage period, resulted in some significant (P<0.05) changes inthe color parameters of fresh mushrooms (Table 1). Hue angle mean values ranged between 77.76- 79.85^o. The non irradiated (0 kGy) fresh mushrooms differed significantly (P<0.05) from the gamma irradiated (1.0, 2.0 and 3.0 kGy) samples of both 0 day and 5 day storage periods (Table 1).

Lightness (L*)mean values ranged between 59.87- 61.31 for the storage period (5 days) and recorded no significant (P>0.05) difference. The red/green (a*) mean values recorded ranged between 3.47-3.97 during storage period. Non irradiated (0 kGy) mushrooms were significantly (P<0.05) different from irradiated samples. Lastly yellow/blue (b*) mean values also ranged 18.09- 19.39 and apparently showed no significant (P>0.05) difference.

Results of the interaction of radiation, storage and color parameters of dried mushroomsare presented in Table 2. Mean range of 69.86-73.99 for hue angle for a storage period of 3months. Dose 1kGy influenced color change and caused a significant (P<0.05) reduction in hue angle (Table 2). Whiteness recorded mean values of range 55.40- 58.92. The control (0 kGy) of the 0 month recorded a higher mean value of 58.92 and differed significantly (P<0.05) from the other dose treatments over the storage period. The red/green (a*) mean values ranged 4.15- 4.64. There wasan observed significant difference (P<0.05). Also yellow/blue (b*) mean values ranged 12.65-14.57 and recorded some significant differences (P<0.05).Generally, both fresh and dried mushrooms had hue angles range within the 90^o region which suggests an apparent reddish yellow color (Pedisic et al., 2009).

Reid, (1995) reported that all organic colors are susceptible to some breakdown after exposure to radiation. Many of these organic colors are based on anthracene-type chemistry and may haveinherent carcinogenic properties or break down into potential carcinogens. Thesuccess of irradiation for products containing organic colors will largely depend uponthe dose required to treat the material containing the color. The lower the dosageemployed the less negative effects. Additionally, color pigment has been reported by Maharaj et al (2010) to decompose and degrade over a period of time.

Table1. Influence of gamma radiation and storage period on the color parameters of fresh *P.ostreatus*

Time	Dose (kGy)	L*	a*	b*	Hue angle ^{O}
0 Day	0	60.46^{a}	3.47^{ab}	19.39^{a}	79.85^{bc}
	1.0	60.77^{a}	3.91^{b}	18.48^{a}	78.05^{a}
	2.0	60.91^{a}	3.89^{b}	18.17^{a}	77.92^{a}
	3.0	61.30^{a}	3.82^{b}	18.13^{a}	78.10^{a}
5 Day	0	59.87^{a}	3.55^{a}	19.26^{a}	79.59^{b}
	1.0	60.69^{a}	3.97^{b}	18.35^{a}	77.76^{a}
	2.0	60.72^{a}	3.90^{b}	18.09^{a}	77.83^{a}
	3.0	61.18^{a}	3.79^{b}	18.10^{a}	78.17^{a}

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

Table 2. Influence of gamma radiation and storage period on the color parameters of dried*P.ostreatus*

Time	Dose (kGy)	L*	a*	b*	Hue angle ^{O}
0 month	0	58.92^{c}	4.18^{a}	14.57^{e}	73.99^{d}
	1.0	56.66^{b}	4.64^{c}	12.65^{b}	69.86^{b}
	2.0	56.83^{b}	4.15^{a}	13.00^{c}	72.30^{d}
	3.0	58.09^{b}	4.17^{a}	13.83^{cd}	73.20^{d}
3 month	0	56.93^{b}	4.19^{a}	14.58^{e}	73.97^{d}
	1.0	55.72^{b}	4.61^{c}	12.92^{c}	70.26^{b}
	2.0	55.40^{b}	4.19^{a}	12.88^{c}	71.98^{bc}
	3.0	57.03^{b}	4.17^{a}	13.82^{cd}	73.20^{d}

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

4. CONCLUSION

This study has demonstrated the connection between lightness and hue angle. The linear correlation makes possible to control the colour change during gamma irradiation bymeasuring only the lightness, which does not need expensive colorimeter, only using a colourfilter and a detector are sufficient.

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