EFFECTS OF UV LIGHT ON MECHANICAL PROPERTIES AND PRODUCTION OF VITAMIN D2 IN MUSHROOMS

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ABSTRACT
The sun emits ultraviolet radiation in form of ultraviolet-A (UV-A), ultraviolet-B (UV-B), and ultraviolet-C (UV-C) bands. Ultraviolet light may boost vitamin D_2 production in mushrooms which human bodies cannot synthesize. The ergosterol in mushrooms, a component of fungal cell membranes which serves the same function as cholesterol in animal cells, can be converted into vitamin D_2 by ultraviolet light. However, mushrooms are conventionally grown in the dark, necessitating artificial ultraviolet irradiation. This study investigated the effects of UV-A and UV-C light on concentration of vitamin D_2 in oyster mushrooms during growth and mechanical properties post-harvest. UV exposure times were varied from 10 to 60 minutes per day at intervals of 10 minutes, and irradiation done for three days. UV spectroscopy was used to determine the amounts of Vitamin D_2 and the mechanical properties were investigated using dynamic mechanical analysis (DMA 2980). Absorbance of vitamin D_2 for UV-A light ranged from 0.18 to 0.49 for 10 to 60 minutes of irradiation, respectively, while for UV-C light the vitamin D_2 content absorbance was 0.38 to 0.81 for 10 to 60 minutes of irradiation, respectively. The storage modulus, loss modulus, and loss factor of the irradiated samples and control samples were determined for both UV bands. UV-C light irradiated samples had higher loss modulus and loss factor, but low storage modulus as temperature increased from 35-100^{o}C with respect to the control sample, while UV-A light irradiated samples had lower loss modulus, low loss factor, and higher storage modulus than UV-C irradiated samples. Thus, oyster mushrooms with a well-defined content of vitamin D_2 can be obtained without largely affecting the mechanical properties and the quality of the mushrooms.
Keywords: Ultraviolet light, Oyster mushrooms, Irradiation, Ergosterol

INTRODUCTION
The sun emits ultraviolet radiation in the form of ultraviolet-A (UV-A; 315-400 nm), ultraviolet-B (UV-B; 280-315 nm), and ultraviolet-C (UV-C; 100-280 nm) bands (Hockberger, 2002). Human bodies through

the skin are only able to synthesize vitamin D_3 from 7-dehydrocholesterol following exposure to ultraviolet B (UV-B) but not Vitamin D_2 (Holick, et al., 1980). Studies have shown that some wild mushrooms have naturally occurring levels of vitamin D_2 in the range of 2.91-58.7 μg/100 g fresh weight (Teichmann, et al., 2007). In addition, it has been shown that vitamin D_2 content of mushrooms can also be enhanced through the by UV light irradiation (Ko, et al., 2008).

Vitamin D is a fat soluble and required by the body in the regulation of calcium and phosphorus and in mineralization of bones (Chung, et al., 2009). Furthermore, receptors for vitamin D are present in a wide variety of cells, meaning this vitamin has biological effects that extend far beyond control of mineral metabolism (Ovesen, et al., 2003). Vitamin D consists of two different compounds, vitamin D_2 from ergosterol and vitamin D_3 from animal products or the action of sunlight on a cholesterol-like precursor, 7-dehydrocholesterol, which is in the skin (Lips, 2006). Ingested vitamin D_2 and endogenously produced D_3 are converted to the biologically active form, 1, 25-dihydroxyvitamin D (1, $25(OH)_2D$) (calcitriol) in the human body (Lorraine, et al., 2011).

Vitamin D deficiency is an ever increasing problem in human nutrition and health. Research has shown that it affects much more than the classic diseases of rickets in children and osteomalacia in adults resulting from inadequate bone mineralization (NIH, 2004:2008). Links of vitamin D deficiency to diseases such as cardiovascular disease (Wang, et al., 2008) and cancer (Lappe, et al., 2007) have been documented. Other diseases with links to vitamin D deficiency include hypertension, stroke, diabetes, multiple sclerosis, rheumatoid arthritis, inflammatory bowel disease, periodontal disease, mental illness, propensity to fall and chronic pain (Cannell, et al., 2008). There are a limited number of natural dietary sources of vitamin D leading to a real need for alternatives to improve dietary intake. Mushrooms are the only non-animal-based food containing vitamin D_2 and ergesterol hence are the only natural vitamin D_2 sources for vegetarians (Mattila, et al., 2000).

Mushroom consumption has increased remarkably because of their desirable aroma and taste and high nutritional content (Vizhanyo and Jozsef, 2000). Color, fresh and clean appearance and uniform closed buttons also have high importance for mushroom quality and consumer preferences (Gonzalez, et al., 2000). The mechanical properties of the mushrooms produced after irradiation during growth is a very important factor to consider to meet consumers' needs. These properties mainly result from the structure, physical state and rheology. They are needed for process design, estimating other properties, characterizing foods, and quality determination. Texture is one of important factors to evaluate quality of mushroom. Undesirably, the stability of texture can be only maintained for a very short period of storage, it is usually changed quickly after harvest (Nichol, 1985). Stiffness, toughness, brittleness and pliability are considerable characteristics during the analysis of fruit body texture.

Improving mushroom quality and texture as well have been preceded by several methods. The texture (Gormley and MacCanna., 1967) was assessed through measuring the force required to shred a bulk sample. A research in which changes through dry matter content were indirectly measured (Gormley, 1969) indicated that the texture may be changed due to the changes of cellular materials and moisture loss. A method to measure tissue compressive stiffness was developed where changes in button mushroom texture in different sizes and stages were evaluated (McGarry and Burton, 1994). Another method to analyze the texture properties (Truong, et al., 2006) focused on the changes of tenderness, pliability, toughness and brittleness of post harvested and cooked mushroom was established. Previous research revealed some relations between textural characteristics and constituents of fruit bodies like hyphae density which was proved to be one of criteria that determined the stiffness in *A. bisporus* (McGarry and Burton, 1994). Another determined stiffness criterion was cell turgidity which was reflected by water content in mushroom (Beelman, et al., 1987).

Dynamic mechanical analysis (DMA 983) can be used to gain insight into the factors affecting food quality through simulation of processing conditions. There have been, however, relatively few studies on the dynamic mechanical properties of food, although a comparative DMA study was perform on starches of wheat where DMA experiments were performed on two food products, commercial white bread and dried pasta (Roulet et al., 1988). The DMA storage and loss moduli obtained provided valuable information about the softness and keeping properties of bread and the cooking characteristics of pasta.

A study on anisotropy of mechanical properties of mushroom (A. *bisporus)* was carried out by (Jerzy, et al., 2013). Strenght tests, hysteresis tests and creep tests of mushrooms compressed between two parallel plates were carried out however the mushroom sample used had not been exposed to UV-A and UV-C during growth. However, only limited information is reported in the literature about mechanical properties of mushrooms especially oyster (*Pleurotus ostreatus species*) that have been exposed to UV-C and UV-A light during growth.

Viscoelastic materials simultaneously exhibit a combination of elastic and viscous behavior. While all substances are viscoelastic to some degree, this behavior is especially prominent in polymers. There's however limited information in the literature concerning the viscoelastic behavior of mushrooms that have been UV irradiated especially during growth.

Various techniques have been used to study mechanical properties of food. They include Instron 5566 stress testing machine and the dynamic mechanical analysis using the Dynamic Mechanical Analyzer, (DMA 983). Historically, the methods used to evaluate and predict these properties have been somewhat arbitrary and non-quantitative. The use of analytical instrument techniques such as thermal analysis provides a more quantitative, reproducible way for characterizing food products. Dynamic Mechanical Analysis (DMA), for example, can provide information about the mechanical properties of food and how they are affected by various processing conditions (Roulet, et al., 1988).

A study on Agaricus *bisporus* mushrooms obtained 1 day after harvesting reported that they were exposed to UV-C irradiation at intensities of 0.403, 0.316, and 0.256 mW/cm^2 from distances of 30, 40, and 50 cm, respectively (Koyyalamudi, et al., 2009). These distances were chosen to determine whether a strategic placement of a UV-C light in the growers' rooms is effective in triggering the conversion of ergosterol to vitamin D_2 in cultivated mushrooms before harvesting. The increase in vitamin D_2 concentrations in micrograms per gram of dry solids was dependent on time and intensity of exposure to UV-C irradiation, which in turn was dependent on distance from the UV source. Irradiation from a distance of 30 cm at an intensity of 0.403 mW/cm^2 produced higher concentrations of vitamin D_2 after treatment for times ranging from 5-60 minutes when compared to those produced with intensities of 0.316 and 0.256 mW/cm^2 at distances of 40 and 50 cm, respectively.

The goal of this study was to irradiate growing mushrooms with UV-A: 365nm and UV-C: 254nm light, and vary exposure times in a situation that is achievable in a mushroom conventional growing environment, and infer the effects of these variations on both the mechanical properties of the mushrooms using DMA 2890 and amount of vitamin D_2 in the mushrooms inferred from the UV spectrometry.

MATERIALS AND METHOD

Growing of Mushrooms

Wheat grains were prepared for grain spawn by being boiled, drained, filled in containers and sterilized. The substrate was then prepared from wheat straw and was pasteurized by hot water immersion to kill contaminants. The pasteurized substrate was then spawned after ensuring that the substrate has cooled down to 30 °C. The spawn was mixed with the substrate when filling thirteen perforated bags labeled B1 to B13. Spawn run followed where the mycelium was grown through the substrate. The bags once spawned were placed in a cage that had been prepared where mycelium colonized the substrate in two to three weeks and started to form small fruiting bodies. In darkness, controlled temperature and humidity conditions were provided. Humidity was maintained between 80-100% by spraying water several times per day and the temperature was maintained between 15-25°C.

Exposure of Mushrooms to UV-C (254nm) and UV-A (365nm) Light During Growth

UV-C light (254nm) and UV-A light (365nm) irradiation begun once the mushrooms cap started opening from the stem. An 8W Ultraviolet fluorescent lamp made by UVITEC (model LF- 204.LS) was used. The lamp irradiates at the ranges (254 nm) and (365nm) with a switch that shifts between the two ranges and the measured intensity was 3.5 W/m^2 for 365nm and 0.0327W/m^2 for 254nm. Bag labelled B1, the control, was not be exposed to UV-C and UV-A light. Six bags labelled, B2 to B7 were exposed to UV-C light while another set of six bags labelled B8 to B13, were exposed to UV-A light. Beginning with the lowest exposure time of 10 minutes for bags B2 and B8, and subsequent 10 minutes increment for the next bag up to 60 minutes for the highest exposed bags (B7 and B13) was done, for UV-C and UV-A respectively. This irradiation procedure was repeated for three days. Once the caps were fully opened and separated from the stem, the mushrooms were ready for harvesting. Harvesting was done by holding the mushrooms by their stalks and breaking them off carefully from the substrate. Samples were picked from each bag and prepared for mechanical properties and vitamin D2 analysis.

Dynamic Mechanical Analysis

The samples were then tested for their storage and loss factor using DMA-2980 instrument. DMA 2980 analytical instrument is used to test the physical properties of material. The samples for experimental studies were cut into cylindrical shapes of diameter 12.50mm and thickness 3.00mm. Each of the samples was placed on the compressional clamp at a time and subjected to changes in stress induced by an oscillating force. The amplitude and the phase of the displacement in the sample in response to applied oscillating force over a range of temperature were measured. Measurement of loss and storage moduli and the loss factor was obtained directly from the DMA. The storage modulus gives the amount of energy the sample stores, the loss modulus gives the amount of energy dissipated by the sample when a sinusoidal force is applied. The loss factor (damping factor) is measured as an angle to indicate the lag between the stress and strain giving information about the samples elastic nature. The storage moduli, loss moduli and loss factors of the samples that had been exposed to UV-A and UV-C light during growth and those had not been exposed (control samples) were tabulated for analysis.

Analysis of Vitamin D_2

The samples for spectrophotometric analysis were prepared by method previously described by (Perera, et al., 2003) where 0.5 g of each mushroom sample powder was weighed into 250 ml round bottom flasks and mixed with 4 ml of sodium ascorbate solution (17.5 g of sodium ascorbate in 100 ml of 1 M NaOH), 50 ml of ethanol and 10 ml of 50% potassium hydroxide. The mixture was saponified under reflux at 80^0C for one hour then it was immediately cooled to room temperature and transferred into a separating funnel. The mixture was first extracted with 15 ml de-ionized water, followed by 15 ml ethanol and then with a three-stage n-pentane extraction of volumes 50, 50 and 20 ml, respectively. The pooled organic layers were washed three times with 50 ml of 3% KOH in 5% ethanol and then finally with deionized water until neutralized. The organic layer was transferred into a round bottom flask rotary and was evaporated to dryness at 40^0C and immediately re-dissolved in 5 ml ethanol. The sample was passed through a 0.45 μm non-pyrogenic filter. UV spectroscopy, which is based on measurement of the intrinsic absorption of calciferols, plays a very modest role in quantification of vitamin D_2. In this study, spectrophotometric determination of vitamin D_2 were then determined by method previously described by (Saad, 1978) where calciferol reacts with 11N hydrochloric acid in the presence of symmetrical tetrachloroethane to develop a greenish yellow colour with maximum absorption at 440-460 nm. Aliquot of 2 ml of the prepared samples of B1 - B13 were evaporated to dryness on a boiling water bath. Then 1 ml of 11 N hydrochloric acid and 1ml of symmetrical tetrachloroethane were added and the tube was warmed for 10 minutes on the water bath with occasional shaking. After cooling the volume was completed to 7 ml with acetone and the absorbance was measured using a spectrophotometer by putting a reference blank solution (the solution of the sample that had not been irradiated during growth) in a cuvette and placed in the spectrophotometer. The absorbance of the reference blank was determined at 450 nm. The blank was removed and the cuvette containing sample solution for B2 was put in the spectrophotometer and the absorbance was determined at 450 nm.

RESULTS AND DISCUSSION

Determination of the change in storage modulus, loss modulus and loss factor of oyster mushroom as a result of exposing them to UV-C and UV-A light during growth

The storage modulus for control, UV-A and UV-C irradiated samples at different temperatures was determined over the temperature range of 25 - 100^{0}C of which 35 -100^{0}C was chosen for analysis. There was a drop in storage modulus after irradiation of the samples by both UV-A and UV-C light during growth. The samples irradiated by UV-C had a higher drop compared to those treated by UV-A light as indicated in the Table 1.

This indicates that irradiation of samples with UV-C light lowers storage modulus of the mushrooms. The samples under UV-C and UV-A exhibited similar viscoelastic behaviour. The regions included the glassy region in which the samples were hard, springy or rock like. In this region the bending of the bonds was occurring and temperature range was 35 - 85^{0}C. Glass transition region then followed in which the samples softened and thus became less hard as storage modulus decreased and tan δ peaks, temperature ranging from 80 - 95^{0}C. The samples then started undergoing slippage of main chain (rubbery plateau region) and the temperature ranged from 95 - 100^{0}C. Samples that were irradiated for longer durations (40, 50 and 60 minutes) registered lower values of storage modulus especially for UV-C irradiated samples compared to those that were irradiated for short time intervals (10, 20 and 30 minutes).

Table 1: The average storage modulus (E′) and itspercentage drop at different exposure times for UV-A and UV-C light from 35 -100^{0}C.

Samples irradiation time (minutes)	Average E′ (MPa)		Percentage (%) drop in E′	
	UV-A	UV-C	UV-A	UV-C
0	8.987	8.987	-	-
10	7.614	6.850	15	23
20	6.367	5.760	29	36
30	5.874	5.540	35	38
40	5.506	5.250	39	42
50	5.269	5.046	41	44
60	5.269	5.046	41	44

The low storage modulus for both UV-C and UV-A irradiated samples as temperature increases can be attributed low levels of ergosterol which was subjected to photolysis and yielded photo-irradiation products, the principal ones being vitamin D_2, tachysterol and lumisterol when the mushrooms were irradiated by UV-C and UV-A light during growth. Samples under UV-C irradiation had lower storage modulus as temperature increased because most of the ergosterol in these samples had undergone photolysis during irradiation (Jones, et al., 1985). This means ergosterol presence in the samples increases the storage modulus since it’s a component of the mushrooms cell membrane.

Table 2: Loss modulus (MPa) for both control and UV-A-irradiated oyster mushroom samples at different temperatures (^{0}C).

	Loss Modulus (MPa)					
Temperature (^{0}C)	Control Sample	UV-A 10 min	UV-A 20 min	UV-A 30 min	UV-A 40 min	UV-A 50 and 60 min
35	1.40	1.20	0.90	0.72	0.60	0.59

40	1.40	1.23	0.90	0.72	0.60	0.59
45	1.40	1.25	0.90	0.72	0.60	0.59
50	1.45	1.28	0.90	0.72	0.60	0.59
55	1.47	1.30	0.90	0.72	0.60	0.59
60	1.50	1.35	0.95	0.72	0.60	0.59
65	1.60	1.45	1.10	0.75	0.60	0.59
70	1.70	1.50	1.25	0.80	0.64	0.59
75	1.85	2.00	1.40	1.10	0.90	0.59
80	3.40	2.70	2.50	1.60	1.15	0.68
85	4.10	3.00	2.60	1.70	1.40	0.53
90	3.60	2.70	2.00	1.50	1.30	0.53
95	2.75	1.65	1.36	1.00	0.78	0.53
100	2.50	1.60	1.25	0.90	0.70	0.53

Tables 2 above shows the loss modulus for both the control and UV-A irradiated samples. Loss modulus of the mushrooms represents the energy lost as heat and is a measure of vibrational energy that has been converted during vibration and that cannot be recovered.

Table 4 shows tan δ (loss factor) for both control and UV-A irradiated samples. Loss factor of mushrooms sample is the measure of the energy lost in terms of the recoverable energy and represents mechanical damping or internal friction in viscoelastic system. There was a significant difference in loss factor between the control and irradiated samples, $p < 0.05$. It was noted that the loss factor for UVA samples was lower than that of the control samples. The low loss factor of UV-A irradiated samples indicated that the samples had an elastic strain component.

Table 3: Loss Modulus (MPa) for both control and UV-C irradiated samples against temperature (^{0}C)

	Loss Modulus (MPa)					
Temperature (^{0}C)	Control Sample	UV-C 10 min	UV-C 20 min	UV-C 30 min	UV-C 40 min	UV-C 50 and 60 min
35	1.4	1.72	1.59	1.57	1.55	1.54
40	1.4	1.72	1.59	1.57	1.55	1.54
45	1.4	1.72	1.62	1.57	1.55	1.54
50	1.45	1.68	1.65	1.56	1.55	1.54
55	1.47	1.81	1.73	1.61	1.55	1.56
60	1.50	1.92	1.88	1.73	1.68	1.62
65	1.60	1.98	1.94	1.85	1.80	1.75
70	1.70	2.85	2.78	2.70	2.67	2.61
75	1.85	3.50	3.35	2.90	2.92	2.80
80	3.40	3.61	3.41	2.84	2.81	2.71
85	4.10	3.40	3.11	2.79	2.75	2.58
90	3.60	3.12	2.71	2.63	2.59	2.47
95	2.75	2.71	2.59	2.51	2.46	2.40
100	2.50	2.46	2.41	2.37	2.35	2.25

Table 4: Tan δ for both control and UV-A-irradiated oyster mushroom samples at different temperatures

	Tan δ					
Temperature (^{0}C)	Control Sample	UV-A 10 min	UV-A 20 min	UV-A 30 min	UV-A 40 min	UV-A 50 and 60 min
35	0.13	0.12	0.12	0.09	0.09	0.08
40	0.13	0.12	0.12	0.09	0.09	0.08

45	0.13	0.13	0.12	0.09	0.09	0.09
50	0.13	0.14	0.12	0.09	0.09	0.09
55	0.14	0.14	0.13	0.11	0.09	0.09
60	0.15	0.15	0.13	0.11	0.09	0.09
65	0.16	0.17	0.15	0.12	0.09	0.10
70	0.17	0.18	0.16	0.12	0.11	0.11
75	0.19	0.25	0.17	0.17	0.16	0.11
80	0.27	0.43	0.35	0.25	0.21	0.13
85	0.48	0.49	0.43	0.30	0.25	0.11
90	0.69	0.55	0.47	0.37	0.32	0.14
95	0.67	0.51	0.45	0.34	0.29	0.20
100	0.60	0.50	0.42	0.32	0.27	0.20

Tables 5 shows tan δ (loss factor) for both control and UV-C irradiated samples. The samples irradiated by UV-C light during growth had high loss factor than those irradiated by UV-A light. The high values of loss factor in UV-C light treated samples were higher than those of the control sample and UV-A sample. This indicated that the UV-C mushroom samples had a non-elastic strain component. Irradiation of mushroom samples for 60 minutes had no further change on the storage modulus, loss modulus, and loss factor of the samples as samples under this time duration recorded similar values as those under 50 minutes of irradiation.

Table 5: Tan δ for both control and UV-C irradiated oyster mushroom samples at different temperatures

	Tan δ					
Temperature (^{0}C)	Control Sample	UV-C 10 min	UV-C 20 min	UV-C 30 min	UV-C 40 min	UV-C 50 and 60 min
35	0.13	0.19	0.20	0.22	0.24	0.24
40	0.13	0.20	0.22	0.22	0.25	0.25
45	0.13	0.21	0.23	0.24	0.25	0.26
50	0.13	0.21	0.24	0.25	0.25	0.26
55	0.14	0.23	0.27	0.26	0.26	0.26
60	0.15	0.26	0.30	0.29	0.29	0.29
65	0.16	0.27	0.32	0.32	0.32	0.32
70	0.17	0.39	0.50	0.48	0.50	0.50
75	0.19	0.49	0.6	0.53	0.55	0.55
80	0.27	0.53	0.63	0.54	0.55	0.56
85	0.48	0.57	0.6	0.55	0.58	0.63
90	0.69	0.69	0.63	0.62	0.68	0.68
95	0.67	0.61	0.65	0.68	0.70	0.73
100	0.60	0.60	0.62	0.67	0.69	0.70

Change in Concentration of Vitamin D_2 in Oyster Mushrooms exposed to 254nm and 365nm UV-light During Growth

The absorbance of vitamin D_2 under both UV light bands increased gradually as time of exposure increased up to 40 minute for UV-C and remained constant up to 60 minutes of irradiation. High values of absorbance implies high concentration of vitamin D_2 The exposure of UV-C light during growth for 60 minutes resulted in the highest absorbance of 0.81 compared to 0.49 for UV-A light exposure (Table 6).

Table 6: Absorbance values of solutions of samples irradiated at different times by UVA and UV-C light during growth.

Time of irradiation (minutes)	10	20	30	40	50	60

UV-A absorbance	0.18	0.22	0.31	0.49	0.49	0.49
UV-C absorbance	0.38	0.45	0.53	0.65	0.81	0.81

The samples of the mushrooms that were grown without exposure to UV-C and UV-A light were found to have lowest absorbance values indicative of low Vitamin D_2 present when compared to samples that were subjected to UV-A and UV-C light irradiation (Figure 1).

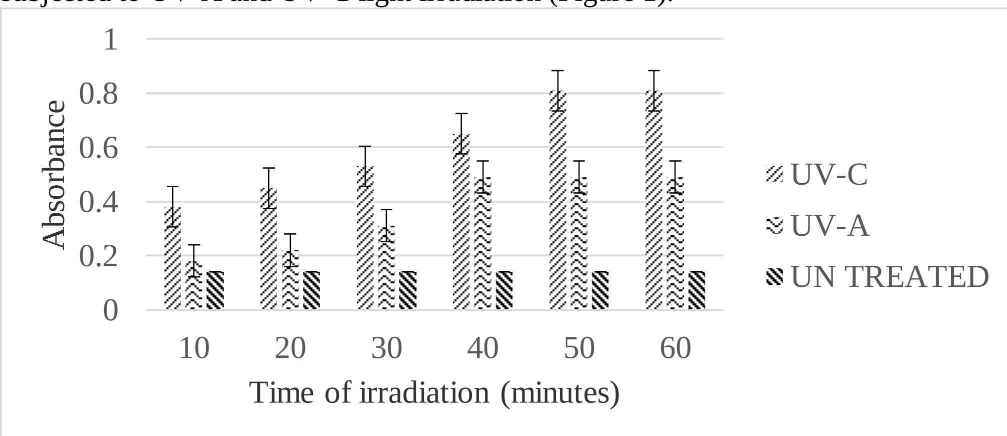

Figure 1: Comparison of absorbance of vitamin D_2 for oyster mushrooms irradiated by UV-C and UV-A light during growth and untreated mushrooms at different time of exposure.

The conversion of ergosterol to vitamin D2 under UV-C and UV-A were shown to be significantly different ($p < 0.05$) as shown with the standard error bars in Figure 1. The difference between the UV-C and UV-A absorbance values can be ascribed to a higher efficiency of vitamin D_2 conversion at exposure to UV-C during the growth than UV-A light. As mushrooms grow, there's increase in the amount of ergosterol, thus an increase in absorbance after repeated exposure in the subsequent days may be explained by the carryover of ergosterol formed in the mushrooms left growing for the next day. The absorbance was much lower in mushrooms exposed for 10 minutes under both UV light bands. Prolonged irradiation produces irreversible over irradiation products by dimerization and ring cleavage (Braun, et al., 1991). In addition, prolonged exposure to a close of two hours subjects the vitamin D_2 formed to the UV radiation and this may result in photo degradation of vitamin D_2 (Webb, et al., 1989).

In the case of UV-A irradiation, the absorbance of vitamin D_2 increases up to 50 minutes and remains constant at 60 minutes of irradiation. The increase in the absorbance of vitamin D_2 is as a result of conversion of ergosterol in the mushroom to vitamin D_2. The absorbance of vitamin D_2 for the untreated samples ranged between (0.14 ± 0.02). A study on comparison of UV-A and UV-C for vitamin D_2 producing capacity in commercial mushroom species has been reported (Teichmann, et al., 2007). For the mushrooms studied, vitamin D_2 formation follows the order UV-C > UV-A after 2 hours of post-harvest exposure with UV-A light not result in any significant changes in vitamin D_2 concentrations from 0 to 2 hours. In this study, there was significant change in vitamin D_2 for both UV-A and UV-C samples with respect to the control sample for 1 hour. Therefore, the most probable reason for differences obtained in vitamin D_2 production after exposure to UV-A light between this study and that of (Teichmann, et al., 2007) could be explained in part by different methodology for vitamin D_2 quantification in mushroom samples, different exposure handlings, different exposure time (during growth). Furthermore it has been reported that temperature, moisture and the part of the mushrooms tissues (gills or caps) exposed to UV irradiation play a role for vitamin D_2 yield (Perera, et al., 2003); (Jasinghe and Perera, 2006).

Change in concentration of vitamin D_2 under both UV- bands increased with respect to time of exposure. The vitamin D_2 level of the biologically active treated mushrooms increased substantially on both wavelengths. In the case of UV-C treatments, even the shortest time period (10 minutes) was enough to cause twice as high vitamin D_2 level in the mushrooms as in control. UV-A irradiation did not cause as intensive change in vitamin D_2 concentration as experienced in case of UV-C radiation.

CONCLUSION

Irradiation of mushrooms during growth with UV-A and UV-C light leads to a decrease in storage modulus with increase in temperature with UV-C irradiated samples having a higher decrease than UV-A irradiated samples. Loss modulus and loss factor decrease with respect to control sample for UV-A light irradiation. For UV-C irradiated samples, the loss modulus and loss factor increase with respect to control sample. UV-C light had a greater impact on the mechanical properties of oyster mushrooms compared to UV-A light. These changes in mechanical properties did not affect the quality of the mushroom.

Therefore exposing mushrooms to UV-A (365nm) and UV-C (254nm) light during growth causes measurable increases in the vitamin D_2 content and as a result, mushroom can provide appreciable amounts of vitamin D_2 to the diet. The concentration of vitamin D_2 depends on the wavelength of UV light and duration of exposure. Consumer quality such as chewiness of the mushrooms irradiated during growth especially with UV-C light is high. UV-C irradiated mushrooms required low chewing force.

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