INFLUENCE OF GAMMA RADIATION ON SOME TEXTURAL PROPERTIES OF FRESH AND DRIED OYSTER MUSHROOMS (*PLEUROTUS OSTREATUS*)

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Abstract
Food processing involves the input of thermal, mechanical, photonic or ionising radiation energy.Gamma irradiation is usually perceived to energize and make foods radioactive which ultimately modify their chemical composition mainly the texture. Texture profile analysis (TPA) was used to evaluate the texture parameters of hardness, fracturability, cohesiveness, springiness, gumminess, chewiness, adhesiveness and resilience of the mushrooms. Fresh, dried and rehydrated mushrooms (Pleurotus ostreatus) were exposed to gamma radiation doses of 0, 0.5, 1, 1.5 and 2 kGy at a dose rate of 1.7 kGy hr^{-1}.The fresh products had an average moisture content of 80.3- 85.0% while dried mushrooms had average moisture content of 11- 14%. Rehydrated mushrooms had moisture content range of 42.3- 49.7%.Dose of 1.5 kGy was most apparent on hardness, resilience, springiness and adhesiveness. Cohesiveness increased as dried mushrooms were rehydrated. Hardness, fracturability, gumminess and chewiness decreased as radiation increased with dried mushrooms. Although the results obtained showed that irradiation had significant (P<0.05) effects on fresh, dried and rehydrated mushrooms, irradiation process is encouraged because of persistent high food losses from infestation,contamination, and spoilage; food-borne diseases; and growing international trade in food products that must meet strict import standards of quality and quarantine.

Key words- TPA, gamma, irradiation, *Pleurotus ostreatus*, texture, mushrooms

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1. INTRODUCTION

Mushrooms are accepted or rejected on the basis of their chemical and physical properties, specially the texture, a physical quality very important in the case of mushrooms (Matser *et al.,* 2000). Mushrooms are soft textured and prone to deterioration shortly after harvest if not stored properly (Walde, 2006). In view of their short shelf life under normal ambient conditions of temperature and humidity, it is imperative to preserve it by processing to extend shelf life for off season use (Kotwaliwale *et al*, 2010). Dehydration, canning, freezing, among others, have been found to be suitable for mushroom preservation (Bernas, 2006; Pal, 1997). Nonetheless, among the various methods employed for preservation, drying is one of the common methods used for mushrooms owing to its easiness and economical nature (Kumar *et al*., 2013; Argyropoulos *et al*., 2011; Kotwaliwale *et al*., 2007; Walde *et al*., 2006; Kar *et al*., 2004; Rai *et al.,* 2003).The dehydrated product offers, apart from increased shelf-life, the advantages of decreased mass and volume which have the potential for savings in the cost of packaging, handling, storage and transport of the product (Karimi, 2010; Amuthan *et al.,* 1999).
To complement the drying method, irradiation technology could be employed for controlling insect infestation, reduce the numbers of pathogenic or spoilage microorganisms, and delay or eliminate natural biological processes such as ripening, germination, or sprouting in fresh food. Like all preservation methods, irradiation should supplement rather than replace good food hygiene, handling, and preparation practices (Food Safety Authority of Ireland [FSAI], 2005).The FDA emphasizes

that no preservation method is a substitute for safe food handling procedures (Arvanitoyannis, 2010).

Texture is composed of several textural properties which involve mechanical (hardness, chewiness, and viscosity), geometrical (particle size and shape) and chemical (moisture and fat content) characteristics (Bourne, 1980).The texture of food material is mainly addressed to describe the structure of the food and the manner in which that structure reacts to applied force (Szczeoeniak, 1968).The texture parameter, together with appearance and flavour, are the organoleptic quality attributes which determine the acceptability of a food by the consumer (Guine and Barroca, 2011).One of the main changes associated with mushrooms deterioration are changes in their texture (Lopez-Briones *et al*, 1992; Villaescusa and Gil, 2003; Ares *et al*, 2006; Parentelli *et al*, 2007).Instrumental measurements of texture have become essential for the assessment of quality in the food industry (Harker *et al*, 2006) and, among the methods used to determine texture, instrumental texture profile analysis (TPA) is the most frequently used to calculate the textural properties, and intend to imitate the repeated biting or chewing of a food (Guine and Barroca, 2011).Also, instrumental measurements of texture are preferred over sensory evaluations since instruments may reduce variation among measurements due to human factors and are more precise (Casas *et al*., 2006).

The aim of the present study was to assess the effect of physical stress (gamma irradiation) on the texture of fresh, solar dried and rehydrated mushrooms (*Pleurotus ostreatus*) by measuring their textural attributes (hardness, fracturability, springiness, cohesiveness, chewiness, gumminess, adhesiveness and resilience) using texture profile analysis.

2. MATERIALS AND METHODS

Sampling

Fresh oyster mushrooms of average sizes were obtained from the Mycology Unit of the Food Research Institute, Ghana. Mushrooms of stipe diameter of about 0.7cm were selected and used in the analysis. Averages of five mushroom fruit bodies were used in the analysis and the mean values determined. They were washed thoroughly under running tap water to remove adhering extraneous matter and then used for the experimental studies.

Processing

Drying of mushroom samples

Drying was carried out by using a solar dryer at a temperature of 50- 60^{o}C to reduce moisture content to about 12% for an average period of 12 days.

Irradiation of mushroom materials

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

Rehydration of mushrooms

Rehydration of mushrooms was determined by a modified method of Giri and Prasad, (2013). Exactly 5g of dried samples were immersed in distilled water at 90- 100^{o}C temperature. The water was drained and the samples weighed at every 2 min intervals until constant weight was attained. Moisture content was about 42.3-49.7%. Triplicate samples were used.

Determination of moisture content

The moisture content was determined by the gravimetric method of (AOAC, 1996).

Instrumental Texture measurement

Texture Analyser (make: Stable Micro Systems, UK—Model: TA-XT2i) was used for texture analysis of all the samples. Texture analysis was carried out under following

instrument parameters: pre-test speed—10 mm/s; testspeed—2 mm/s; post-test speed—10 mm/sec; time lag between two compressions—2 sec; strain—30% of sample height; trigger force—0.05 N; data acquisition rate—200 pps; 10 mm hemispherical plastic probe; load cell—25 kg with 1 g least count. Hardness, springiness, cohesiveness, and chewiness of the samples were calculated using the expressions as shown in Fig. 1.
The textural properties: hardness, adhesiveness, springiness, cohesiveness, and chewiness were calculated after (1) to (5) (see Fig. 1):

Hardness (kgf) = F1 ………………………(1)
Adhesiveness (kgf.s) = A3 ………………(2)

Springiness = (t2/t1)…… …………… (3)
Cohesiveness (dimensionless) = A2/A1…. (4)
Chewiness (kg.f) = (F1) (t2/t1) (A2/A1)… (5)

where F1 is the maximum force, i.e., the force in the first peak, A1 and A2 are the areas of the first and second peaks, respectively, and T1 and T2 are the time intervals for the first and second peaks, respectively. The area of the negative peak, that should be visible between vertical lines 3 and 4 (the vertical lines are auxiliary to compute the textural parameters), represents adhesiveness, and would be visible only when the food has measurable adhesiveness, which was sparingly recorded.

3. RESULTS AND DISCUSSIONS

Table 1. Shows the moisture content of fresh mushrooms which ranged 80.8-83.7%;dried mushrooms recorded 11.5-13.1% while rehydrated mushrooms also recorded 42.3-49.7%. According to Ares et al, (2007), mushrooms are only protected by a thin and porous epidermal structure, lacking the specialized epidermal structure of higher plant tissues. This epidermal layer does not avoid a quick superficial dehydration causes important quality losses (Singer, 1986). Post harvest senescence in a variety of horticultural commodities is accompanied by changes in cell membrane characteristics, which leads to loss of barrier function and loss of turgor (Mazliak, 1987)..

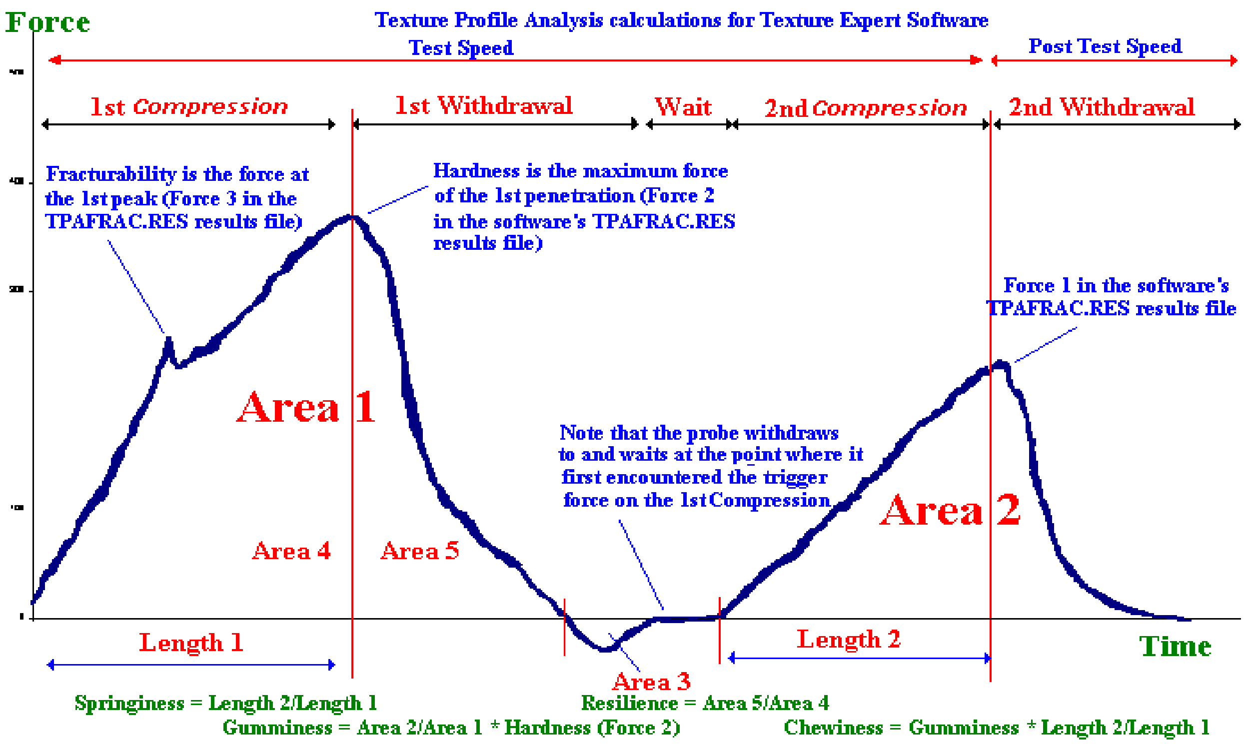

Fig.1. Texture Profile Analysis (TPA) (Source: Anonymous 2005)

Softening of mushrooms and firmness loss during postharvest storage has been ascribed to membrane changes which are directly linked to moisture content of cells(Beelman, 1987; Waldron, 1997; Marsilio, 2000)

Table 1. Mean moisture content (%) of fresh, dried and rehydrated irradiated oyster mushrooms

Dose (kGy)	Moisture content (%)Fresh	Dried	Rehydrated
0	80.8	12.443.2	
0.5	81.3	11.545.6	
1	83.7	12.548.6	
1.5	81.5	13.1	42.3
2	80.9	12.8	49.7
S.D	1.3	0.4	1.1
Mean	81.6	12.5	45.9

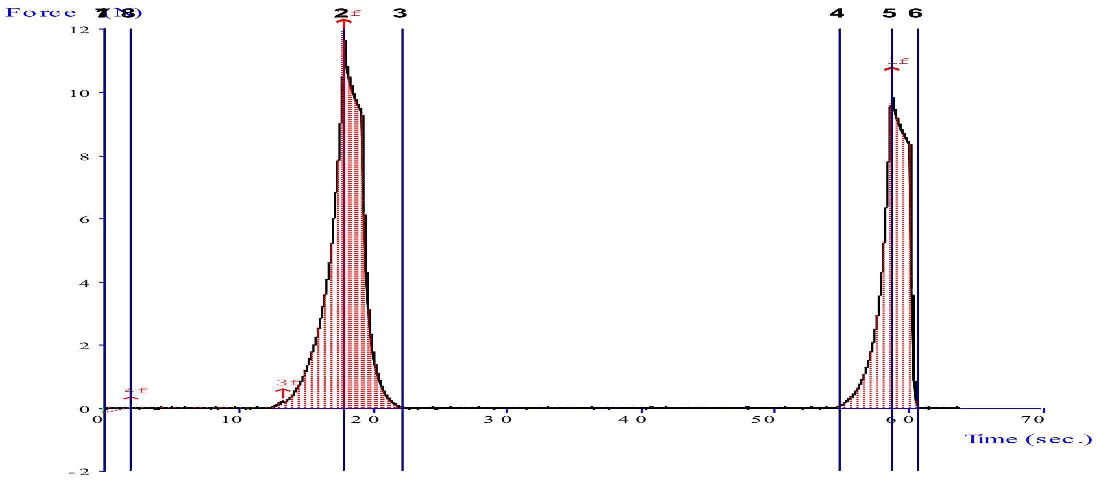

Fig.2: Texture profile analysis curve of fresh oyster mushrooms irradiated at 2 kGy

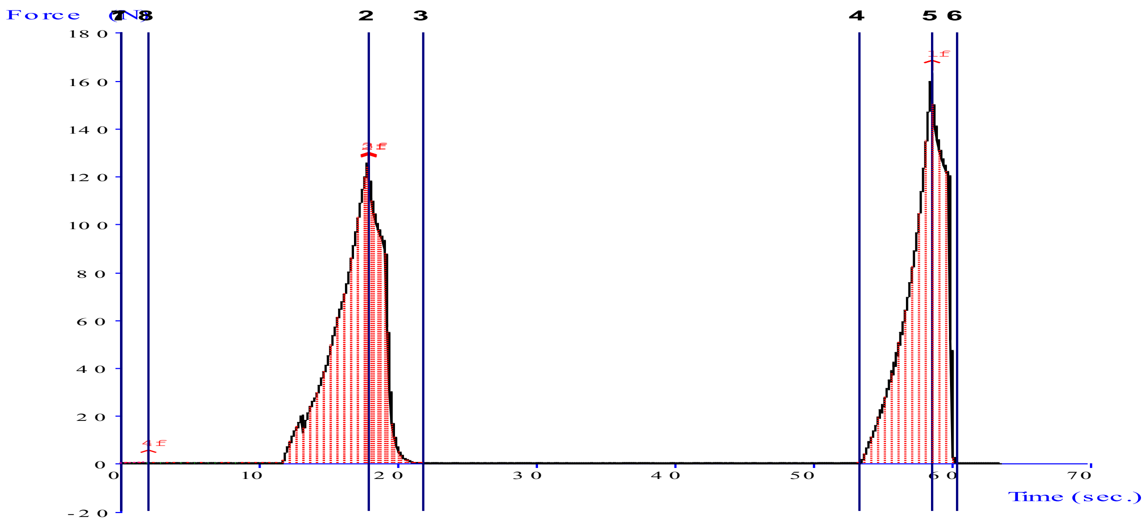

Fig.3. Texture profile analysis curve of dried oyster mushrooms irradiated at 2 kGy

Influence of irradiation on the texture of fresh, dried and rehydrated mushrooms

Texture results from complex interactions between food components, and is affected by cellular organelles and biochemical constituents, water content as well as and cell wall composition. Hence, external factors affecting these qualities can modify texture (Guiné and Barroca, 2011). The changes in texture that occur during the processing of mushroom materials or certain physiological events have been related with tissue and cell micro-structural changes (Marsilio et al, 2000).The effect of processing treatments such as irradiation, dehydrating and rehydrating had significant (P< 0.05) on the textural parameters of the Pleurotus ostreatus and the results evaluated. The results are presented in Figures 2-11.

Hardness

The hardness of the samples taken from irradiated fresh, dried and rehydrated mushrooms are presented in Fig. 2. This property corresponds to the maximum force recorded during the first cycle of compression, and represents the force required between the molars for chewing a food, being in most cases related to the tensile strength of the sample. Generally, higher values were recorded for dried mushrooms (Fig.3) and there were no significant (P> 0.05) differences between doses 0, 0.5, 1 and 1.5 kGy which ranged between 63- 74 kgf. Irradiation dose of 2 kGy however showed an apparent decrease in hardness of the dried samples to a low value of 29 kgf. Fresh mushrooms recorded low values of the range 0.2- 0.4 kgf. There were significant (P< 0.05) differences among the treatment doses. Rehydrated mushrooms also recorded similarly low values of 0.1- 0.2 kgf which were not significantly different (P> 0.05). Hardness in dried mushrooms decreased from 1.5 kGy and above doses (Fig.4). This might be due to the hydrolytic effect of gamma radiations on the cell membranes (Mamiet al, 2013; Gbedemah et al, 1998). Giri and Prasad, (2013) recorded higher values in their work. While Kotwaliwale et al, 2007 recorded lower values.

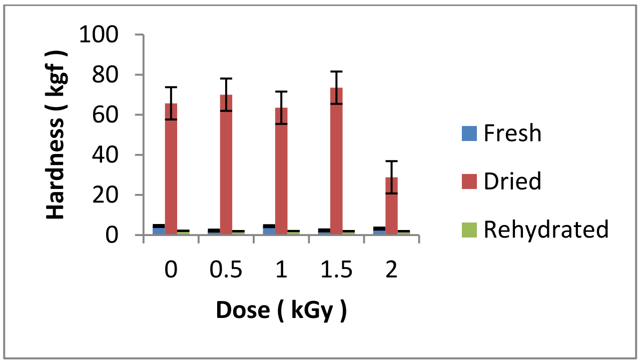

Fig. 4: Influence of gamma radiation on Hardness of oyster mushrooms

Fracturability

Not all products fracture; but when they do fracture the fracturability point occurs where the plot has its first significant peak (where the force falls off) during the probe's first compression of the product. Dried mushrooms irradiated with 0, 0.5 and 1 kGy doses of radiation required a force of 14.8- 15.9 N and were not significantly different (P>0.05) (Fig.5). However, the force decreased to 12.9- 13.2 N as the doses were increased to 1.5 and 2 kGy which recorded no significant difference (P> 0.05). Fresh and rehydrated mushrooms recorded minimal forces of 0 - 1.7 N as radiation doses increased (Fig.5). Statistical analysis showed no significant difference (P>0.05). This is suggestive of increased gamma radiation doses having an apparent effect on protein and polysaccharide degradation, hyphae shrinkage, central vacuole disruption and expansion of intercellular space (Zivanovic *et al*, 2000).

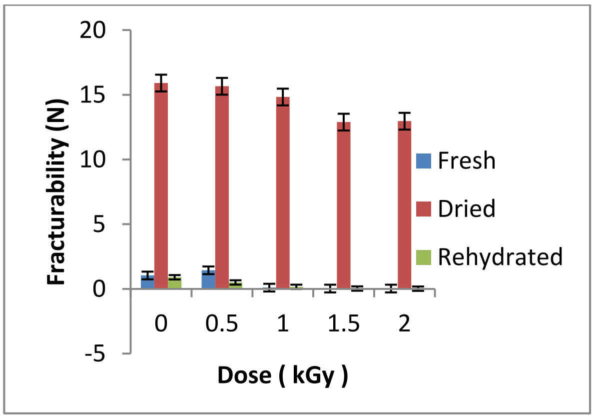

Fig. 5: Influence of gamma radiation on Fracturability of oyster mushrooms

Cohesiveness

Cohesiveness represents the ratio between the work done in the second compression and the work done in the first compression, and reflects the ability of the product to stay as one. The cohesiveness of dried mushrooms ranged between 0.6- 0.78 (Fig.6). The various doses showed significant differences (P< 0.05). Fresh mushroom cohesiveness also ranged0.65- 0.8 which were comparable to the rehydrated oyster mushrooms. Generally, cohesiveness of rehydrated mushrooms was increased and so ranged between 0.75- 0.86 and showed significant differences with respect to the various doses (Fig.6). Our results are in agreement with some researchers (Kotwaliwale *et al*, 2001; Zivanovic *et al*, 2000; Parentelli *et al*, 2007) who recorded an increase in cohesiveness after rehydration. This trend has been attributed to an increase in chitin content and formation of covalent bonds between chitin and β-glucan, increasing rigidity of the hyphal wall (Zivanovic *et al,* 2000).

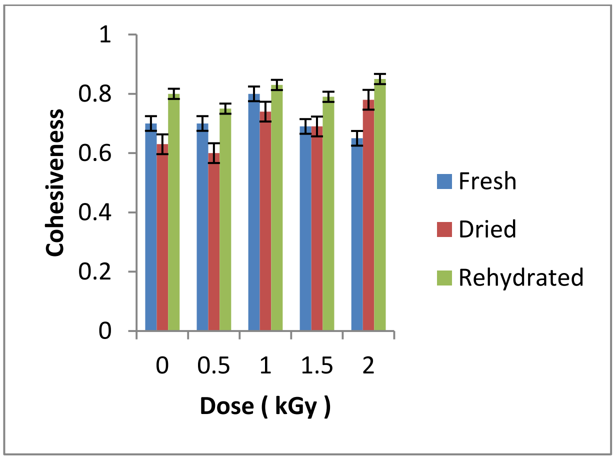

Fig.6: Influence of gamma radiation on cohesiveness of oyster mushrooms

Chewiness

Chewiness represents the energy required to disintegrate a solid material in order to swallow it and data is presented for the fresh, dried and rehydrated mushrooms at study in Fig.7. The dried mushrooms recorded highest values of chewiness of ranged from 5-16N and showed significant differences (P<0.05) (Fig.7).Fresh and rehydrated mushrooms also ranged 0.1- 2.0 N and 0.2- 1.9 N respectively and also showed significant differences (P<0.05). Values recorded for fresh mushrooms were consistent with data from the paper of Santos *et al,* (2012).

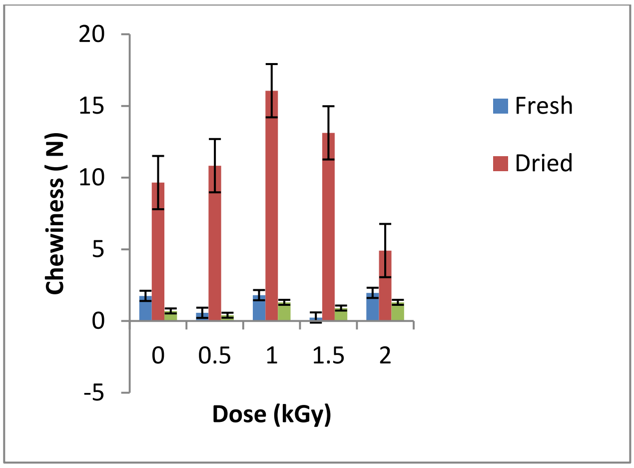

Fig.7: Influence of gamma radiation on Chewiness of oyster mushrooms

Springiness

Springiness is the ratio between the times in the two deformations, and represents the ability to regain shape when the deforming stress is removed or reduced, i.e., expresses the percent of recovery of the sample. Generally, dried mushrooms recorded comparatively lower values of the range 0.23- 0.31mm(Fig.8) while fresh and rehydrated mushrooms ranged between 0.12- 0.51 mm and 0.14- 0.50 mm respectively (Fig.8). Statistically, there was no difference (P>0.05) between fresh and rehydrated but differed (P<0.05) from the dried samples. The ability of the fresh and rehydrated oyster mushrooms to regain their shapes after the stress is reduced is suggestive of the presence of moisture in the cells of the mushrooms which causes turgidity to aid in strengthening the cell walls. The results for fresh and rehydrated oyster mushroom were similar to the data of Riebroy *et al,* (2010). Conversely, dried and irradiated mushrooms have depleted moisture to a stage that capillary voids were created hence reduced springiness. This trend is in agrees with data from studies by Kotwaliwale *et al*, (2007).

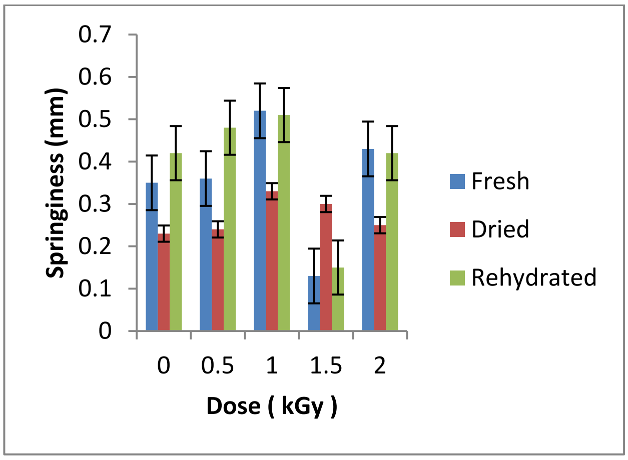

Fig.8: Influence of gamma radiation on Springiness of oyster mushroom

Gumminess

Gumminess is mutually exclusive with Chewiness since a product would not be both a semi-solid and a solid at the same time. It is a product of Hardness and Cohesiveness (which is Area 2/Area1) (Fig.1).The gumminess of dried mushrooms ranged between 30- 38. Fresh and rehydrated mushrooms also ranged between 1.0- 5.0 and 1- 3 respectively. There was an apparent difference in Gumminess of dried mushrooms generally decreased with increasing radiation doses and recorded significant changes (P<0.05). Gamma radiations might have caused a weakening of the intermolecular bonds and so slightly affected (IAEA, 1999).

Adhesiveness

Adhesiveness represents the work necessary to overcome the forces of attraction between the sample and the probe surface, and is given by the value of the area corresponding to the negative force (A3 in Fig. 1). Fig.9 shows the absolute values for adhesiveness in the fresh, dried and rehydrated mushroom samples when applicable, since in most of the cases the rehydrated samples had highest values of range -0.2 and -0.8 kgf.s. Radiation doses showed significant differences (P<0.05). The results show that, even in the case of the dried and irradiated, the adhesiveness was very low (-0.002 and -0.009), almost negligible. Statistically, there was no significant difference (P>0.05) between all the applied doses. The values were consistent with works of Guine and Barroca (2011) and Riebroy *et al,* (2010).

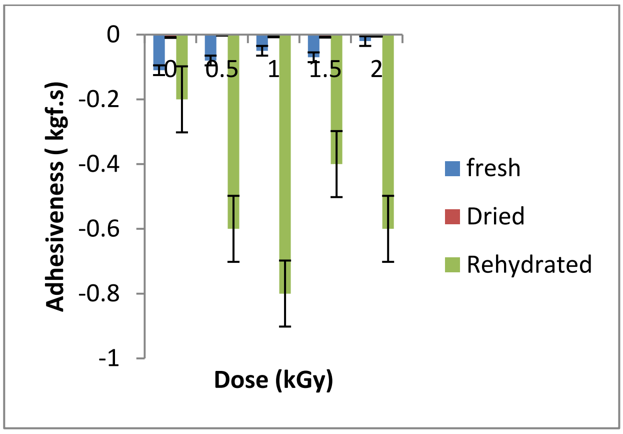

Fig.9: Influence of gamma radiation on the adhesiveness of mushrooms

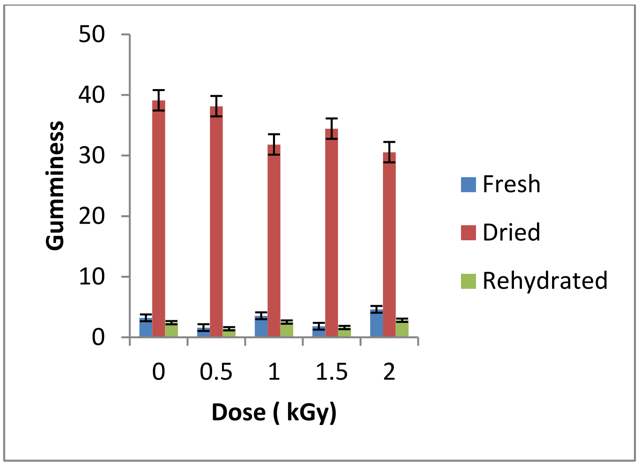

Fig.10: Influence of gamma radiation on Gumminess of oyster mushroom

Resilience

Resilience is how well a product "fights to regain its original position". The calculation is the area during the withdrawal of the first compression, divided by the area of the first compression. (Area 5/Area4 on Fig.1). Fresh mushrooms demonstrated highest (0.84- 1.71) resilience for all radiation doses. Doses 0, 0.5, 1 and 2 kGy showed no significant difference (P>0.05) (Fig.10). However, dose of 1.5 kGy showed significant difference between other doses (Fig.10).The ability of fresh and irradiated mushrooms to exhibit high resilience could be ascribed to its original and unaltered cell membrane as it has not undergone senescence (Beelman *et al*, 1987).Recorded values were consistent with Riebroy *et al*, (2010). Dried and rehydrated mushrooms recorded resilience of ranges 0.42- 0.51 and 0.30- 0.41 respectively. Dehydration has a very pronounced effect on the structure of foods, due to the loss of a considerable amount of water, increasing density by shrinkage in the case of convective drying. Apparently, rehydrated mushrooms could not regain its original shape after subjection to stress probably because water molecules could not fill all the pore spaces of the cell membrane and so turgidity was minimal.

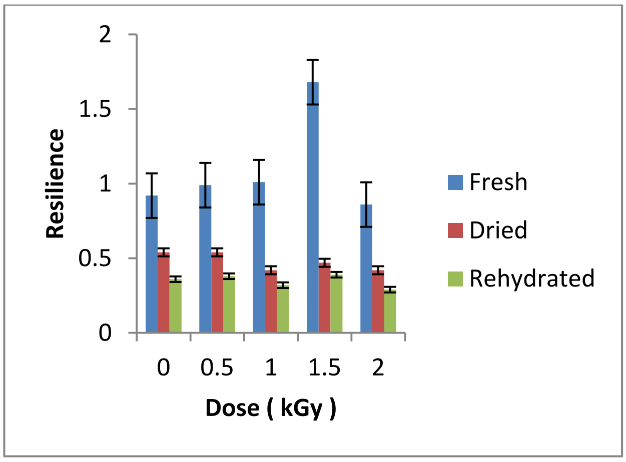

Fig.11: Influence of gamma radiation on the resilience of mushrooms

4. CONCLUSION

The Textural Profile Analysis results obtained for the parameters investigated for *Pleurotus ostreatus* revealed an apparent effect of gamma radiation on the fresh, dried and rehydrated states of the mushroom. Gamma radiation could however be used to prolong shelf life of mushrooms during storage.

5. ACKNOWLEDGEMENT

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