Scientific African 8 (2020) e00328

Contents lists available at ScienceDirect

Scientific African

journal homepage: www.elsevier.com/locate/sciaf

Sensory evaluation, descriptive textural analysis, and consumer acceptance profile of steamed gamma-irradiated *Pleurotus ostreatus* (Ex. Fr.) Kummer kept in two different storage packs

Nii Korley Kortei[a,*], George Tawia Odamtten[b], Mary Obodai[c], Papa Toah Akonor[c], Michael Wiafe-Kwagyan[b], Serwah Buckman[c], Seth William Nii Odartey Mills[d]

[a] University of Health and Allied Sciences, School of Allied Health Sciences, Department of Nutrition and Dietetics, PMB 31, Ho, Ghana
[b] University of Ghana, College of Basic and Applied Sciences, Department of Plant and Environmental Biology, P. O. Box LG 55, Legon, Ghana
[c] Council for Scientific and Industrial Research- Food Research Institute, P.O. Box M20, Accra, Ghana
[d] Ghana Atomic Energy Commission, Radiation Technology Centre, P.O. Box AE 1, Kwabenya-Accra, Ghana

ARTICLE INFO

Article history:
Received 10 December 2019
Revised 11 February 2020
Accepted 20 February 2020

Editor: Dr. B Gyampoh

Keywords:
Sensory evaluation
Texture
Gamma radiation
Pleurotus ostreatus
Hedonic scale

ABSTRACT

The influence of gamma irradiation on the sensory, acceptability and some descriptive textural attributes of dried *P.ostreatus* were evaluated. Sensory evaluation was carried out using steamed mushroom samples irradiated at doses 0 (control), 1, 2, 3, 4 and 5 kGy at a dose rate of 1.7 kGy/h from a Cobalt 60 source (SLL 515, Hungary) batch irradiator and stored in either polythene or polypropylene packs for 12 months at 28–30 °C. Using a structured questionnaire, 44 male and female panelists independently assessed the samples for sensory attributes. Organoleptic scores were made according to a nine (9) point hedonic scale. The evaluation showed mean scores of general likeness. There were no significant differences ($p > 0.05$) recorded for attributes such as appearance, aroma, taste, and mouthfeel. color and overall acceptability recorded some significant differences ($p < 0.05$). Also, descriptive textural attributes of hardness, adhesiveness, chewiness, and smoothness recorded no significant difference ($p > 0.05$). Cohesiveness however differed significantly ($p < 0.05$). Gamma irradiation of samples recorded no adverse effect on its organoleptic attributes. In the consumer acceptability test, the two differently treated samples; mushrooms irradiated with 1kGy and kept in polypropylene packs and non-irradiated mushroom (control) were rated similarly ($p > 0.05$), although more respondents preferred the control. Mostly, consumers wrongly perceive gamma irradiation to influence organoleptic properties of foods and also destructive to the food matrix hence the need to assess the quality difference organoleptically by human sensory analysis.

https://doi.org/10.1016/j.sciaf.2020.e00328

Introduction

Mushrooms are consumed and appreciated for their superior nutritional [1–3] attributes and have been included in the category of functional foods [4,5]. Functional foods are those foods that are enriched or modified and consumed as a normal diet to provide health-giving benefits. They provide ample supply of qualitatively good proteins, vitamins (folic acid, biotin, niacin, B complex, A, D, and C) and minerals such as phosphorus, potassium, calcium, zinc, sodium, iron and magnesium [6,7]. They are considered to be healthy food that can reduce malnutrition and help the country deliver the global commitment of achieving the Millennium Development Goals on health, poverty, and hunger (MDG1 and 3) [8].

Mushrooms are known to be medically active in several therapies, such as antitumor, antibacterial, antiviral, antioxidant, hematological and immunomodulating treatments [9–11]. The therapeutic effect had been linked to the presence of bioactive compounds in mushrooms. Some of these bioactive include glycolipids, compounds derived from the shikimic acid pathway, aromatic phenols, fatty acid derivatives, polyacetylamine, polyketides, sesquiterpenoids, and many other complex compounds of different origins [12,11]. They are highly-priced delicacies that are gaining so much popularity in Ghana.

Despite their overwhelming attributes, mushrooms are highly perishable owing to their high moisture content. Several methods are employed to extend their shelf life. Gamma irradiation although a recent acceptable technology is one of the few processes that can help attain this goal. The use of irradiation as a preservation process without loss of sensory and organoleptic qualities is well documented for various foods [13–16].

Although there have some negative reportages regarding the effect of irradiation on the sensory properties of foods [17]. This is likely to result in the development of off-odors and off-flavors in irradiated foods by which several factors including temperature, the environment within the package, packaging material, radiation dose, post-irradiation storage time, and the condition of the food before irradiation [18], could be responsible.

According to Spoto et al. [19] sensory alterations in irradiated foods, more specifically in the texture, color, rancidity, and odor can be eliminated with low temperatures at the time of irradiation, with the application of absorbent substances and the use of condiments. Textural profile analysis (TPA) using standard mechanical equipment to evaluate texture parameters of hardness, fracturability, cohesiveness, springiness, gumminess, chewiness, adhesiveness and resilience of fresh, dried and rehydrated irradiated (0–2 kGy) mushrooms (*Pleurotus ostreatus*) has been reported by Kortei et al., [20].

Quantitative and multiscale descriptive analyses are sensory tests of great interest as they allow the analysis and quantification of the different attributes that configure the sensory quality of the food. Their utility and applicability to solve several problems associated with quality control, new product development, or consumers' preferences analysis make their use more and more frequent [21].

The objective of this paper was to report on the effect of low dose gamma irradiation of 0–5 kGy on the sensory evaluation, descriptive textual analysis, and overall consumer acceptance profile evaluated by a trained human sensory panel using fruit bodies of *P.ostreatus* stored in different packaging materials.

Materials and methods

Mushroom samples

Pleurotus ostreatus mushroom samples were grown on composted sawdust as described by Kortei et al. [22] and harvested at maturity from the cropping house of the Mycology Unit, Food Research Institute, Accra, between the periods of February to May 2013.

Drying of mushroom samples

Drying was carried out by using a solar dryer at a temperature of 50–60 °C to reduce the moisture content to about 12% for an average period of 12 days following the procedure of Kortei et al. [23].

Storage

Forty (40) grams of dried oyster mushrooms (*Pleurotus ostreatus)* were packed into the various containers (polythene and polypropylene) and stored at room temperature.

Irradiation of mushroom materials

Irradiation was carried out at the Radiation Technology center of the Ghana Atomic Energy Commission with a Cobalt 60 source gamma irradiator (SLL 515, Hungary) at doses of 0 (control), 1, 2, 3, 4 and 5 kGy at a dose rate of 1.7 kGy per hour in the air. Absorbed doses were confirmed using the conventional Fricke's dosimetry system.

* Corresponding author.
E-mail address: nkkortei@uhas.edu.gh (N.K. Kortei).

Table 1
Samples codes and treatments.

Sample code	Treatment
808	Control
512	1 kGy/ polythene
667	2 kGy/ polythene
891	3 kGy/ polythene
837	4 kGy/ polythene
491	5 kGy/ polythene
753	1 kGy/ polypropylene
371	2 kGy/ polypropylene
606	3 kGy/ polypropylene
412	4 kGy/ polypropylene
948	5 kGy/ polypropylene

Sample preparation

The dried mushroom samples were grouped according to storage package (polypropylene and polythene) as well as the method of pretreatment (non-irradiated and irradiated) (Table 1). Equal amounts (18.76 g) of all samples were cooked by steaming in a pressure cooker (Binatone®, Japan) in a slightly saline water medium without spicing for 30 min and used in the study. The maximum temperature, which occurred about 30 s after the mushrooms exited the pressure cooker was recorded as the final internal cooked temperature. The mean cooked temperature was 83.4 °C with an SD of 2.9. Temperature rise was monitored with a handheld thermometer (Cole-Parmer, Vernon Hills, IL). The samples were labeled by numerical coding and interpreted as follows:

Sensory evaluation

To carry out a sensory evaluation of the dried and gamma radiation pretreated mushroom samples, a panel of 44 evaluators were sought by putting up notices for volunteers made up of male (19) and female (25) trained panelists were well educated (majority tertiary and above) and well conversant with agricultural products. Most of them were Food Scientists and Technicians from CSIR- Food Research Institute. The panelists were aged between 18 and 55 years. Using a well-structured questionnaire, the panelists independently assessed the samples for appearance, color, aroma, taste, mouthfeel and overall acceptability. Water was provided to rinse the mouth each time a panelist carried out an evaluation. Organoleptic scores were made according to a nine-point hedonic scale in which 9 = Like extremely, 8 = Like very much, 7 = Like moderately, 6 = Like slightly, 5 = Neither like nor dislike, 4 = Dislike slightly, 3 = Dislike moderately, 2 = Dislike very much and 1 = Dislike extremely, which showed the degree of likeness. Panelists indicated their rating for each sample by choosing the appropriate numerical score. The evaluation was conducted in individual sensory booths consistent with ISO 8589 acceptable method. Consumers were asked to rinse their palates with tap water between samples. Mushrooms were cooked as described for trained panel evaluation. The evaluation was carried out before lunch.

Descriptive texture analysis

The same treatments of mushroom samples were used for the analysis by the same evaluators. The panelists again independently assessed the samples for hardness, cohesiveness (integrity), adhesiveness (stickiness), chewiness (stringiness) and smoothness. Organoleptic scores were made according to a nine-point hedonic scale as described above.

Acceptability test

Based on the outcome of the sensory evaluation, two different treatments were selected for the consumer preference test. One hundred and fifty-eight consumers evaluated the steamed gamma-irradiated mushroom for acceptability. Participants were consumers of fried foods and were selected after reading and signing a consent form. Three pieces of each of the two mushroom samples were presented to panelists on a white styrofoam platter, labeled with a unique 3-digit code. Unsalted crackers and water were provided to clean and refresh the palate before evaluating different samples. A 7-point Hedonic scale ranging from 1 'dislike very much' to 7 'like very much' was used to rate product acceptability as described by [24–26]. Consumers were also given the option of writing their comments about the two products.

Following the acceptability test, each consumer was also made to complete a questionnaire of closed-ended questions. The questionnaire was used to collect information on product acceptability.

Table 2
Mean scores of sensory analysis of gamma irradiated dried mushrooms stored in polythene and polypropylene packs.

Samples	Appearance	Color	Aroma	Taste	Mouthfeel	Acceptability
371	5.9 ± 0.5^{a}	5.6 ± 0.5^{a}	5.6 ± 0.4^{a}	5.3 ± 0.5^{a}	5.3 ± 0.5^{a}	5.4 ± 0.5^{a}
412	5.9 ± 0.4^{a}	5.6 ± 0.5^{a}	6.1 ± 0.4^{a}	5.8 ± 0.3^{a}	5.7 ± 0.3^{a}	5.9 ± 0.4^{ab}
491	6.4 ± 0.3^{a}	5.8 ± 0.3^{a}	6.2 ± 0.4^{a}	5.7 ± 0.3^{a}	5.7 ± 0.4^{a}	5.8 ± 0.4^{ab}
512	5.7 ± 0.5^{a}	5.9 ± 0.4^{a}	6.1 ± 0.5^{a}	5.9 ± 0.4^{a}	5.7 ± 0.5^{a}	6.0 ± 0.5^{ab}
606	5.9 ± 0.3^{a}	5.4 ± 0.3^{a}	5.9 ± 0.2^{a}	5.4 ± 0.4^{a}	5.4 ± 0.3^{a}	5.5 ± 0.3^{a}
667	5.6 ± 0.4^{a}	5.9 ± 0.3^{a}	6.1 ± 0.4^{a}	5.8 ± 0.3^{a}	5.6 ± 0.3^{a}	5.6 ± 0.3^{ab}
753	6.5 ± 0.4^{a}	6.6 ± 0.3^{ab}	6.6 ± 0.2^{a}	6.3 ± 0.4^{a}	6.1 ± 0.4^{a}	6.8 ± 0.3^{bc}
808	7.4 ± 0.4^{a}	7.4 ± 0.4^{b}	6.7 ± 0.2^{a}	7.1 ± 0.3^{a}	6.6 ± 0.4^{a}	7.3 ± 0.3^{c}
837	5.8 ± 0.4^{a}	5.5 ± 0.3^{a}	5.9 ± 0.4^{a}	5.5 ± 0.4^{a}	5.4 ± 0.3^{a}	5.6 ± 0.4^{ab}
891	6.1 ± 0.4^{a}	5.9 ± 0.4^{a}	5.9 ± 0.4^{a}	5.7 ± 0.5^{a}	5.4 ± 0.3^{a}	5.7 ± 0.4^{ab}
948	6.1 ± 0.3^{a}	6.1 ± 0.3^{a}	5.8 ± 0.3^{a}	5.5 ± 0.5^{a}	5.3 ± 0.5^{a}	6.0 ± 0.4^{ab}

Means within a column with different superscripts are significantly different ($p < 0.05$).

Table 3
Mean scores of sensory analysis of gamma irradiated dried mushrooms stored in polythene and polypropylene packs.

Sample	Hardness	Cohesiveness	Adhesiveness	Chewiness	Smoothness
371	5.9 ± 0.4^{a}	5.6 ± 0.3^{a}	5.6 ± 0.4^{a}	5.7 ± 0.4^{a}	5.4 ± 0.4^{a}
412	5.9 ± 0.4^{a}	5.8 ± 0.4^{a}	6.0 ± 0.5^{a}	5.6 ± 0.5^{a}	5.7 ± 0.4^{a}
491	5.7 ± 0.3^{a}	5.8 ± 0.3^{a}	5.1 ± 0.4^{a}	5.7 ± 0.4^{a}	5.8 ± 0.4^{a}
512	5.6 ± 0.3^{a}	6.1 ± 0.3^{a}	5.5 ± 0.4^{a}	5.5 ± 0.3^{a}	5.6 ± 0.5^{a}
606	5.8 ± 0.4^{a}	5.8 ± 0.3^{a}	5.2 ± 0.3^{a}	5.7 ± 0.4^{a}	5.6 ± 0.4^{a}
667	5.9 ± 0.3^{a}	5.9 ± 0.4^{a}	5.7 ± 0.4^{a}	6.0 ± 0.3^{a}	6.3 ± 0.4^{a}
753	6.4 ± 0.4^{a}	6.1 ± 0.5^{a}	5.9 ± 0.5^{a}	6.5 ± 0.4^{a}	6.3 ± 0.3^{a}
808	6.9 ± 0.4^{a}	7.4 ± 0.3^{b}	6.6 ± 0.5^{a}	7.3 ± 0.4^{a}	7.1 ± 0.4^{a}
837	5.9 ± 0.3^{a}	5.9 ± 0.3^{a}	5.6 ± 0.5^{a}	6.4 ± 0.6^{a}	6.0 ± 0.4^{a}
891	5.6 ± 0.3^{a}	5.5 ± 0.3^{a}	5.3 ± 0.4^{a}	6.0 ± 0.3^{a}	5.6 ± 0.3^{a}
948	6.5 ± 0.4^{a}	6.4 ± 0.3^{a}	6.3 ± 0.4^{a}	6.2 ± 0.4^{a}	6.3 ± 0.4^{a}

Means within a column with different superscripts are significantly different ($p < 0.05$).

Statistical analysis

Oneway analysis of variance (ANOVA) was used. Means were compared using the least significant difference (LSD), DMRT was used to separate the means. Mean differences were considered statistically significant at $p < 0.05$ with SPSS v 16.0 (Illinois, USA) for Microsoft windows.

Results

The mean scores for the acceptability attributes (appearance, color, aroma, taste, mouthfeel, and overall acceptability) and descriptive texture attributes (hardness, cohesiveness, adhesiveness, chewiness, and smoothness) of steamed gamma-irradiated *P.ostreatus* are presented in Tables 2 and 3. Mean values after analysis of variance (ANOVA) showed some significant differences ($P < 0.05$) in the attributes in some instances.

Appearance recorded mean scores of range 5.6 ± 0.4–7.4 ± 0.4 which corresponded to dried mushrooms irradiated at 2 kGy and stored in polythene packs (code 667) and non- irradiated mushrooms (0 kGy) (code 808) respectively. The appearance attribute for all samples showed no significant ($P > 0.05$) differences (Table 2).

Colour which is perhaps the most important organoleptic attribute, recorded mean scores of range 5.4 ± 0.3–7.4 ± 0.4 which corresponded to dried mushrooms irradiated at 1kGy and stored in polypropylene packs (code 606) and non- irradiated dried mushrooms. The samples (code 808) differed significantly ($P < 0.05$) from the other samples (Table 2).

Aroma recorded mean scores of range 5.6 ± 0.4–6.7 ± 0.2 which corresponded to dried mushrooms irradiated at 2 kGy and stored in polypropylene pack (code 371) and dried unirradiated mushrooms at 0 kGy (code 808) respectively. There were no significant differences ($P > 0.05$) recorded between the samples (Table 2).

Mouthfeel recorded mean scores of range 5.3 ± 0.5 - 6.6 ± 0.4 which corresponded to both dried mushrooms irradiated at 2 kGy and 5 kGy, stored in polypropylene packs (codes 371 and 948) and non- irradiated dried mushrooms respectively. There were no significant differences ($P > 0.05$) recorded between the tested samples in terms of the mouthfeel (Table 2).

Taste recorded mean scores of range 5.3 ± 0.5–7.1 ± 0.3 which corresponded to dried mushrooms irradiated at 2 kGy and stored in polypropylene pack (code 371) and dried mushrooms irradiated at 0 kGy (code 808) respectively. However, there was no significant difference ($P < 0.05$) recorded between all the samples in terms of taste.

Table 4
Mean score for steamed gamma-irradiated mushroom acceptability.

Sample	Percentage	Mean score	Inference
808	51.1	7.3 ± 0.3[a]	Like moderately
753	48.9	6.8 ± 0.3[a]	Like slightly

Means within a column with different superscripts are significantly different ($p < 0.05$).

Overall acceptability recorded mean scores of range 5.4 ± 0.5–7.3 ± 0.3 which corresponded to dried mushrooms irradiated at 2 kGy and stored in polypropylene pack (code 371) and non-irradiated dried mushrooms. There were significant ($P < 0.05$) differences in overall acceptability.

Hardness recorded mean scores ranging from 5.6 ± 0.3–6.9 ± 0.4 which corresponded to both dried mushrooms irradiated at 1 and 3 kGy and stored in polythene packs (codes 891 and 512) and the control (0 kGy coded 808). However, there were no significant differences ($P > 0.05$) observed among all the samples (Table 3).

Cohesiveness (integrity) recorded mean scores ranging from 5.5 ± 0.3–7.4 ± 0.3 which corresponded to samples irradiated with 3 kGy and stored in polythene pack (code 891) and non-irradiated (0 kGy) sample (code 808) respectively. Non-irradiated samples (control) significantly differed ($P < 0.05$) from all other samples (Table 3).

Adhesiveness (stickiness) recorded mean scores of range 5.1 ± 0.4–6.6 ± 0.5 which corresponded to samples irradiated at 5 kGy and stored in polythene packs (code 491) and non-irradiated (0 kGy) (code 808) samples respectively. There were however no significant differences ($P > 0.05$) observed between all the samples tested.

Chewiness (stringiness) recorded mean scores of range 5.5 ± 0.3–7.3 ± 0.4 which corresponded to samples irradiated at 1 kGy and stored in polythene pack (code 512) and non-irradiated (0 kGy) (code 808) respectively. There were again no significant differences ($P > 0.05$) shown in all samples.

Lastly, smoothness recorded mean scores of range 5.4 ± 0.4–7.1 ± 0.4 which corresponded to samples irradiated at 2 kGy and stored in polypropylene pack (code 371) and non-irradiated (0 kGy) (code 808) respectively. Statistical analysis showed that there were no significant differences ($P > 0.05$) observed in all samples.

Consumer acceptability

Based on the mean overall acceptability the control and 1 kGy/polypropylene pack were selected for the consumer acceptability survey. This reiterates the point that low dose gamma irradiation (<10 kGy) does not alter the organoleptic properties of food [27–29].

The control sample was the most preferred among the selected steamed mushroom variants and was the choice of 51.1% (of 120 consumers) surveyed. Mushrooms irradiated at 1 kGy and kept in polypropylene pack followed closely with 48.9% of 120 consumers. Nonetheless, the mean acceptability score assigned was not significantly different ($p > 0.05$) among the two samples, although the control had a higher mean rating of 7.3 (Table 4).

Appearance and color primarily influenced the choice and acceptability of the treated mushrooms by scoring averages of 6.11 and 5.97 respectively as can be seen in Fig. 1.

Discussion

A hygienically and neatly prepared mushroom samples were presented for consumption which enhanced the appearance of the samples hence, they were appreciated by the panelist.

Gamma irradiation and storage of dried mushrooms in polypropylene and polythene packages at the doses used in the present study had no significant effects ($P > 0.05$) on the majority of the sensory attributes of the steamed mushrooms samples. Panelists gave similar preference scores for both irradiated and non-irradiated samples, which indicated that all were highly satisfactory as judged by appearance, aroma, taste, and mouthfeel (Table 2). Nonetheless, panelists showed some significant ($P < 0.05$) preferences for color and acceptability for non-irradiated and 1 kGy irradiated samples probably because higher doses might have caused an activation of tyrosinase enzymes to undergo some biochemical reactions to produce melanin which made the color not appealing enough to the panelists as suggested by some researchers [30,31]. The flavor experienced from eating mushrooms, or any other food, comes from a combination of taste, texture, temperature, spiciness, and aromatic qualities [30]. Effects of irradiation on odor and flavor have been studied with sensory panels of varying degrees of training; however, few consumer studies have been conducted. According to Hallock [32], the taste and smell of mushrooms are important for both the issues regarding gustation and olfaction important to the mycophagist. Also, the mouthfeel of all sample treatments observed was regular and was appreciated as no extraordinary mouthfeel was recorded. Product acceptability of mushroom in general varying probably due to the diversity of preference of different mushroom species, method of cooking and some other factors by the consumers.

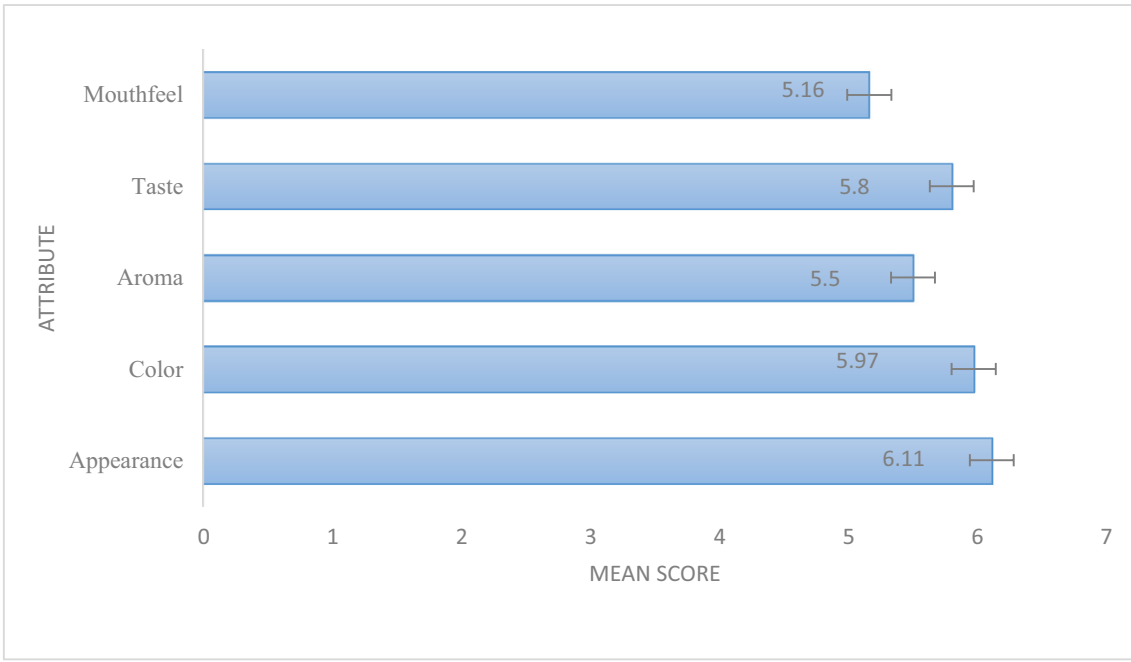

Fig. 1. Attributes of steamed gamma-irradiated mushrooms that influenced acceptability.

Descriptive texture analysis

This was carried out primarily to authenticate results obtained by the instrumental evaluation method. The mean scores of the descriptive texture analysis of irradiated and non-irradiated dried mushrooms stored in polythene and polypropylene packs are presented in Table 3. Texture is a sensory attribute that greatly influences taste perception and the marketability of a product. The observed high score of non-irradiated *P.ostreatus* for hardness might be due to the ability of high doses of gamma radiation to cause a weakening of covalent bonds to cause depolymerization [31,33]. Hardness, adhesiveness, chewiness, and smoothness of all the variously treated samples were normal and so were liked by the panelist confirming the textural measurement on the instrument. However, the cohesiveness of the control sample was preferred most over the others. This observation is an agreement with the findings of some researchers [34,35] who carried out an analysis to assess consumer attitudes to irradiated foods. Niemira and Fan [36] reported that treatment up to 0.5 kGy did not change the hardness of different types of iceberg lettuce. Studies by Foley et al. [37] and Hagenmaier and Baker [38] also demonstrated that doses of 0.5 kGy did not induce alterations on visual attributes or softening in iceberg lettuce. Nonetheless, disagreeing with those by [39] who observed changes in the texture of some minimally processed apples irradiated with doses of 0.34 kGy and greater. In a related study by Song et al. [40], reported a decrease in the hardness of low-salt sausages irradiated with ionizing radiations. The degree of hardness was lower than that of L-control sausage ($p < 0.05$).

Results have consistently shown that many consumers have misconceptions about the technology and believe that it makes food radioactive. When consumers are given information about the process and a chance to try irradiated products for themselves they are much more likely to accept the technology such as in this case reported in this paper.

Acceptability

This observation verifies the results of the sensory evaluation conducted before the consumer acceptability survey, which also had acceptability scores not being significantly different ($p > 0.05$) between these two samples. Reasons for consumers' choice of control (0 kGy) were based on appearance, color, and taste as indicated in Fig. 1. This trend was similar among the two variants of irradiated mushrooms. A remarkable observation of this result is the fact that none of the participants' choice was influenced by mouthfeel or aroma.

Conclusion

Sensory evaluation of the gamma-irradiated mushrooms showed acceptability for samples from non-irradiated mushrooms with taste and texture influencing the selection of preferred choice. Two other attributes, color, and aroma did not contribute significantly to the preferred option of sensory panelists. Consumer acceptability survey revealed that more consumers (>51%) liked the non-irradiated mushroom (control) than mushrooms irradiated (1 kGy/polypropylene) (<48%). Gen-

erally, the developed gamma-irradiated (1 kGy/polypropylene pack) product was acceptable since it had an acceptability score of 6.5–6.8 as 'like moderately' to 'like slightly' on a 9-point Hedonic scale.

Often times, consumers wrongly perceive gamma irradiation to influence the organoleptic properties of foods and also destructive to the nutrients and matrix. Hence, this evaluation proved that both treatments were comparable organoleptically.

Declaration of Competing Interest

The authors declare they have no actual or potential competing financial interests.

CRediT authorship contribution statement

Nii Korley Kortei: Conceptualization, Formal analysis, Resources, Supervision, Writing - review & editing. **George Tawia Odamtten:** Conceptualization, Formal analysis, Resources, Supervision, Writing - review & editing. **Mary Obodai:** Conceptualization, Formal analysis, Resources, Supervision, Writing - review & editing, Data curation, Writing - original draft. **Papa Toah Akonor:** Investigation, Validation, Data curation, Writing - original draft. **Michael Wiafe-Kwagyan:** Investigation, Validation. **Serwah Buckman:** Investigation, Validation. **Seth William Nii Odartey Mills:** Investigation, Validation.

Acknowledgement

Authors would like to express their gratitude to the Sensory Evaluation Unit, Department of Food Processing and Engineering, Food Research Institute, CSIR, Accra and Messers S.N.Y. Annan, J.N.O. Armah and S.A. Acquah of Radiation Technology center, Ghana Atomic Energy Commission for gamma irradiating the samples and their technical assistance.

Funding

This research received no grant from any funding agency in the public, commercial, private, or not-for-profit sectors.

References

[1] P. Kalač, Chemical composition and nutritional value of European species of wild-growing mushrooms: a review, Food Chem. 113 (2009) 9–16.
[2] V.K. Singh, Y. Patel, R. Naraian, Medicinal properties of *Pleurotus* species (oyster mushroom): a review, World Journal of Fungal and Plant Biology 3 (1) (2012) 01–12.
[3] N.K. Kortei, M. Wiafe- Kwagyan, A comparative appraisal of the total phenolic content, flavonoids, free radical scavenging activity and nutritional qualities of *Pleurotus ostreatus* (EM- 1) and *Pleurotus eous* (P- 31) cultivated on rice (*Oryzae sativa*) straw in Ghana, J. Adv. Biol. Biotechnol. 3 (4) (2015) 153–164.
[4] C.M. Hasler, Functional food: the western perspective, Nutr. Rev. 54 (1996) 506–510.
[5] S.T. Chang, J.A. Buswell, Mushroom nutraceuticals, World J. Microbiol. Biotechnol. 12 (1996) 473–476.
[6] N.K. Kortei. Comparative effect of gamma irradiation and steam sterilization of sawdust compost on the yield, nutrient, and shelf-life of *Pleurotus ostreatus* (Jacq.Ex.Fr.) Kummer stored in two different packaging materials. Ph.D. thesis, Graduate School of Nuclear and Allied Sciences, University of Ghana, Legon. (2015).
[7] V.O. Oyetayo, O.O. Ariyo, Micro and macro nutrient properties of *Pleurotus ostreatus* (Jacq: fries) cultivated on different wood substrates, Jordan J. Biol. Sci. 6 (2013) 223–226.
[8] United Nations, Millennium Development Goals, United Nations, New York, USA, 2000.
[9] S.P. Wasser, Medicinal mushrooms as a source of antitumor and immunomodulating polysaccharides (minireview), Appl. Microbiol. Biotechnol. 60 (2002) 258–274.
[10] U. Lindequist, T.H.J. Niedermeyer, W.D. Julich, The pharmacological potential of mushrooms: evidence-based complement, Alternative Med. 2 (2005) 285–299.
[11] N.K. Kortei, G.T. Odamtten, M. Obodai, , V. Appiah, F. Akuamoa, , A.K. Adu-Bobi, S.N.Y. Annan, J.O. Armah, S.A. Acquah. Evaluating the effect of gamma radiation on the total phenolic content, flavonoids and antioxidant activity of dried *P. ostreatus* (Jacq.ex.Fr.) Kummer stored in packaging materials. Advances in pharmaceutics, article ID 262807 (2014) 1–8.
[12] T. Mizuno, H. Saito, T. Nishitoba., H. kawagishi. Antitumour- active substances from mushrooms, Food Rev. Int. 11 (1995) 23–61.
[13] J. Farkas,. Irradiation of dry food ingredients, crc press inc., Boca Raton. (1988).
[14] International Atomic Energy Agency (IAEA)., TECDOC- 639, Vienna, Austria. (1992).
[15] Council for agricultural science and technology (CAST), Radiat. Pasteurization of Food 7 (1996) Issue Paper NoCAST.
[16] American Society for Testing and Materials (ASTM), Standard Guide for Irradiation of Spices, Herbs, and Vegetable Seasoning to Control Pathogens and other Micro-Organisms, ASTM Standard F, Denver, USA, 1998.
[17] D.W. Thayer, Food irradiation: benefits and concerns, J. Food Qual. 13 (1990) 147–169.
[18] D.G. Olson, Irradiation of food, Food Technol. 52 (1998) 56–62.
[19] M.H.F. Spoto, C.R. Gallo, A.R. Alcarde, M.S. Amaral Gurgel, L. Blumer, J.M.M. Walder, R.E. Domarco, Gamma irradiation in the control of pathogenic bacteria in refrigerated ground chicken meat, Sci. Agric. 57 (3) (2000) 389–394.
[20] N.K. Kortei, G.T. Odamtten, M. Obodai, V. Appiah, L. Abbey, C. Oduro-Yeboah, P.T. Akonor, Influence of gamma radiation on some textural properties of fresh and dried oyster mushrooms (*Pleurotus ostreatus*), Annals. Food Sci. Technol. 16 (1) (2015) 11–19.
[21] D. Singh–Ackbarali, R. Maharaj, Sensory evaluation as a tool in determining acceptability of innovative products developed by undergraduate students in food science and technology at the university of trinidad and tobago, J. Curric. Teach. 3 (1) (2014) 10–27.
[22] N.K. Kortei, G.T. Odamtten, M. Obodai, V. Appiah, S.N.Y. Annan, S.A. Acquah, J.O. Armah, Comparative effect of gamma-irradiated and steam sterilized composted 'wawa' (*Triplochiton scleroxylon*) sawdust on the growth and yield of Pleurotus ostreatus (Jacq.Ex.Fr.) Kummer, Innov. Rom. Food Biotechnol. 14 (2014) 69–78.
[23] N.K. Kortei, G.T. Odamtten, M. Ayim-Akonor, P.T. Akonor, Modeling the solar drying kinetics of gamma irradiation-pretreated oyster mushrooms *(Pleurotus ostreatus)*, Int. Food Res. J. 23 (1) (2016) 34–39.
[24] H. Stone, J.L. Sidel, Sensory Evaluation Practices, 3rd Edition, Elsevier Academic Press, San Diego, California, 2004.

[25] H.T. Lawless, H. Heymann, in: Sensory Evaluation of Food Principles and Practices, 2nd edition, Springer Science and Business Media, LLC, New York, 2010, pp. 1–21.
[26] C. Tortoe, P.T. Akonor, S. Nketia, M. Owusu, M. Glover-Amengor, L. Hagan, Evaluation of the sensory characteristics and consumer acceptability of deep-fried yam (*Dioscorea rotundata*) crisps in the Accra Metropolitan Area, J. Food Nutr. Sci. 2 (1) (2014) 19–23.
[27] Revised Codex General Standard for Irradiated Foods (CX STAN 106-1983, Rev.1) FAO/WHO Codex Alimentarius Commission. (2003) 1-3.
[28] World Health Organization (WHO). Safety and Nutritional Adequacy of irradiated Food. Geneva: Switzerland. (1994) pp 16–29. https://apps.who.int/iris/bitstream/handle/10665/39463/9241561629-eng.pdf?sequence=4&isAllowed=y (Date accessed- 12th August 2019).
[29] IAEA-TECDOC-1530, Use of irradiation to ensure the hygienic quality of fresh, pre-cut fruits and vegetables and other minimally processed food of plant origin, in: Proceedings of a final research coordination meeting organized by the Joint FAO/IAEA program of nuclear techniques in food and agriculture, Pakistan, 2005.
[30] N.D. Zasler, R. McNeny, P.G. Heywood, Rehabilitative management of olfactory and gustatory dysfunction following brain injury, J. Head Trauma Rehabilit. 7 (1992) 66–75.
[31] G. Ares, C. Lareo, P. Lema, Modified atmosphere packaging for postharvest storage of mushrooms. A review, Fresh Produce 1 (1) (2007) 32–40.
[32] S. Zivanovic, R.W. Buescher, K.S. Kim, Textural changes in mushrooms (*Agaricus bisporus*) associated with tissue ultrastructure and composition, J. Food Sci. 65 (2000) 1404–1408.
[33] R.M. Hallock, Taste of mushrooms, Spring 17 (1) (2007) 33–41.
[34] J.A. Fox, Influences on the purchase of irradiated foods, Food Technol. 56 (11) (2002) 34–37.
[35] R.M. Nayga Jr., W. Aiew, J.P. Nichols, Information effects on consumers' willingness to purchase irradiated food products, Appl. Econ. Perspect Policy 27 (1) (2005) 37–48.
[36] B.A. Neimira, X. Fan. Low dose irradiation of fresh and fresh-cut produce: safety sensory and shelflife. In'Food Irradiation Research and Technology, Ed. C. Sommers and X. Fan. Blackwell Publishing and the Institute of Food Technologists, Annual meeting., Chicago, IL. (2005) 169–181.
[37] D.M. Foley, A. Duffuor, L. Rodriguez, F. Caporaso, A. Prakash, Reduction of Escherichia coli 0157: H7 in shredded iceberg lettuce by chlorination and gamma irradiation, Radiat. Phys. Chem. 63 (3– 6) (2002) 391–396.
[38] R.D. Hagenmaier, R.A. Baker, Low-dose irradiation of cut iceberg lettuce in modified atmosphere packaging, J. Agric. Food Chem. 45 (1997) 2864–2868.
[39] G. Gunes, J.H. Hotchkiss, C.B. Watkins, Effects of gamma irradiation on the texture of minimally processed apple slices, J. Food Sci. 66 (2001) 63–67.
[40] D-H. Song, H.-.W. Kim, K.-.E. Hwang, Y.-.J. Kim, Y.-.K. Ham, Y.-.S. Choi2, D-J Shin, T.-.K. Kim, J.H. Lee, C.-.J. Kim, H.-.D Paik, Impacts of irradiation sources on quality attributes of low-salt sausage during refrigerated storage, Korean J. Food Sci. An. 37 (5) (2017) 698~707 doi, doi:10.5851/kosfa.2017.37.5.698.