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Composition and quality characteristics of loquat (*Eriobotrya japonica* L.) kernel

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Abstract

The aim of this study was to evaluate the effect of gamma irradiation treatment (at 3, 6 and 9 kGy) on proximate composition, chemical and microbial characteristics of loquat (*Eriobotrya japonica* L.) kernel. The results indicate that the loquat kernel (LK) was found to be very rich in nutritional content in terms of sugars (68.76%) proteins (9.46%), reducing sugar (3.49%), crude fat (3.98%), and total minerals (7.52%). Furthermore, the LK exert good quality properties including the low acidity (0.73%), medium pH value (6.33), and acceptable total volatile basic nitrogen value (TVBN) (32.00 ppm). Gamma irradiation had no effect on the moisture, lipid, ash, and reducing sugar content of LK. While, gamma irradiation increased crude protein, and decreased the total sugar. During storage, the total fat and total protein were increased, but the total sugar was decreased. The total acidity increased due to irradiation doses and storage period. Irradiation treatment and storage time caused no significant (p >0.05) difference between the VBN composition of the LK. Total viable count (TVC), total mould and yeast count (TMYC), and total coliform count (TCC) of irradiated LK and there comparison with control samples suggest that gamma irradiation treatment at medium doses is an effective post-harvest treatment and quarantine control for TVC, TMYC, and TCC.

Keywords: Loquat seed kernel, gamma irradiation, composition, microbial load, chemical properties

1. Introduction

Loquat (*Eriobotrya japonica* L.) is a fruit in the Rosaceae family, and originated in China and has been widely cultivated for commercial purposes since the 19th century [1]. It spread quickly throughout the Mediterranean regions, and it was already being used for productive ends, as well as for ornamental [2]. Loquat fruit is delicious, and has a high economic value, and typically has many seeds, each loquat fruit usually has 4-7 large seeds [3]. The processing of fruits results in high quantities of waste materials as by-products including seeds. It is well known that by-products are an important source of nutrients [4,5]. In terms of weight, the seeds comprise about 20–30% of whole fresh loquat fruit, and discarded as a non-utilized part of the fruit [6]. While, the kernel of loquat seed is very rich in protein (22.5%) and carbohydrates (71.2%) [7]. Loquat kernels are high in starch, amygdalin, amino acid, and fatty acid content. It has a bitter taste, making it unsuitable for human consumption. These kernels have useful medicinal properties, therefore, loquat kernels, attract the attention of health food companies, and can be used for the treatment of cough, hemia, and edema. It can significantly improve the immune function in animal studies [8-10].

Loquat seed play an important part for certain plants in the production of the new plant generation. Additionally, its seeds have several industrial preparations [11] and used as a traditional medicine to treat cough and indigestion [12].

Gamma irradiation was effectively proven to control microbial contamination without adversely affecting the biologically active substances of plant products [13]. Irradiation treatment is one of the main processing operations applied to edible seeds and nuts and it can cause various physico-chemical

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changes [14,15]. Irradiation with gamma rays has been recognized as a safe and reliable method for improving nutritional value and removing or inactivating certain microorganisms in food [13,16].

However, there is limit information about the employment fields of loquat seeds in the world. Generally, the seeds are not used for any purpose after consumption of fresh fruit and currently discarded. Also, until recently it has been almost neglected in term of research in Syria. In this context, the aim of this work was to determine the microbial, physicochemical characteristics of the loquat kernel (LK) of local cultivar, since; his characterization is important and necessary to provide an understanding of the potential that these kernels offer in terms of consumption or for industrial processing. As well as this study also investigated the quality parameters of LK under various gamma irradiation treatment doses.

2. Materials and Method

2.1. Preparation of loquat kernel

Loquat cultivar was analyzed: *Baladi cv*. The fruits were produced at the Gota area located in the city of Damascus, Syria (33°21'N, 36°28'E) at 617 m above sea level, and were harvested at the commercial ripening stage from May to June 2018. Samples of loquat fresh fruits were obtained from local fruit market in Damascus, Syria. The seeds were separated from their fruit pulp and washed with water. The kernels of the seeds were manually separated from the seed by removing the outer shells to separate the kernels from the seeds. Kernels were crushed in a blender to obtain homogenized powders. For obtaining same particle size, powders were passed through the micromesh sieves.

2.2. Irradiation treatment

The loquat kernels (LK) were exposed to gamma radiation at doses of 3, 6 and 9 kGy. Multipurpose gamma irradiator with a Cobalt 60 source was used (compact-type semi commercial radiator) at the gamma irradiation facility (ROBO, Russa). The samples of LK were irradiated at place with a dose rate of 7.775 kGy h^{-1}, at room temperature and atmospheric pressure [14]. The non-irradiated kernels were served as control. After irradiation, the irradiated and non-irradiated LK were kept in sealed bags at room temperature (20 °C) without exposure to direct sunlight until further analysis.

2.3. Chemical analysis

Moisture (by drying for 6 h at 105 ºC), crude protein (using micro-Kjeldahl method), crude fat (as extractable component in Soxhlet apparatus), and ash contents (by ashing for 4 h at 550 ºC) of LK were determined according to AOAC methods [17]. The pH value of the LK solutions were measured using an HI 8521 pH meter (Hanna Instruments, Woonsocket, RI, USA). The total acidity was determined by a direct titration with 0.1 N NaOH and calculated as mL of 0.1 N NaOH = 0.0090 g lactic acid [17]. Total volatile basic nitrogen (TVBN) in the sample in terms of mg VBN kg^{-1} LK (ppm) was determined [15]. All reagents used in this study were of reagent grade.

2.4. Microbiological analysis

Microbial load was evaluated using the standard spread plate method [17]. The LK product (10 g) was homogenized with 90 mL of sterile physiological water (9 g NaCl L^{-1}). The substance was then serially diluted and appropriate dilutions were plated on plat count agar (PCA) (Oxoid, CM 325, UK) (30 °C, 48 h) for total viable counts (TVC), Violet Red Bile Agar (VRBA) (Oxoid, CM 485, UK) (37 °C, 48 h) for total coliform count (TCC), and Dichloran Rose-Bengal Chloramphenicol Agar (DRBC) (Merck, 1.00466, Germany) (25 °C, 5 days) for total mould and yeast (TMY). Microbial counts were transformed to lg(cfu) g^{-1}.

2.5. Statistical analysis

The means were compared to determine the influence of each treatment on the dependent variable. The data were statistically evaluated by the one-way analysis of variance procedure (ANOVA). All data were reported as means of triplicate measurements with standard deviation (SD). Statistical significance was declared at $p<0.05$. In addition, all tests were performed in Microsoft Excel.

3. Results and Discussion

3.1. Proximate composition of LK

Chemical composition of loquat kernel (LK) per 100 g is depicted in Table 1. Results indicate that the moisture content of LK was on average 6.12%. Crude protein, crude fat, crude ash, total sugar and reducing sugar contents of LK were found to be approximately 9.46, 3.98, 7.52, 68.76, and 3.49%, respectively. Ash is a reflection of the amount of mineral elements in the samples and therefore serves as the main source of mineral elements needed for human health. These results mean that LK had high total carbohydrate contents but low fat contents. The current results are in accordance with the proximate composition of LK samples already reported in the literature. Taskin and Erdal [1] reported that the moisture content of kernel was on average 9.8%. Crude protein, total carbohydrate, crude fat, and crude ash contents of LK were found to be approximately 22.5, 71.2, 3.4, and 2.9 % on dry basis, respectively. A study was reported that loquat seeds from the Turkey market had the high amount of total carbohydrate and protein content but low-fat content and ash [1]. The oil content of LK were 1.21% and 14.3% for mesocarp and seeds, respectively [18]. Therefore LK have importance from the point of dietary components which is related to the intestinal regulation, the intestinal absorption of glucose and reduction of cholesterol levels [19,20].

The low moisture percentage of LK samples could store for longer period without spoilage, since a higher amount of moisture could lead to food spoilage through increasing microbial action [14].

It was reported that the oil content of LK was so lower than those of in common oilseeds, including rapeseed (40-48%), cottonseed (22-24%), soybean (18-22%), safflower (30-35%), and olive (12-50%) [21]. However, LK contains about 71% starch, and extracted loquat seed starch (LSS) has been recently reported by Barbi et al. [21]. In addition, LSS contains high percentage amylose, suggesting that it may serve as an excellent material for the production of edible films [6,22].

3.2. Effect of gamma irradiation and storage period on proximate composition of LK

As shown in Table 1 the moisture, crud fat, ash, and reducing sugar content of LK were not significantly ($p>0.05$) changed due to irradiation. Similar finding showed that gamma irradiation treatment with doses of 1, 2, and 3 kGy had no real effect on moisture, lipid, protein, ash and fiber of almond kernels [15], pistachio kernels [14], and peanut seeds [13]. Al-Bachir and Khalil [16] reported that gamma irradiation produced no significant ($p>0.05$) change in fat, ash, total sugar, and reducing sugar contents of faba bean kernel. Moreover, extensive research showed that the contents of macronutrients (proteins, carbohydrates and lipids) were relatively stable against irradiation with doses up to 10 kGy [23].

The present results indicated that the crude protein and total sugar content of LK were affected by gamma irradiation. Gamma irradiation resulted in an increment in crude protein at higher irradiated doses (control, 9.46%; 6 kGy, 11.79%; 9 kGy, 11.39%). While, gamma irradiation resulted in an reduction in total sugar at higher irradiated doses (control, 68.76%; 6 kGy, 67.90%; 9 kGy, 67.81%). This result is in agreement with other study, which reported that, the total carbohydrate contents decreased with increasingly higher dosage of gamma irradiation caused by higher metabolic activities and hydrolyzing enzyme activity in seed [14,24]. The dose-dependent decrease in total sugar on irradiation has been attributed to de-polymerization and de-lignification of the plant matrix [25]. The increase in carbohydrates might be attributed to radiation-induced breakdown of complex sugar (polysaccharides) into simple extractable forms (e.g., free sugars) [13].

As seen in Table 1 storage period affected the proximate composition parameters of LK significantly ($p<0.05$). The total protein content were found to be depleted by storage in all LK samples (irradiated and non-irradiated), whereas, the total sugar was increased due to the decreasing of protein.

Our results, related to the effect of storage on proximate analysis, are in agreement with previous studies which also reveal significant decrease in protein during storage in all pistachio nut samples (irradiated and non-irradiated) [14].

3.3. Effect of gamma irradiation and storage period on acidity and pH value of LK

The total acidity (TA) of LK in term of % lactic acid as affected by the gamma radiation doses and storage time is presented in Table 2. The TA content of LK was found to be 0.73% prior to the irradiation treatment. The results revealed that the TA in LK increased with an increase in the radiation dose and storage period. The LK of irradiated or stored samples had significantly ($p \leq 0.05$) higher levels of TA than those of control samples (un-irradiated or un-stored samples). After radiation at dose levels of 3, 6 and 9 kGy, it is clearly observed that the TA content of LK significantly ($p < 0.05$) increased to 0.77, 0.94, and 0.97%, respectively.

Table 1. Effect of gamma irradiation and storage period on moisture, ash, protein, total sugar, reducing sugar and fat contents (%) of loquat kernel.

Storage period / (Months)	**0**	6	**12**	**P-level**
Treatment		***Moisture (%)***		
Control	$6.12\pm^{Ba}0.74$	$8.15\pm^{Aa}0.14$	$8.33\pm^{Ab}0.23$	0.0018
3 KGY	$5.63\pm^{Bab}0.19$	$8.12\pm^{Aa}0.49$	$8.60\pm^{Aab}0.07$	0.0001
6 KGY	$6.16\pm^{Ba}0.52$	$8.29\pm^{Aa}0.02$	$8.68\pm^{Aa}0.17$	0.0001
9 KGY	$5.06\pm^{Bb}0.17$	$7.93\pm^{Aa}0.07$	$8.53\pm^{Cab}0.08$	0.0001
P-level	0.0636	0.4317	0.1079	
		Crud protein (%)		
Control	$9.46\pm^{Ab}0.51$	$8.30\pm^{Bb}0.46$	$6.26\pm^{Ca}0.14$	0.0002
3 KGY	$87.99\pm^{Ab}0.11$	$8.68\pm^{Bab}0.06$	$6.22\pm^{Ca}0.17$	0.0001
6 KGY	$11.79\pm^{Aa}0.10$	$9.16\pm^{Ba}0.68$	$6.21\pm^{Ca}0.02$	0.0001
9 KGY	$11.39\pm^{Aa}0.19$	$9.14\pm^{Ba}0.14$	$6.26\pm^{Ca}0.08$	0.0001
P-level	0.0001	0.1046	0.9435	
		Crud fat (%)		
Control	$3.98\pm^{Aa}0.12$	$3.69\pm^{ABa}0.18$	$3.52\pm^{Ba}0.21$	0.0473
3 KGY	$3.95\pm^{Aa}0.32$	$3.76\pm^{Aa}0.14$	$3.35\pm^{Ba}0.06$	0.0275
6 KGY	$3.80\pm^{Aa}0.16$	$3.59\pm^{Aa}0.25$	$3.62\pm^{Aa}0.21$	0.1151
9 KGY	$3.95\pm^{Aa}0.12$	$3.68\pm0.20\ ^{BAa}$	$3.40\pm^{Ba}0.26$	0.0416
P-level	0.9965	0.7727	0.4012	
		Ash (%)		
Control	$7.52\pm^{Ab}0.57$	$3.42\pm^{Ca}0.11$	$4.23\pm^{Ba}0.08$	0.0001
3 KGY	$7.80\pm^{Aab}0.32$	$3.44\pm^{Ba}0.03$	$4.14\pm^{Ca}0.04$	0.0001
6 KGY	$7.59\pm^{Aab}0.26$	$3.42\pm^{Ca}0.07$	$4.16\pm^{Ba}0.05$	0.0001
9 KGY	$8.23\pm^{Aa}0.23$	$3.46\pm^{Ca}0.07$	$4.20\pm^{Ba}0.11$	0.0001
P-level	0.1574	0.9179	0.5180	
		Total sugar (%)		
Control	$68.76\pm^{Aa}0.54$	$69.57\pm^{Aa}0.36$	$69.91\pm^{Ab}0.77$	0.1201
3 KGY	$69.06\pm^{Ba}0.15$	$69.07\pm^{Bab}0.45$	$71.23\pm^{Aa}0.63$	0.0016
6 KGY	$67.90\pm^{Bb}0.21$	$68.88\pm^{Bb}0.37$	$71.17\pm^{Aab}0.85$	0.0009
9 KGY	$67.81\pm^{Cb}0.23$	$68.79\pm^{Bb}0.07$	$70.70\pm^{Aab}0.31$	0.0001
P-level	0.0030	0.0887	0.1367	
		Reducing sugar (%)		
Control	$3.49\pm^{Ba}0.06$	$3.73\pm^{Aa}0.2$	$3.64\pm^{Aa}0.02$	0.0005
3 KGY	$3.52\pm^{Ba}0.01$	$3.59\pm^{Ab}0.02$	$3.58\pm^{Ab}0.03$	0.0293
6 KGY	$3.52\pm^{Ba}0.02$	$3.60\pm^{Ab}0.01$	$3.59\pm^{Ab}0.02$	0.0011
9 KGY	$3.51\pm^{Ba}0.02$	$3.60\pm^{Ab}0.01$	$3.59\pm^{Ab}0.03$	0.0052
P-level	0.3381	0.0001	0.1030	

^{abc} Means values in the same column not sharing a superscript are significantly different.
^{ABC} Means values in the same row not sharing a superscript are significantly different.

Table 2. Effect of gamma irradiation and storage period on total acidity (% Lactic acid), pH value and total volatile basic nitrogen (TVBN, ppm) of loquat kernel

Storage period /(Months)	**0**	6	**12**	**P-level**
Treatment		***Total acidity (% Lactic acid)***		
Control	$0.73\pm^{Bb}0.19$	$0.80\pm^{Ab}0.03$	$1.14\pm^{Ba}0.02$	0.0078
3 KGY	$0.77\pm^{Cab}0.02$	$0.82\pm^{Aab}0.02$	$1.11\pm^{Ba}0.03$	0.0001
6 KGY	$0.94\pm^{Bab}0.09$	$0.85\pm^{Ba}0.03$	$1.11\pm^{Aa}0.01$	0.0035
9 KGY	$0.97\pm^{Ba}0.10$	$0.83\pm^{Cab}0.02$	$1.11\pm^{Aa}0.02$	0.0037
P-level	0.0837	0.2445	0.2900	
		pH value		
Control	$6.33\pm^{Aa}0.03$	$6.39\pm^{Ba}0.03$	$5.34\pm^{Aa}0.06$	0.0001
3 KGY	$6.28\pm^{Bab}0.02$	$6.36\pm^{Aa}0.03$	$5.35\pm^{Ca}0.02$	0.0001
6 KGY	$6.25\pm^{Bbc}0.03$	$6.36\pm^{Aa}0.04$	$5.34\pm^{Ca}0.03$	0.0001
9 KGY	$6.23\pm^{Bc}0.03$	$6.29\pm^{Ab}0.04$	$5.38\pm^{Ca}0.02$	0.0001
P-level	0.0126	0.0197	0.4215	
		Total volatile basic nitrogen (ppm)		
Control	$32.00\pm^{Aa}6.36$	$25.80\pm^{Aa}1.83$	$25.97\pm^{Aab}2.50$	0.1876
3 KGY	$27.07\pm^{Aa}1.08$	$28.91\pm^{Aa}0.79$	$31.30\pm^{Aa}6.98$	0.4918
6 KGY	$29.93\pm^{Aa}2.60$	$25.12\pm^{Ba}1.85$	$30.28\pm^{Aab}0.68$	0.0335
9 KGY	$25.93\pm^{Aa}4.78$	$24.19\pm^{Aa}5.88$	$23.72\pm^{Ab}1.39$	0.8198
P-level	0.3692	0.3696	0.1183	

[abc] Means values in the same column not sharing a superscript are significantly different.
[ABC] Means values in the same row not sharing a superscript are significantly different.

Also, after 12 months of storage, the TA content of LK significantly ($p < 0.05$) increased to 1.14%.

The quantity of TA in seeds or nuts is an important quality factor and its determination is essential for industrial purposes since its presence in large quantity can change the organoleptic and physicochemical properties of oil content [26]. The increase in TA as radiation doses increased as observed in this study is similar to those reported for irradiated grape seed [27], peanut seed [13], walnut kernel [28], and almond kernel [29]. Total acidity values of LK samples are very small between 0.73 and 1.14% and lies within desirable limits 0.0-3.0% [14]. Given the very low moisture content of LK, it is most probable that negligible amount of free fatty acids (FFA) were produced through triglycerides hydrolyses. However, Mahmoud et al. [30] and Pankaj et al. [31] reported an opposite result for irradiated LK. They reported that TA concomitantly decreased as the irradiation doses increased in millet kernels and wheat bran. On other hand, Guler et al. [32] reported that gamma radiation had no significant effect on the FFA in hazelnuts and walnuts of both irradiated and non-radiated nuts.

The control sample of LK was found to have pH 6.53 with a pH range of 5.34 to 6.39 in LK treated at 0, 3, 6 and 9 kGy and stored up to 12 months (Table 2). There was non-significant ($p>0.05$) difference found in between the pH values of the treatments but the pH increases with the increase in the radiation dose and storage period. According to Sharma et al. [33], the pH values should be between 4 to 9 and all the values observed during present study were found well within the range.

3.4. Effect of gamma irradiation and storage period on TVBN of LK

The effect of gamma irradiation treatment (at doses of 3, 6 and 9 kGy) and storage time (6 and 12 months) on total volatile basic nitrogen (TVBN) contents of LK is shown in Table 2. The data present in Table 2 illustrated that the amount of the TVBN in non-irradiated (control) sample of LK were 32.00 g TVBN kg^{-1} LK (part per million, ppp). Immediately after irradiation and after 6 and 12 months of storage there were no significant ($p>0.05$) differences in TVBN between LK irradiated and control ones. These results agree with previous observations in pistachio kernel [14], and faba bean [16], they reported that gamma irradiation

Table 3. Total bacterial (lg(cfu) g^{-1}) and fungal (lg(spores) g^{-1}) count of loquat kernel

Storage period / (Months)	**0**	6	**12**	**P-level**
Treatment	***Total bacterial count (lg(cfu) g^{-1})***			
Control	$4.16\pm^{Ba}0.09$	$5.26\pm^{Aa}0.03$	$5.51\pm^{Aa}0.27$	0.0001
3 KGY	$2.43\pm^{Cb}0.18$	$2.52\pm^{Bb}0.11$	$2.83\pm^{Ab}0.13$	0.0328
6 KGY	0	0	0	0
9 KGY	0	0	0	0
P-level	0.0001	0.0001	0.0001	
Fungal count (lg(spores) g^{-1})				
Control	$2.21\pm^{C}0.09$	$2.59\pm^{B}0.14$	$3.14\pm^{A}0.20$	0.0009
3 KGY	0	0	2.23±0.11	0.0001
6 KGY	0	0	0	0
9 KGY	0	0	0	0
P-level	0.0001	0.0001	0.0001	
Total coliform(lg(cfu) g^{-1})				
Control	$0.99\pm^{B}0.50$	$1.66\pm^{AB}0.31$	$1.90\pm^{A}0.09$	0.0415
3 KGY	0	0	0	0
6 KGY	0	0	0	0
9 KGY	0	0	0	0
P-level	0.0027	0.0001	0.0001	

^{abc} Means values in the same column not sharing a superscript are significantly different.
^{ABC} Means values in the same row not sharing a superscript are significantly different.

had no real effect on the TVBN content of pistachio and faba bean. However, Al-Bachir [15] and Al-Bachir and Othman [13] reported an opposite result for irradiated LK. They reported that TVBN concomitantly decreased as the irradiation doses increased in almond kernel ad peanut seed. The increase in TVBN in stored and irradiated almonds nuts could be due to the formation of oxidation or radiation-induced degradation products [15].

The effect of storage time on NBV content of LK is shown in Table 2. Storage time caused no significant ($p > 0.05$) difference between the TVBN composition of the LK. Moreover, the TVBN of LK remained unaffected during storage. Therefore, such storage conditions are recommended for this LK. The TVBN value, which is regarded as one of the standard chemical indices of freshness of protein component was assessed because the LK contained protein as the major component. The TVBN is related to protein breakdown and the increases of TVBN may be due to the production of ammonia or other basic compounds due to microbial activity [34]. The high TVBN content in the loquat seed kernels was determined to be due to hydrolysis caused by interactions between amygdalin and emulsin resulting from the destruction of the seed cell wall after grinding of the samples [11].

3.5. Effect of gamma irradiation and storage period on microbial load of LK

The impact of gamma radiation on the total viable count (TVC), total mould and yeast count (TMYC), and total coliform count (TCC) growth and colony formation (cfu) g^{-1} in LK is shown in Table 3. The treatment of LK with gamma rays at the doses used significantly ($p \leq 0.05$) reduced the TVC, TMYC, and TCC growth in a dose-dependent manner. It can be observed from the table that, before irradiation, the TVC, TMYC, and TCC were 4.16±0.09, 2.21±0.09, and 0.99 ± 0.50 lg(cfu) g^{-1}, respectively.

Colony formation of TVC, however decreased significantly ($p \leq 0.05$) as the irradiation dose increased, reaching its minimum (2.43±0.18, lg(cfu) g^{-1}) at 3 kGy. After the application of irradiation process, the initial TVC, MYC and TC in LK samples treated with 6 kGy were below the level of detection (less than 1 lg(cfu) g^{-1}) [16]. A similar observation on the reduction in microorganism growth was reported for millet grains [30] pistachio kernels [14], almond kernels [15], wall nut kernel [28], faba bean seed [16], sesame seeds [26], and peanut seeds [35] treated with medium doses of gamma rays. The decontamination of LK with gamma rays at the doses applied in this study could elongate the shelf-life and preserve the quality of LK during post-harvest processing.

The inhibition of TVC, MYC and TC growth and colony formation by gamma irradiation could be attributed to the damaging effects of gamma irradiation on the microorganism membrane which might lead to losses in nucleic acids, proteins, and osmatic balance, thereby causing the death of the cells of microorganisms [26].

Gamma irradiation induces various degrees of cell damage to caused degradation of important macromolecules, including DNA and cell membranes. The biological damage of cell due to irradiation is mostly in direct, and un-direct by reactive oxygen species (ROS) generated by the radiolysis of water in irradiated product [36,37]. These ROS are known highly reactive to cell components (lipids and protein) and DNA, and cause rapid cellular damage [38].

4. Conclusion

The results indicate that the loquat kernel (LK) as by-products still contain high valuable compounds. Based on the high amount of total carbohydrate, protein and mineral contents in LK, it is recommended more research should be conducted using this by products in food industry in the future.

The results clearly showed that gamma irradiation has reduced the total viable count (TVC), total mould and yeast count (TMYC), and total coliform count (TCC) and preserved nutritive value of LK, as well as increase the shelf life of LK without changing chemical properties. Among the treatments, the medium irradiation dose (6.0 kGy) showed best results in terms of overall acceptability, microorganisms control and for shelf life extension of LK.

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Compliance with Ethics Requirements. Authors declare that they respect the journal's ethics requirements. Authors declare that they have no conflict of interest.

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