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Effect of gamma irradiation and calcium carbonate on the overall quality of pumpkin jam during storage

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Abstract

This study was to investigate the effects of combination of calcium carbonate with irradiation technique on quality characteristics, nutritional values, bioactive components, microbiological loading, and sensory evaluation of pumpkin jam during storage period for 12 months. Pumpkin jam samples were treated with calcium carbonate 1% (CCS), irradiation (2 kGy) and the combination of CCS + 2 kGy. The results indicated that the CCS + 2 kGy treatment significantly helped in retaining ascorbic acid content, which established a little decrease. CCS and CCS + 2 kGy treatments reported similar values for carotenoid contents. Whereas, CCS + 2 kGy treatment showed the highest total flavonoid content. The application of CCS + 2 kGy treatment also reduced the microbial growth for total aerobic plate, yeast and mold counts. The degree of color was higher recorded for CCS treatment, while CCS + 2 kGy treatment gained the highest scores for texture, flavor, taste, and overall acceptability at the end of the storage period. Overall the results pertained that the use of Gamma irradiation combined with calcium carbonate prolonged the shelf life of the pumpkin jam by reduced the microbial load, maintained the quality characterizes, nutritional values, bioactive components, and consumer acceptability of pumpkin jam during storage.

Keywords: pumpkin; calcium carbonate; irradiation; phenolic compounds; jam; sensory evaluation.

Practical Application: offer solution for challenges of plant breeding by prepare new product combine nutritional quality with good industrial yield and decrease post-harvest losses.

1 Introduction

The pumpkin fruits *(Cucurbitapepo*) belongs to the *Cucurbitaceae* family. It is classified as functional food due to its rich content of bioactive compounds, minerals, and antioxidants in the fruit pulp, making pumpkin a (Buzigi et al., 2020; Priori et al., 2022). It contains low calories, with a good amount of fibers and vitamin C (Amin et al., 2019). Pumpkin can be used to developing several types of food and food products such as jam, jelly, puree, marmalades, chutney, sauces, pickle, cookies and others. Therefore, jam is considered as a nutritious food that plays an important role in human health due to its good taste and nutritional compounds (Dubey et al., 2021). It is a semi-solid food, made to preserve the fruit so that it can be consumed out of season. In general, jam has at least 45% (by weight) of fruit (rich in natural pectin) and 55% (by weight) of sugar (Awulachew, 2021). Nutritional quality with good industrial yield and decrease post-harvest losses is One of the challenges of plant breeding (Pereira et al., 2020). The contents of phenolic compounds in such food varieties vary according to many factors such as genetics, growing conditions, processing and storage(Soares et al., 2022). Overall acceptability and other sensorial properties are important quality parameters of in the acceptance and rejection of the product, therefore, they are usually when processed food into other forms such as sweetened juice, compote, puree, marmalade, jam, jelly, cake, or liquor, it is important to choose satisfy mothed which improve both sensorial properties and the nutritional aspects (Nistor et al.,, 2022). Many techniques have been used for food preservation such as drying, chilling, freezing, and fermentation which have been improved and modernized and latest innovations used to increase shelf life of foods. (Sridhar et al., 2021). Infrared radiation, Emerging technologies processing, have been used to extract compounds and improve color, aroma, flavor, and texture properties (Scudino et al., 2022; Rocha et al., 2022; Deshwal et al., 2022; Ding et al., 2022).The irradiation technology is one of the main preservation technique and it intends to expose food to one of the sources of radioactive energy (Martin, 2018). Radiation is a safe method that can be replaced with the chemical decontaminant, low dose gamma radiation can improve the post-harvest safety (Berrios-Rodriguez et al., 2022). While microbial contamination is significant decisive factor in the food industry and health (Roobab et al., 2018). The combination of a low dose of radiation with some food preservatives considered one of the effective methods to extend the shelf life and avoid the undesirable flavor changes and to reduce the dissolution of pectin caused by high radiation treatment (Mashiane et al., 2021; Martin, 2018). The objective of the current research was to investigate the effects of Gamma Irradiation and Calcium Carbonate on the Overall Quality of Pumpkin Jam during Storage.

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2 Materials and methods

2.1 Materials

Fresh pumpkin (*Cucurbitapepo*) with average weight of 20 kg was obtained from a local market in Riyadh, Kingdom of Saudi Arabia. The fruit was clean with chlorinated water to removing dust or other infectious materials after transferred to the laboratory and stored at 10 °C till further processing. The analytical grade of chemicals, reagents and other ingredients (sugar) used in the jam processing were procured from Sigma Aldrich Inc. (Corp., MO, U.S.A.) and a local supermarket in Riyadh, Kingdom of Saudi Arabia.

2.2 Sample preparation

The whole pumpkin fruit was peeled manually and cut into small cubes in dimensions size as 2 cm x 2 cm x 2 cm with a sharp sterile knife. The cubes were divided into four different sub lots such as control, and the others were treated by CCS, 2 kGy and CCS + 2 kGy. The control samples were dipped into distilled water for 1 min. Second sub lots (CCS) the pumpkin cubes were dipped into 1% W/V calcium carbonate solution (CCS) for 6 h, then 1 min in distilled water. In third sub lot (2 kGy) pumpkin cubes were exposed to 2 kGy irradiation, while in forth sub lots (CCS + 2 kGy) pumpkin cubes were dipped into 1% (CCS) for 6 hours then were exposed to 2 kGy irradiation respectively.

2.3 Jam processing

Irradiation

The cubes were subjected to radiation dose of 2 kGy in a cobalt-60 irradiator (Gammacell 220, MDS; Nordion Initial Canada) with 1.64 Gy/s of dose rate Gy/s. at King Abdul Aziz City for Science and Technology (KACST) (Tripathi et al., 2014) The quantity of each sub lots was about 1 kg.

Pumpkin jam was made according to the method described by Awulachew (2021). Pumpkin cubes were placed in an open stainless steel bowl, the required amount of sugar (55% of sugar added) was added and heated over a low flame when the reading of the total dissolved solids (TSS) reaches 60 °Brix, citric acid was added with a continuous stirring. When the concentration reaches 67-68 °Brix, heating was stopped and produce jam was packed in sterile glass containers. Analyses were performed immediately after production and after 6 and 12 months of storage period at 10 °C. Figure 1 presents the formulations, jam processing, and quality evaluations for shelf life extension.

2.4 Color measurement

The color was determined using CIE-Lab Color Meter (CIELAB SPACE, Color Tech-PCM, USA). The color scale a^* Value (–a greenness; +a redness), b^* Value (–b blueness; +b yellowness) and L^* Value (lightness) were evaluated for all sample groups (Saleem et al., 2014).

2.5 pH and Total Soluble Solids (TSS)

The pH was measured by ELTOP-3030 pH meter with buffer solutions of PH 4.0, 7.0 and 9.0 (Oguntunde et al., 2021). TSS was measured using a refractometer (Atago PAL^{-1}, Tokyo, Japan) at 20 °C. Few drops of the samples were placed on the refractometer and the readings were detected; the results are expressed as °Brix degree (El-Gioushy et al., 2021).

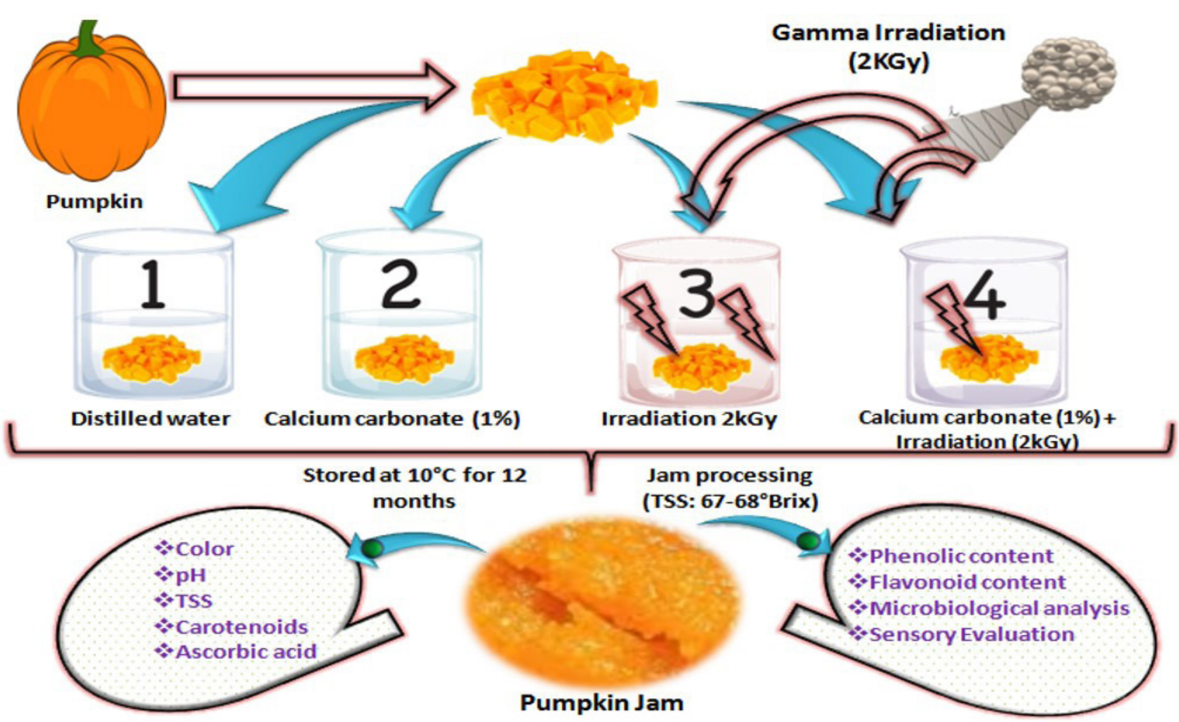

Figure 1. Jam formulations, processing, and quality evaluations for shelf life extension.

2.6 Ascorbic acid and carotenoids

The ascorbic acid of the samples was evaluated using a titration method. Process was transferred from the deep blue color to pink as the oxidized dye (l-a ascorbic acid is oxidized to dehydroascorbic acid) with a 2, 6-dichlorophenol-indophenol indicator (Zhou et al., 2017). Results were expressed in mg/100 g. The carotenoids evaluation was achieved according to the HOLM methodology by a UV spectrophotometer (754 PC, China) at 440 nm (Kampuse et al., 2019). Results for carotenoids were expressed in µg/g.

2.7 Bioactive components

Total phenolic content

The total phenolic contents (TPC) of the samples were determined using standard Folin-Ciocalteu (FC) reagent assay (Kampuse et al., 2019). 2 g of jam samples were extracted and centrifuged at 10,000 rpm/min for 15 min at 4 °C. Approximately 0.7 mL of the supernatant was mixed with 0.3 mL of water, 5 mL of FC reagent, and 4 mL of sodium carbonate and incubated in the dark for 2 h. The absorbance of samples was recorded at wavelength of 760 nm using spectrophotometer. Gallic acid standard curve was used to calculate the results and expressed as mg/100 g dry weight (DW).

Flavonoid content

The flavonoid content of the jam samples were determined using spectrophotometer method (Marinova et al., 2005). 30 µL aliquots of jam samples were diluted with a mixture of (90 µL methanol, 6 µL of 10% aluminum chloride, and 6 µL of 1 mol/L potassium acetate) was also added. The absorbance was measured by a spectrum spectrophotometer 754 PC, China at 415 nm. Quercetin was used as a standard and results were expressed as mg Qe/g DW (Nistor et al., 2022).

2.8 Microbiological analysis

The microbial load population such as total aerobic plate counts, bacteria, yeast and mold counts were determined at an interval of six months and carried out up to one year during storage. The total aerobic bacteria cells were performed by using rose bengal medium (GB4789.15-2016), while yeast and mold counts were performed by using (GB4789.2-2016) medium. Plates were incubated at (37 °C) for 3–5 days. The results were expressed as log CFU/g (colony forming units) per gram.

2.9 Sensory evaluation

Sensory evaluation for the processed pumpkin jam was carried out by twenty arbitrators for a color, texture, flavor, taste and overall acceptance according to the previous procedure and expressed in scores by using a 10-point scale (Awolu et al., 2018). Jam samples (30 g) were compared with zero time of storage, 6 months, and 12 months of storage.

2.10 Statistical analysis

The obtained data in triplicate for the combination of calcium carbonate with irradiation technique on quality characterizes, nutritional values, microbiological loading, and sensory evaluation of pumpkin jam during storage were statistically analyzed using SPSS statistical software with ANOVA and Dunken's tests to signify significant variations among means ($P < 0.05$).

3 Results and discussion

3.1 Color profile

Color is an important sensory characteristic for consumer acceptance. The control jam showed the highest L^* values (39.66) followed by CCS + 2 kGy (39.04) at the initial day of preparation, Figure 2. The redness values (a^*) were the highest in the control sample (17.74) and were decreased significantly after jam processing to 16.52, 16.45, 16.65 for CCS, 2 kGy and CCS + 2 kGy, respectively. While a light, difference was detected during storage period to reach 14.12 and control to 16.42 for CCS + 2 kGy treatment. Similar results were detected for reducing in formation of pigments may be attributed to the lack of free proteins and the reduced availability of hydrolyzed saccharides (Aljahani, 2022). The yellowness values (b^*) in the control jam were the lowest (24.25) and increased significantly after jam processing to reach 25.13, 25.00, 25.20 for CCS, 2 kGy and CCS + 2 kGy, respectively. No significant differences ($P = 0.05$) during storage and among storage times were observed. The color changes of pumpkin jam might be due to the loss of original colors during processing step (Fratianni et al., 2010). While adding orange juice when having good color properties and perfect sensory properties (Awad & Shokry, 2018).

3.2 Physico-chemical characteristics

The pH is an important parameter to gel formation, According to (Soares et al., 2022) fruits with low acidity require the addition of acids to correct the pH and enable gel formation. Figure 3a showed a little lower acidity values from the initial pH values. The decrement in pH values was recorded for CCS jam sample 5.33 at the end of the storage period compared to the inertial acidity 5.77. Singh et al. (2018) reported that pH value can control the activation of the microorganisms on food during storage time. Figure 3b shows the effect of calcium carbonate with irradiation technique on total soluble solids of pumpkin stored jam, the TSS in pumpkin jam samples (control) was decreased from 97.15% to 93.35%, while CCS samples were decreased from 98.35% to 97.35%, 2 kGy samples were decreased from 96.05% to 95.35%, and CCS + 2 kGy samples were decreased from 97.05% to 96.35% at the end of the storage period. The subsequent decrease in the soluble solids of sugars in pumpkin fruit may be associated with a process of oxidative breakdown as result of the respiration process (Jesmin et al., 2016).

3.3 Vitamins

It was obvious the reduction in the content of ascorbic acid after 12 months of storage in all treated samples. Figure 4 shows the ascorbic acid content (mg/100 g) in pumpkin jam. The combination

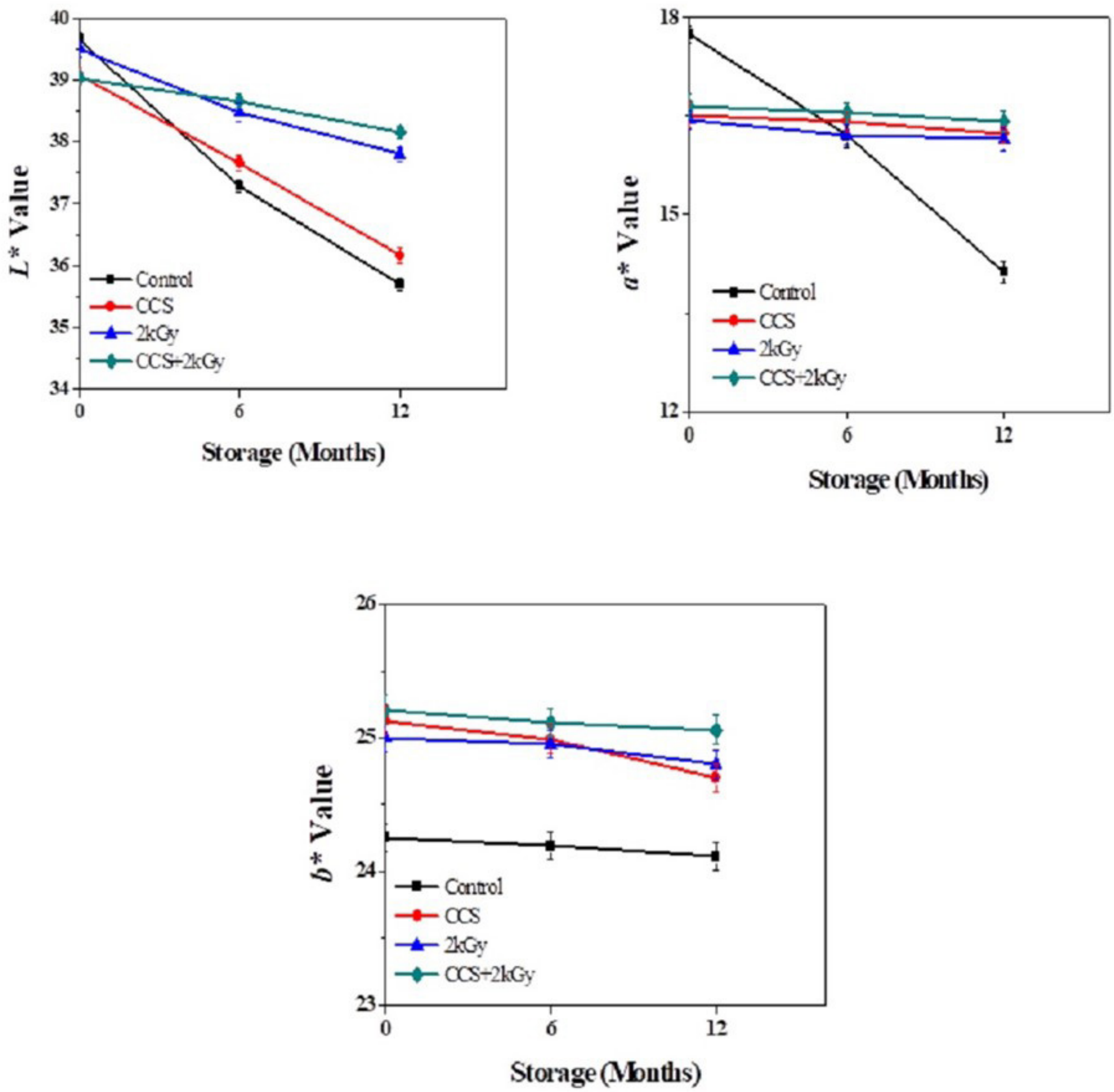

Figure 2. Changes in lightness *(L*)*, redness *(a*)*, and yellowness *(b*)* values of pumpkin jam during storage.

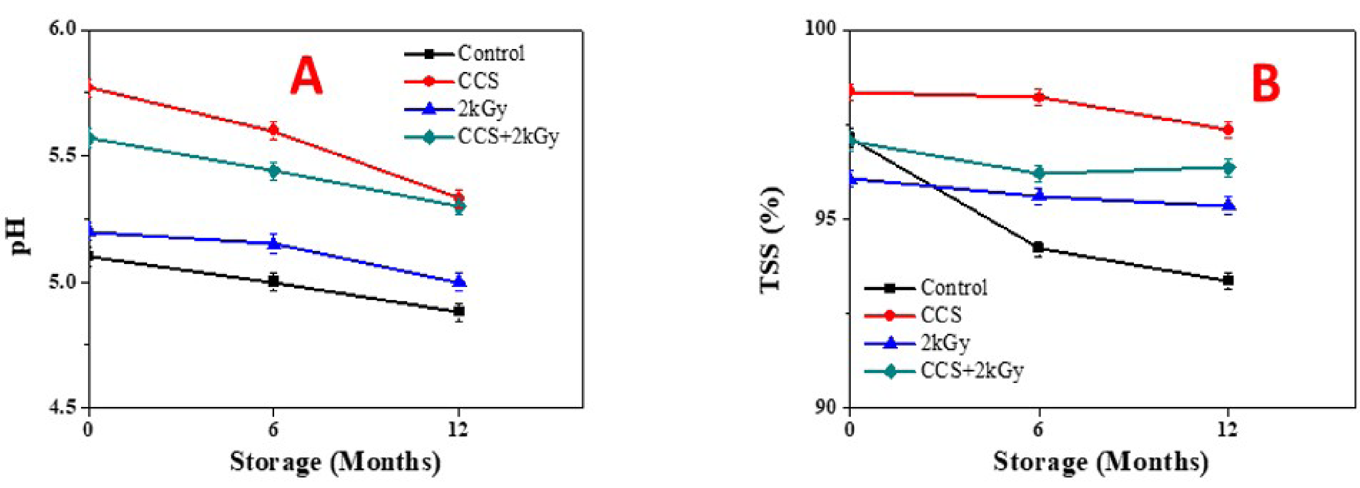

Figure 3. Changes in physio-chemical characteristics(pH) (a) and total soluble solids (TSS) (b) of pumpkin jam during storage.

of calcium carbonate and irradiation technique helped in retaining ascorbic acid content in CCS + 2 kGy, which established a little decrease from 13.90 to 12.80 mg/100 g. The ascorbic acid content of irradiated samples reported a little high value (11.30 mg/100 g) followed by CCS treatment (10.31 mg/100 g) when compared to the control samples (8.20 mg/100 g) at the end of the storage period. The ascorbic acid content decrease can be due to the respiration-decreased rate (Treviño-Garza et al., 2019). The reported that combination of calcium carbonate 1% with irradiation technique 2 kGy can maintain the quality of fruits and be a sign of higher vitamins for jam manufacturing with a low cost compared to other commercial techniques. Carotenoid contents in preserved food categories may be influenced by many factors such as variety, climate, genetics, and fertilizers (Dias et al., 2021). In the current work, Figure 4b presents the highest carotenoid contents, which was detected in control samples (40.45 µg/g) compared to other treatments at the end of the storage period. Namely, CCS and CCS + 2 kGy treatments reported similar values (40.01 - 40.07 µg/g), respectively. Provesi et al. (2011) reported stability on carotenoid after processing and storage of pumpkin puree amounts of carotenoids was similar as in our sample. The technological processes specifically thermal processes is strongly influenced of total carotenoids content in pumpkin products by inactivation of enzymes and micro-organisms (Provesi et al., 2011). This happens not only because of extrinsic factors, such as the severity of heat treatment, presence or absence of light, temperature of storage, packaging, but also because of the characteristics of the food matrices, such as their chemical composition, the oxygen dissolved in the samples, size of the particles, and the physical state

3.4 Bioactive components

The changes in total phenolic contents of processed jam samples during the whole storage period are presented in Figure 5a. In current study, jam samples treated with irradiation only presents a high value 26.58 mg/100 g DW during the first 6 months of storage. At the end of the storage period, the total phenolic contents of CCS + 2 kGy was (26.11 mg/100g DW), compared to 2 kGy (26.51 mg/100 g DW). The quantity of total phenolic contents was increased from 27.1 mg/100 g in the control sample at the beginning of the experiment, to 35.2 mg/100 g after 12 months of storage, and no significant increase or change was observed in the jam sample produced from pumpkin treated with

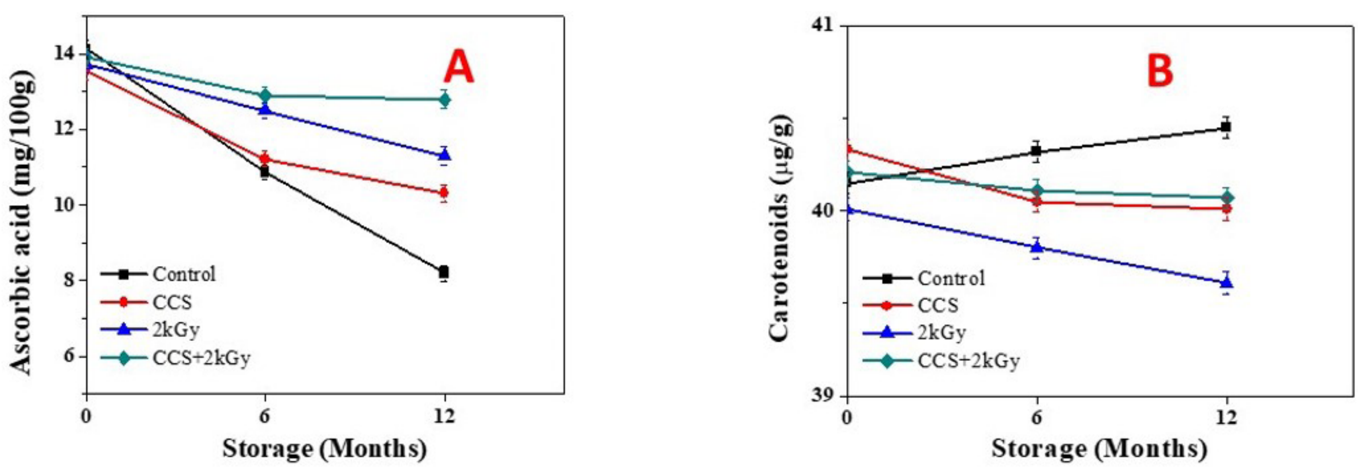

Figure 4. Changes in vitamin contents; ascorbic acid content (a) and carotenoid contents (b) of pumpkin jam during storage.

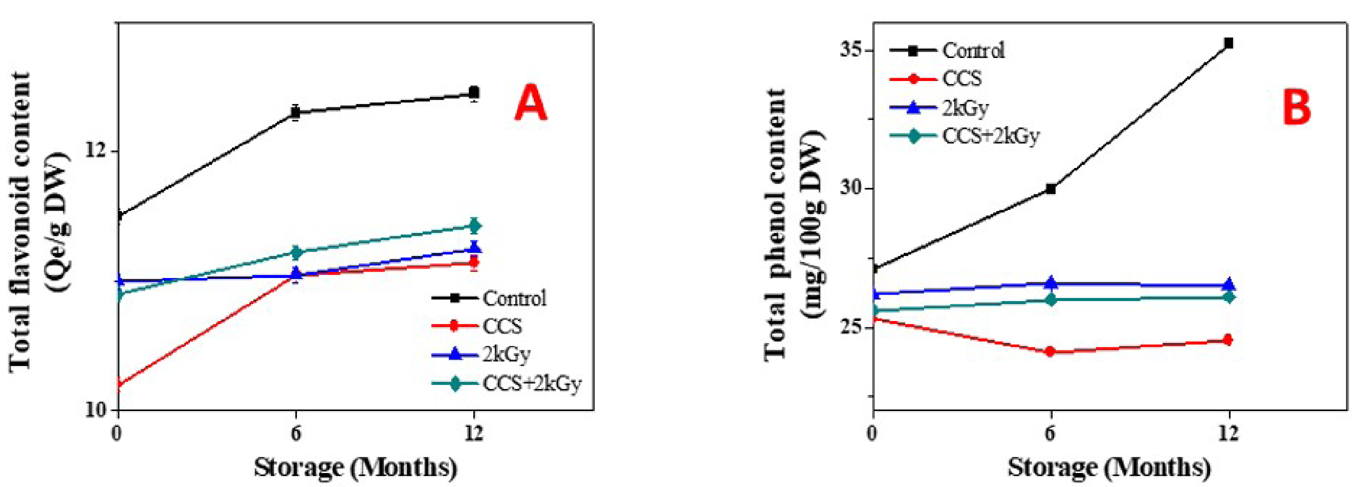

Figure 5. Changes in bioactive components; total phenolic contents (a) and total flavonoid contents (b) of pumpkin jam during storage.

calcium carbonate and those exposed to irradiation or even those treated with the combination of calcium carbonate and irradiation during storage periods. Kampuse et al. (2019) reported that total phenol content (TPC) of pumpkin puree during 26-week storage with different method (sterilized, frozen, vacuum-cooked stored at room temperature, and vacuum-cooked stored at 4 ± 2 °C.) was increased by 63.7%, on average, during storage. However, total phenolic, vitamin C and antioxidant activity (DPPH) compounds in low-calorie mixed Brazilian cerrado fruit jam was better preserved by thermal vacuum processing than thermal processing without vacuum (Brandão et al., 2021). According to (Shiri et al., 2011) an increase phenylalanine ammonialyase (PAL) activity was happened as result of physical damage of plant tissue, which leads to an increase in phenolic compounds

The results for total flavonoid contents of jam samples are presented in Figure 5b. The results showed that the amount of total flavonoid did not change significantly ($P \leq 0.05$) in the case of using calcium carbonate 1% compared to the control in line with the storage period. CCS + 2 kGy contained the highest total flavonoid contents of11.43 mg Qe/g DW followed by 2 kGy which was recorded as 11.25 Qe/g DW. The integration of irradiation technology with other techniques such as calcium carbonate solution (CCS), to improve the quality of the processed foods; namely, flavonoid contents are efficient biological component against free radicals (Kumar et al., 2021).

3.5 Microbiological analysis

The irradiation technique has become accepted in maintaining the quality of the products after harvesting because it reduces microbial contamination and slows down spoilage. Also, the irradiation technique prevents early germination and preserves ripening. It is known that most microorganisms have a high sensitivity to radiation, which facilitates the process of inhibiting them with low and medium doses of it between 1 kGy and 7 kGy (Arapcheska et al., 2020). Results of the microbiological analysis are depicted in Table 1. Results showed that the total aerobic plate counts of control jam samples increased upon continues storage period (3.1×10^2 - 7.2×10^2 log CFU/g). In the recent work, (CCS + 2 kGy) treatment was more capable to inhibit the growth after 12 months of storage. Irradiation treatment alone (2kGy) detected similar value to CCS + 2 kGy which reported 2.3×10^2 and 2.1×10^2 log CFU/g, respectively. Moreover, (CCS) treatment decreased the aerobic plate counts to reach 3.9×10^2 log CFU/g compared to control samples 7.2 ×

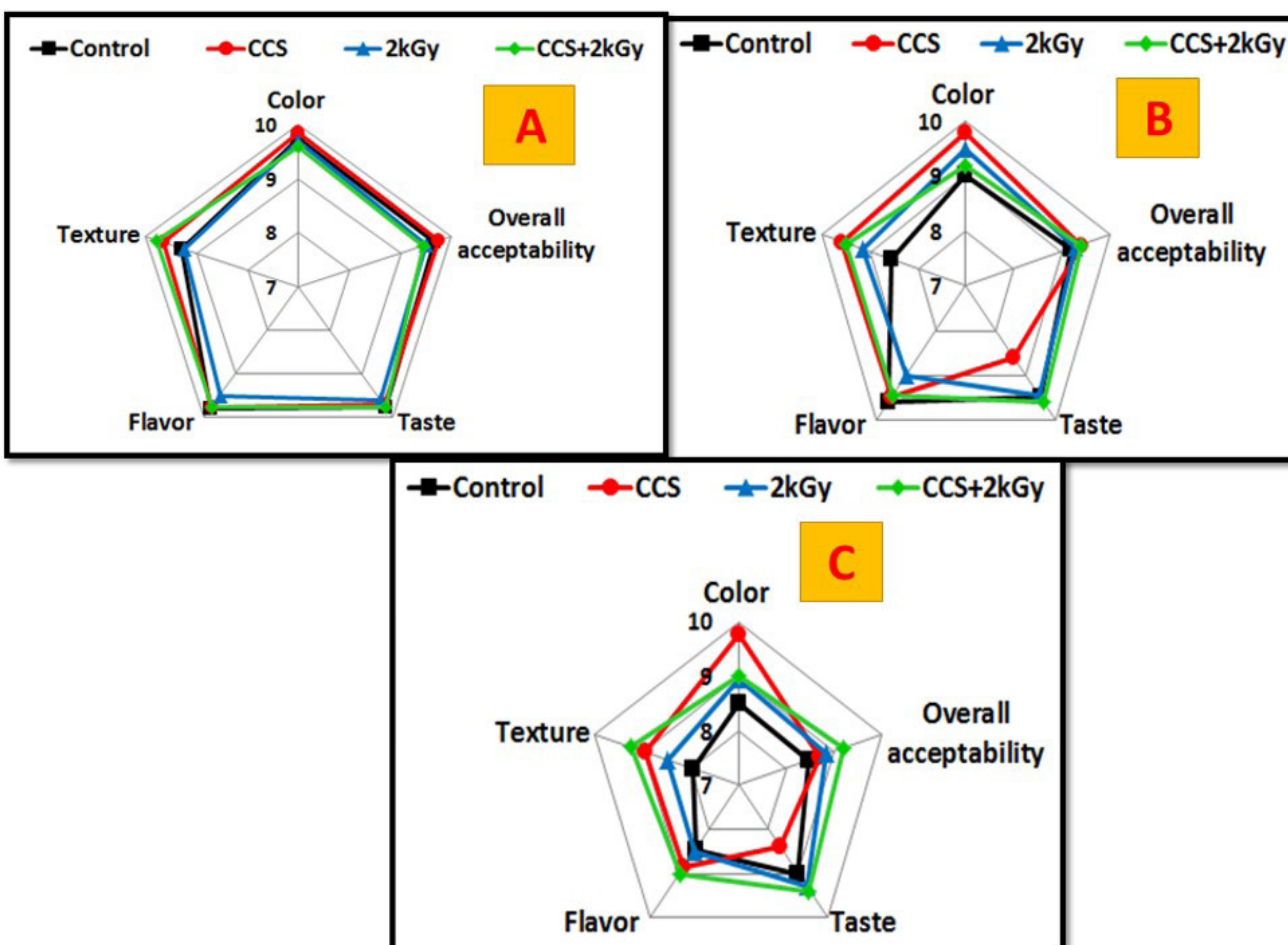

Figure 6. Changes in sensory evaluation of pumpkin jam during storage; at preparation day (a), after 6 months (b), and after 12 months (c).

Table 1. Microbiological loading changes of pumpkin jam during storage.

	Storage (months)	Control	CCS	2kGy	CCS + 2 kGy
Total aerobic plate count	0	3.1×10^2	2.0×10^2	6.1×10	4.2×10
	6	4.0×10^2	3.5×10^2	7.5×10	5.0×10
	12	7.2×10^2	3.9×10^2	2.3×10^2	2.1×10^2
Total yeast	0	3.0×10^2	2.5×10^2	4.0×10	<10
	6	6.2×10^3	2.3×10^2	5.5×10	<10
	12	9.33×10^3	2.5×10^2	7.5×10	5.2×10
Total mold	0	1.5×10^2	1.2×10^2	3.5×10	<10
	6	1.8×10^2	1.6×10^2	8.4×10	<10
	12	1.2×10^3	8.2×10^2	$1. 9 \times 10^2$	4.4×10

Mean (n = 3). Different superscript letters indicate significant difference at $p < 0.05$ between storage periods.

10 log CFU/g, that reported significantly brown spots on the media. The presence of yeast and mold counts is shown in Table 1. CCS + 2 kGy treatment reduced the growth to reach (5.2×10 log CFU/g) and (4.4×10 log CFU/g) for total yeast and mold counts, respectively, while 2kGy treatment had a microbial level of (7.5×10 log CFU/g) and (1.9×10^2 log CFU/g) at the end of the storage period for total yeast and mold counts, respectively. The control samples recorded the highest total yeast counts as (9.33×10^3 log CFU/g). CCS treatment slightly reduced the total yeasts and molds compared to other treatments. The reduction of the microbial growth might be due to the irradiation and calcium carbonate processes in food preservation to reduce the antimicrobial activity, these results are in a good agreement with the previous findings of Al-Kuraieef et al. (2019) who applied irradiation dose of 3 kGy with potassium sorbate to extend the shelf life to 21 days.

3.6 Sensory evaluation

The results for sensory evaluation were detected by twenty arbitrators; they are presented in Figure 6. Namely, Figure 6a presents the change in sensory scores of pumpkin jam at preparation day, while Figure 6b and Figure 6c present the changes after 6 months and 12 months of storage, respectively. The highest degree of color was for CCS treatment (9.75), while CCS + 2 kGy treatment gained the highest scores for texture (9.25), flavor (9.00), taste (9.40), and overall acceptability (9.20) at the end of the storage period. 2 kGy treatment reported the lowest color (8.95), texture (8.50), and flavor (8.50) values compared to the other treatments. Besides, CCS treatment reported the lowest taste (8.40), and overall acceptability (8.70) at the end of the storage period. Thus, the treatment with the CCS + 2 kGy mixture was the most acceptable one, followed by the 2 kGy treatment, where both control and CCS were the least favored overall. It is clear that the results of this research were in agreement with the previous results published by (Campos et al., 2021) who showed beyond any reasonable doubt that adding 10% -20% of pumpkin powder had a strong effect on the sensory properties of cakes made with flour mixed with pumpkin powder; they indicated that the sensory characteristics of the cakes produced from the mixture are due to the strong color and flavor of the pumpkin powder.

4 Conclusion

The combination of calcium carbonate 1% and Gamma radiation technique at a dose of 2 kGy was found potential to extend the shelf life of the pumpkin jam up to 12 months of storage by maintained their higher nutritional attributes and reduction microbial load. The practical applications of this research confirmed that the novel technique improved the quality of preserved food such as jam, it could be used for other type of fruit preservations as well.

Conflict of interest

There is no conflict of interest that I should disclose, having read the above statement.

Availability of data and material

The data used to support the findings of this study are included within the article.

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