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Original Article

Postharvest shelf life extension of Cucumber (*Cucumis sativus*) and Irish potato (*Solanum tuberosum*) using X-rays in Benue State, Nigeria

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ABSTRACT

This paper investigates the postharvest shelf life extension of cucumber and irish potato using X-rays, in Benue State, Nigeria. The selection of samples for the research was done from the traditional markets in Gboko for similar properties as depicted in the literature. For both products, six samples each with one kept as the control sample were X-ray irradiated with $60, 70, 80, 90,$ and $100\ kVp$ of X-rays. An ambient storage temperature range of 27 – 30^{o}C was recorded. The measured density, moisture content M.C (%), and pH were in the intervals: $0.934 - 1.201\ g/cm^3$, $94.98 - 98.67\%$, and $6.1 - 4.2$ for cucumber, and $0.0874 - 1.0867\ g/cm^3$, $70.82 - 79.93\%$, and $8.9 - 7.1$ for irish potato respectively. The percentage mass shrinkage ($\Delta M(\%)$) of the control and $100\ kVp$ X-ray irradiated samples were: 45.0% and 31.6% for cucumber, and 23.8% and 20.5% for irish potato respectively. The mass shrinkage (ΔM) was found to increase during preservation and higher kVp values extended the shelf life of the products. The $90 - 100\ kVp$ of X-rays was effective in preserving cucumber for an additional 7 – 8 days and irish potato for additional 10 – 15 days of storage. In essence, cucumber and irish potato can be stored by exposure to specific kVp values of diagnostic X-rays.

1. Introduction

The economy of developing countries like Nigeria and Cameroon is widely impacted in the aspect of food security that observed storage difficulties with respect to spoilage and titchy shelf life. Sustainability processes of living have categorized the relationship between the consumption and production of food regarding religion, ethnicity, and social gatherings worldwide having a regular pattern with few changes occurring [1]. In the agricultural industry, a greater portion of products experiences losses and wastages in the manufacture to utilization processes which is a regular challenge. In Nigeria, a greater portion of this wastage accounts for an equivalent diet of approximately ten to twenty million people [2]. The wastages and losses are not limited to microbial and fungal contamination of these agricultural products. The general problem is that of food preservation. Conventional storage practices used over time are subjected to major drawbacks which are not limited to color and flavor of the food, changes in smell, and loss in nutrient quality. These difficulties gave birth to food irradiation, a better technique for food preservation which is a unique, yet modern technology for the sterilization of products and enhancement of shelflife. Food irradiation is gaining research interest with an applicable variety of agricultural products [3]. Combine

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FAO/IAEA/WHO research association categorizing extreme doses of irradiation showed the ready-to-use and no harmful effects of exposing food products to radiation doses as high as 10 kGy since problems relating to microbiology and nutrition challenges are not applicable [4]. The advent of irradiation processes in food preservation in scientific experimentations and the uniting of different improved techniques as cited in the literature [5,6] could be the ‘‘go-to’’ technologies in future applications.

Cucumis sativus is a widely cultivated creeping vine plant, which anchor to the soil and elevates with the aid of objects for support as it wrapped itself on these objects with the help of spiraling tendrils [7-9], in the Cucurbitaceae gourd family, while the *Solanum tuberosum* is one of some 150 tuber-bearing species of the genus Solanaceae or Nightshade family [10]. Food preservation via irradiation processes commonly employs three types of radiation sources which include accelerated electron beams (E-beams), gamma irradiation with cobalt-60 or cesium-137, and X-ray machines. Categorizing among them, the use of gamma irradiation is common and commercialized to a greater extent [11]. Irradiation processes of these agricultural products have been exploited in the literature which is not limited to the absorption of gamma irradiation and attenuation coefficients of different varieties of potato, mango, and prawn with storage time and physiological conditions in which a decreased attenuation coefficient during storage was reported in potato [12]. Baskaran *et al*. evaluated the contribution of low-dose gamma-irradiation on the shelf life of minimally processed potato cubes [13]. The effects of gamma-irradiation of minimally processed cabbage and cucumber on microbial safety, texture, and sensory quality aimed at reducing the postharvest losses of these products were carried out by Khattak *et al*. [14]. Other works are not limited to sprouting inhibition of potato tubers via different doses of gamma-irradiation and different storage temperatures [15], the association of gamma-irradiation on essential minerals content of *Cucumis sativus* [16], the contribution of gamma irradiation on the properties of cucumber with storage period [17], comparative study on absorbed dose distribution of potato and onion in X-ray and Electron Beam System by MCNPX2.6 Code carried out by Peivaste and Alahyarizadeh [18], and experimental implementation and investigation of electronic sensing techniques for rapid discrimination of electron-beam, c-ray, and X-ray irradiated of dried green onions (*Allium fistulosum*) [19].

Liken to maintaining nutritional values in fruits, vegetables, and tubers, the phenomenon of quality is defined with major physicochemical and exploitable (or measurable) parameters and is continually appreciated in response to storage mechanisms and methodologies [20]. Preservation mechanisms in essence concern the maintenance of acceptable quality in horticultural yields. Acceptable storage techniques regarding transportation, packaging and harvesting side by side with delivering relationships are subject to increasing the duration for admirable quality [21]. In this study, physicochemical variables such as density, pH, and M.C (%) as reported in the finding of Ref. [22] with the different products considered are examined, including the maximum acceptable period of storage. In alignment with the objectives of this research, sorting was done via the physical evaluation approach. This is an important technique for selecting horticultural yields as a result of considerable advantages such as less time consumption and variety in differentiating [23], non-destructive, inexpensive, and accurate. Considering this demonstration, several characteristics can be observed from captures including the turgidity, color, and appearance features [24]. In literature, the application of color features was observed in the works of Wu and Sun [25], and Zhang *et al*. [26], texture features in the study of Ref. [27], and appearance features as described in Ref. [28] in food quality assessment have been reported.

2. Materials and Methods

2.1. Material

The fresh *Cucumis sativus* and *Solanum tuberosum* were gotten from the traditional markets in Gboko by the application of the physical (image) sorting procedures with great importance cited in the literature [23]. The products were considered for characteristics namely homogeneity in appearance, maturation (considered by the postharvest professionals from CEFTER), and weights to explore the major objective of this article [24].

2.2. X-rays spectroscopy

Six samples of cucumber and irish potato were sealed in plastic papers. While keeping one sample each as the control sample which was not X-ray irradiated, five remaining samples of cucumber and irish potato were X-ray irradiation at the clinic of the Federal University of Agriculture, Makurdi. The X-ray machine was the YZ100C 100mA X-ray with X-ray tube Model: DX4-2.9/100, and the mean temperature during the exposure of the samples was 27oC. Exposure parameters such as tube current and exposure time were kept constant respectively at 32 mA and 2 s, and changing the kilovoltage peak in an interval of 10 kVp from 60-100 kVp at a constant distance of 80cm for different sealed samples. This was done as depicted in Ref. [29].

2.3. Moisture content

The $M.C(\%)$ was obtained using the oven-dry as in Ref. [30]. The samples were cut into particular shapes and sizes. The samples were kept in the dry oven model: DHG-9053A for 72 hours at a steady temperature of 100 ± 5^{o}C. The following measurement was done: Mass (m_a) of the crucible dish and Mass (m_b) of the crucible dish containing the sample, and lastly the mass (m_c) of the crucible dish and dried sample. The procedures followed those of [31]. The $M.C$ (%) is given by Eqn. (1):

$$M.C(\%) = \frac{m_b - m_c}{m_b - m_a} \times 100\%. \quad (1)$$

2.4. Density measurement

The density of the samples was evaluated by measuring the density of the juice from the respective samples using the density bottle and a balance as demonstrated in Ref. [32, 33] via the formula of Eqn. (2).

$$\rho = \frac{m_j}{v_j}, \quad (2)$$

where ρ is the density, m_j and v_j are respectively the mass and volume of the juice.

2.5. Evaluating the pH

The pH was evaluated via the pH meter with a standard glass electrode at a mean room temperature range of 27 – 30^{o}C and in this study was the Radiometer (Cleveland, OH) Model ROHS pH meter. This was done via the following procedures: The pH meter was used to steer the solution (the extracted juice via a Juicer) until the reading of the meter stabilizes. This was repeated three times and the average value was recorded.

2.6. Shelf life

The masses of the various samples were recorded in intervals with the help of a balance. This was done for both the X-ray irradiated and the control samples. The shelf life for cucumber was evaluated for 25 days while that of irish potato was evaluated for 45 days of storage. These procedures were strictly followed from the works of Ref. [29,30,32,33] using equations (3) and (4).

$$\Delta M = m_\alpha - m_\varsigma \quad (3)$$

and,

$$\Delta M(\%) = \frac{m_\alpha - m_\tau}{m_\alpha} \times 100\%, \quad (4)$$

with m_α the masses of the fresh samples, m_ς the masses during storage, and m_τ the masses of the samples at the end of preservation.

Data were plotted and represented with the help of computer software, the Origin 2021 64-bit.

3. Results and Discussion

Cucumbers and irish potato are highly perishable vegetables and tubers, respectively. Shelf-life extension as reported in [32, 33] which is one of the major factors investigated in this research work is affected by the three most influential variables including; preservation criteria, the nature of the sample at the beginning of the preservation process, and the duration of preservation [34]. Wastages as a consequence of storage are associated with a decrease in mass (shrinkage) and destruction of the acceptable nutritional value as a result of respiration [35], ackerspyring [36], transpiration [37], variation in chemical and physical parameters of the sample [36], and spoilage by high temperatures.

The density, M.C (%), and pH of Cucumbers were evaluated during the study for a storage period of 16 days. In this work, the following parameters were reported: $0.934\ g/cm^3$, 97.52%, and 5.8 for average density, M.C (%), and pH respectively for the freshly collected samples. These values are closer and in agreement with those in the literature [2, 36, 37]. The density varies with exposure parameters (kVp values) of X-ray irradiation and storage periods. For the control sample, the density varies with a slightly decreasing trend from $1.053 - 0.795\ g/cm^3$ and from $1.074 - 1.022\ g/cm^3$ for the 100 kVp value of X-ray irradiated samples. On the 16th day, the density of the control sample recorded a maximum decrease of 0.80 g/cm^3, while the 90 and 100 kVp samples were very close to the density at the start of the experiment of about 1.05 g/cm^3 showed a slight decrease and acceptable quality. The M.C (%) observed a trend inversely to that of the density which experienced an increasing trend with storage and varies with storage as: 94.98%-98.71%and 97.52%-97.78%, for both the control and 100 kVp samples respectively. It is interesting to note that at the 16th day of storage, the M.C(%) of the control sample was at 98.8%, while that of the 80, 90, and 100 kVp samples were approximately 97.0% showing slight variation from the initial M.C(%) at the start of the experiment. The pH had a decreasing trend, which varies with storage between 6.0-4.2 and 5.8-5.3 for the control and the 100 kVp value of X-ray irradiated samples. At the 16th day, the pH of the 90 and 100 kVp samples were 5.3 and 5.2, respectively which is closer to the original pH values of the samples, unlike the control sample which experience a greater trend recording a pH of 4.2 on the 16th day of storage.

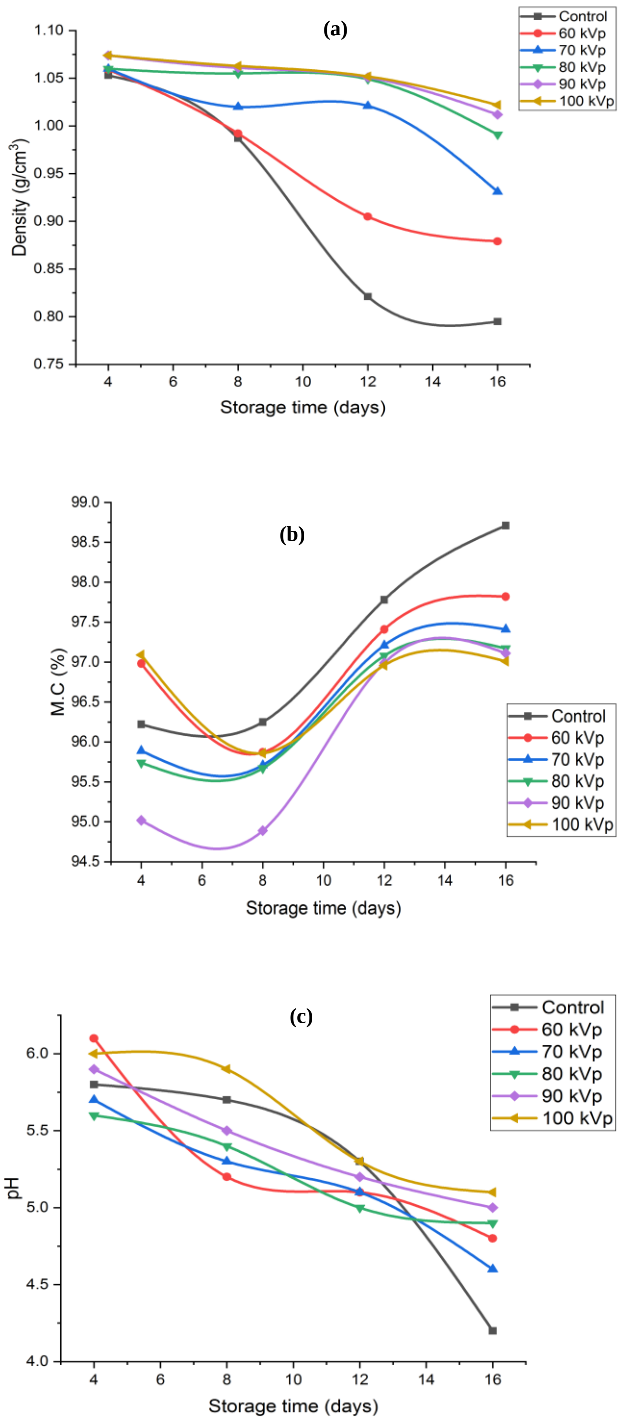

Fig 1. Variation of properties of Cucumber: (a) Density; (b) Moisture content; (c) pH; with preservation duration.

These variations in trends, decreasing for density, increasing for M.C (%), and slightly decreasing throughout the storage period for the pH are depicted in Figures 1(a-c) respectively. The results of this finding are presented with the methodology and presentation of those of Ref. [17]. The results of the study showed that cucumber can be preserved best after X-ray irradiation with the range of 90 – 100 kVp values of X-rays. This range of kVp values gives a very slight change to the density, M.C (%), and pH of the samples, hence keeping the samples fresh for an additional 7-8 days.

The density, M.C (%), and pH of irish potato samples varied over the study for a storage period of 45 days. There existed a relationship between storage period and kVp values of X-ray irradiation for the control, 60, 70, 80, 90, and 100 kVp values of X-ray irradiation and the variation in the various trends within the storage period evaluated in 10 days intervals. The following parameters were recorded: 1.0494 g/cm^3, 76.82%, and 7.2 for average density, M.C (%), and pH respectively for the freshly collected samples and find some agreement with the works from the following Ref. [38, 39]. For the control samples, the density varies with a slightly increasing trend from $1.0494 - 1.907\ g/cm^3$ and from $1.0688 - 1.0842\ g/cm^3$ for the 100 kVp X-ray irradiated samples. At the 20th day, the control sample recorded the highest density of 1.09 g/cm^3, while 90 and 100 kVp X-ray irradiated samples recorded 1.081 g/cm^3 and 1.08 g/cm^3, on the 45th day of storage respectively. This shows a greater variation trend and spoilage capacity of the control sample to the 90 and 100 kVp X-ray irradiated samples. The M.C (%) observed a decreasing trend in this study. The M.C (%) varies with storage as: 79.931%-74.72% and 76.821%-70.82%, for both the control and 100 kVp samples respectively. On the 20th day, the control sample recorded an M.C(%) of 71%, while the 90 and 100 kVp of X-ray irradiated samples recorded 73% and 74% on the 45th day of storage respectively proving acceptable quality and shelf life elongation compared to the control sample. And lastly, the pH has an increasing trend, which varies with the storage period between 7.4-8.0 and 7.2-8.9 for the control sample and the 100 kVp of X-ray irradiated samples respectively. At the 20th day of storage, the control sample recorded a pH of 9.0, while the 90 and 100 kVp of X-ray irradiated samples recorded 7.9 and 7.8 on the 45th day of storage respectively. The maximum variation in the trend of the control sample leading to fast deterioration compared to the 90 and 100 kVp of X-ray irradiated samples is reported. These variations in trends for density, M.C (%), and pH are depicted in Figures 2(a-c) respectively. The results of this finding are presented with the methodology and presentation of those of Ref. [17].

These variations are a result of the sprouting of the tubers, loss of water on the tuber's surface, and respiration and are not limited to the conversion of starch in the tuber to sugar [14]. The results of the study show that irish potato can be preserved best after exposure to X-rays within the range of 90 – 100 kVp values of X- ray irradiation. This range of kVp values gives a very slight change to the density, M.C (%), and pH of the samples as observed with the results of this study, hence keeping the samples fresh, inhibiting sprouting, and deterioration for an additional 15 days of storage by extending the shelf life from 30 days to 45 days of storage.

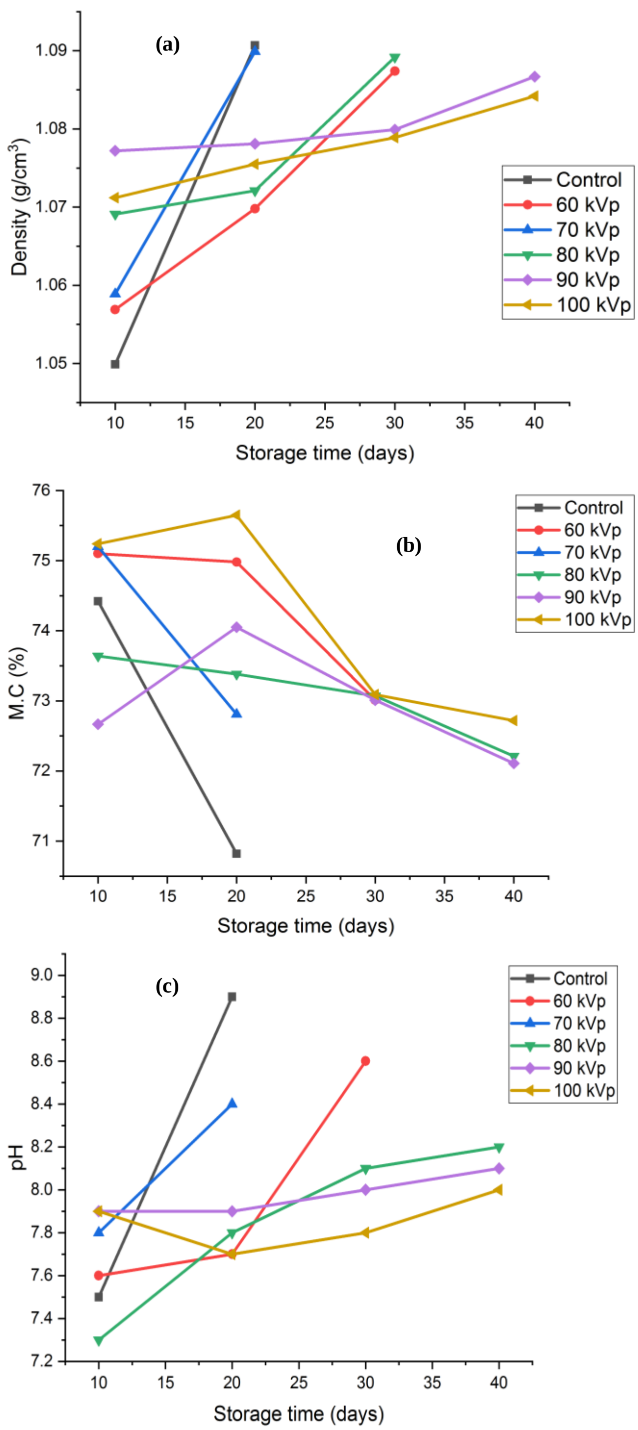

Fig 2. Variation of properties of Irish Potato: (a) Density; (b) Moisture content; (c) pH; with preservation duration.

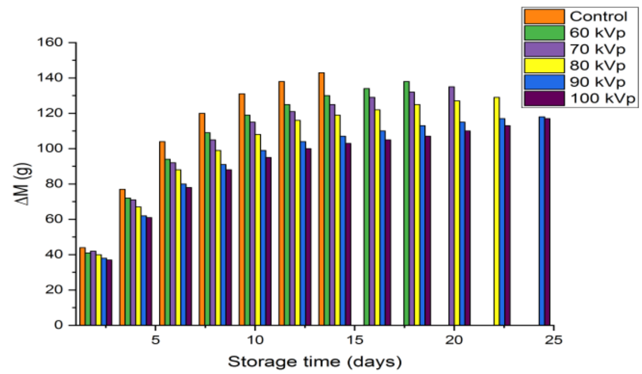

Fig 3. Effect of X-ray irradiation on ΔM (g) for Cucumber against the duration of preservation in days of the samples.

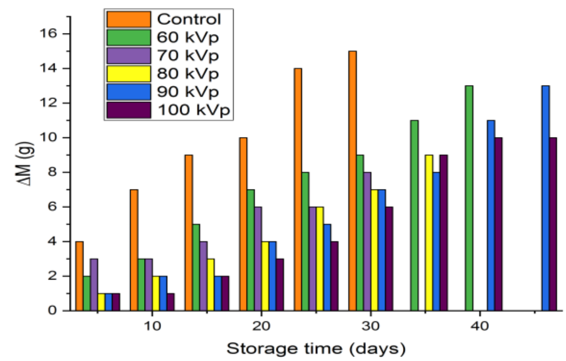

Fig 4. Effect of X-ray irradiation on ΔM (g) of irish potato against the duration of preservation in days of the samples.

The ΔM is established to increase with preservation for both the cucumber and irish potato samples. This variation is relative as the untreated sample observed a greater increase shown by the bar chart representation of Figures (3) and (4) for both the cucumber and irish potato respectively, while the 100 kVp has the lowest. This shows why the control sample deteriorated first, with the shortest shelf life compared to the 100 kVp samples which observed a longer storage period while still fresh. The initial masses of cucumber were 379 g, 346 g, 311 g, 319 g, 302 g, and 348 g for the control, the 60, 70, 80, 90, and 100 kVp of X-rays irradiated samples respectively while the masses of the irish potatoes were 64 g, 74 g, 64 g, 64 g, 70 g, and 97 g for the control, the 60, 70, 80, 90, and 100 kVp of X-rays irradiated samples respectively. The ΔM(%) of cucumber was 45.0% and 31.6% for the control sample and 100 kVp samples respectively and 23.8% and 20.5% for the control sample and 100 kVp respectively for irish potato. Physical examinations are presented in Fig. 5.

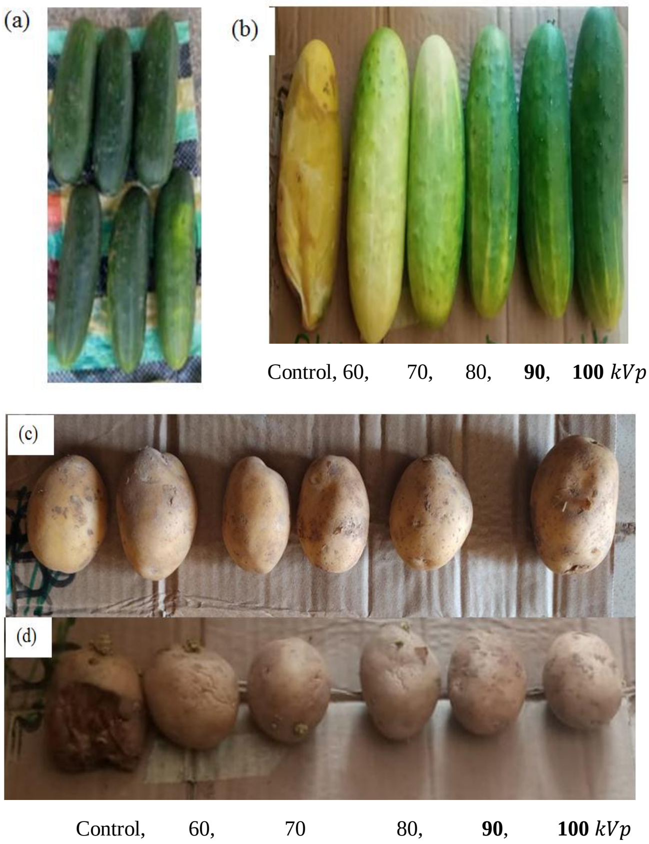

Fig 5. Spoilage observation in cucumbers and sprouting in irish potato during storage for control and irradiated samples: (a) freshly harvested cucumbers (b) cucumbers after 21 days of storage (c) freshly sorted irish potato (b) irish potato after 5 weeks of storage.

The results for firmness and texture were done by physical examination and pictures recorded. The shelf life evaluation showed that the 90-100 kVp of X-ray irradiation can preserve cucumbers for an additional 7 – 8 days of storage and irish potato for an additional 2 – 3 weeks of storage. This elaboration is depicted in Figure 5 (a-d) where the samples placed in increasing kVp values of X-ray irradiation from the control to 60-100 kVp are observed to deteriorate for cucumbers and as well, deterioration and sprouting were enhanced for the irish potato samples.

4. Conclusion

In this study, diagnostic X-rays affected the density, moisture content, pH, and mass shrinkage of cucumbers and irish potato during storage. The changes in these parameters affect the firmness, and freshness of the products which are directly related to the sample's storage period as; the samples X-ray irradiated with the 90-100 kVp of X-rays extended the storage of cucumber for an additional 7 – 8 days of preservation, and irish potato for an additional 2 – 3 weeks of storage. Hence this article recommends the utilization of X-rays with specific kVp values to reduce postharvest losses of horticultural yields.

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Conflict of Interest

The authors declare that they have no conflict of interest

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