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Investigation of gamma irradiation and storage period effects on the nutritional and sensory quality of chickpeas, kidney beans and green lentils

Ayca Aylangan*, Erhan Ic, Berna Ozyardimci

Turkish Atomic Energy Authority, Saraykoy Nuclear Research and Training Center, Kazan, Ankara, Turkey

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A B S T R A C T

The objectives of this study were to determine the effects of gamma irradiation and storage period on the content of the total carotenoids, the oligosaccharides raffinose and stachyose, and the vitamins thiamine (B1) and riboflavin (B2) in pulses. Chickpea, kidney bean and green lentil samples were subjected to gamma irradiation doses of 0.25, 0.50 and 1.0 kGy followed by storage at room temperature for 12 months. The total carotenoids content was measured by spectrophotometer. Raffinose and stachyose were determined by high-performance liquid chromatography (HPLC) with refraction index detection and thiamine and riboflavin concentrations by HPLC with fluorescence detection. The impact of the irradiation dose can be seen in the result of the total carotene tests for lentils. The three different irradiation doses applied did not have significant effects on the levels of riboflavin and thiamine. The effect of the storage period was found to be significant on the raffinose and stachyose content but there were no significant changes following the applied irradiation doses. In the sensory evaluation the testers were not be able to differentiate between the 0.25, 0.50 and 1.0 kGy applied irradiation doses and the unirradiated samples. The results of these studies suggest that irradiation with 1.0 kGy gamma rays cause tolerable losses in the nutrients studied in chickpeas, kidney beans and green lentils.

1. Introduction

Pulses are a cheap and important source of plant-based proteins and are consumed in large quantities by the population in Turkey. They are valuable sources of complex carbohydrates, protein and dietary fiber, contribute significant amounts of vitamins and minerals, and have high energy value (El-Niely, 2007). Of the total sown area in Turkey, 806,000 ha is utilized for pulses. Turkey produced 1140 tons of pulses in 2013. The main pulses produced in Turkey are chickpeas (506,000 tons), kidney beans (195,000 tons) and lentils (417,000 tons). The amount of pulse consumption per capita is relatively large quantity compared with the world pulses consumption; for example chickpeas are 4.61 kg per year, lentils are 5.22 kg per year and kidney beans are 2.88 kg per year (Anonymous, 2013). Generally, post-harvest losses in pulses (20–25%) arise mostly from transportation and storage food pests. Over the centuries, efforts have been made to control storage losses and maintain the quality of foods. One of the main problems in domestic and export market is infestation by stored-product insects. Vast quantities of stored grains and pulses are lost annually as a result of insect infestation (Khattak & Klopfenstein, 1989).

The increasing volumes of commodities being traded worldwide has created an urgent need for effective disinfestation treatments to prevent the dissemination of alien invasive pests (Cannon, Hallman, & Blackburn, 2012). Post-harvest control of insects in pulses is essential under quarantine regulations in many countries (El-Naggar & Mikhaiel, 2011). Current available methods for post-harvest control are based on fumigation (Jemâa, Haouel, Bouaziz, & Khouja, 2012). The traditional treatment is chemical fumigation due to its low cost, fast speed in processing and ease of use (El-Naggar & Mikhaiel, 2011). However, the banning of the fumigant methyl bromide for all purposes (including phytosanitary and preshipment uses) in the European Union has further increased the

* Corresponding author.
E-mail addresses: ayca.aylangan@taek.gov.tr (A. Aylangan), erhan.ic@taek.gov.tr (E. Ic), berna.ozyardimci@taek.gov.tr (B. Ozyardimci).

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need for effective alternatives (Cannon et al., 2012). For insect disinfestation in pulses and grains, irradiation may offer an attractive alternative to chemicals (Villavicencio, Mancini-Filho, Delince, & Bognar, 2000).

Protecting food from insect infestation is one of the most important goals of irradiation and the process effectively eradicates insect pests at all life stages (Machaiah & Pednekar, 2002). Food irradiation in Turkey has a very promising future having contributed to the conservation of food, the reduction of post-harvesting losses, and the possibility of improving food availability. The U.S. Food and Drug Administration (FDA) has approved irradiation of pulses up to 1.0 kGy. The irradiation process applied to pulses has already been described in the literature (Al-Kaisey, Alwan, Mohammad, & Saeed, 2003; El-Niely, 2007; Khattak & Klopfenstein, 1989; Lima, Souza, Godoy, França, & Lima, 2011; Villavicencio et al., 2000). However, no study has directly examined the effects of the gamma irradiation and storage period on the total carotenoids content, oligosaccharides (raffinose and stachyose) and B vitamins (thiamine and riboflavin) in chickpea, kidney bean and green lentil samples. Carotenoids are a class of natural fat-soluble pigments found in pulses. These pigments also play roles in human health, preventing certain types of cancer, cardiovascular diseases and eye disorders (Nunes et al., 2013). Thiamine (vitamin B1) and riboflavin (vitamin B2) are important essential vitamins in pulse products. Research has shown that the change in nutritional value caused by irradiation depends on a number of factors. Among these are radiation dose, type of food, packaging and processing conditions such as temperature and oxygen exposure during irradiation and storage time (Crawford & Ruff, 1996). For example, Fox, Ackerman, and Thayer (1989) reported that some vitamins, especially B1, are partially lost during irradiation; however this loss can be minimized by choosing appropriate conditions. Research has also shown that the loss of riboflavin (vitamin B2) and thiamine is no greater than that experienced during thermal processing (Steele & Engel, 1992). Raffinose and stachyose have been implicated as the causative factor for flatulence and abdominal discomfort (Dixit, Kumar, Rani, Manjaya, & Bhatnagar, 2011). In the literature, it has been reported that various processing methods, including gamma irradiation, could be possible alternative and additional processing techniques for reducing antinutrients like raffinose and stachyose. The irradiation methods applied to some pulses have already been described in the literature and represent alternative ways to fight harvesting losses because they contribute to the disinfestation of wheats, some type of pea and beans, grains and some pulses which allows them to keep their chemical and nutritional qualities and increases their shelf life (El-Naggar & Mikhaiel, 2011; El-Niely, 2007; Hajare, Saroj, Dhokane, Shashidhar, & Bandekar, 2007; Khattak & Klopfenstein, 1989; Lima et al., 2011; Villavicencio et al., 2000). Studies pertaining to the effect of gamma irradiation on nutritional components and storage period of chickpeas, kidney beans and green lentils are limited. In the present work, gamma irradiation was applied to chickpeas, kidney beans and green lentils, at low doses (0.25, 0.50 and 1.0 kGy), and the effects on nutritional and sensory parameters were evaluated during one year of storage (immediately after the irradiation process, 6 and 12 months).

2. Material and methods

2.1. Samples and chemicals

The nonfumigated chickpea and kidneybean samples were obtained from a company (Memişler Group, Mersin, Turkey), the nonfumigated green lentil samples were obtained from the Ministry of Food Agriculture and Livestock, Central Research Institute for Field Crops, Ankara, Turkey. The samples were cleaned, placed in polyethylene bags (500 g each) and irradiated at the doses of 0.25 kGy, 0.50 kGy and 1.0 kGy (target doses) from the ^{60}Co source at Turkish Atomic Energy Authority, Sarayköy Nuclear Research and Training Center, Ankara, Turkey. Unirradiated samples served as controls. The absorbed dose was checked using the Harwell perspex dosimetry (Harwell Gammachrome YR®, Perspex Dosimeter, Batch 62, Harwell, UK). The amounts of the measured doses are given in Table 1. Raffinose, stachyose, riboflavin, thiamine, acid phosphatase, papain, alpha-amylase, beta-glucosidase, glyoxylic acid and glutathione were purchased from Sigma Chemical Co. The Millex membranes (0.45 μm) were obtained from Millipore and the Sep-Pak C18 cartridges were purchased from Waters Corporation (Milford Massachusetts, USA). All other chemicals were analytical grade.

2.2. Measurement of total carotenoids

The total carotenoids were measured according to the criteria by Alasalvar, Al-Farsi, Quantick, Shahidi, and Wiktorowicz (2005). The homogenate was filtered through a Whatman No.4 filter paper and washed until the residue was colorless. Finally, extraction solvent was added to the filtrate to a total of 100 mL and the absorbances at 471 and 477 nm were measured against an acetone blank using a Jenway 6505 UV/Vis spectrophotometer. The total carotenoids were calculated according to the following equation.

$$\text{Total carotenoids (\%)} = (\text{Abs}_{max}/250) \times [(25 \text{ ml acetone} \times \text{dilution} \times 100) / \text{sample weight}]$$

2.3. Analysis of oligosaccharides

2.3.1. Extraction of oligosaccharides

The extraction of the raffinose and stachyose was conducted according to the process given by Xiaoli et al. (2008). The samples (1.0 g) were extracted 3 times with 10 mL 50% ethanol-water at a ratio of 10:1 (solvent to samples) in a water-bath at 50 °C for 30 min. After each extraction, the samples were centrifuged at

Table 1
Harwell perspex dosimetry results for target and measured dose (kGy) uniformity of chickpea, kidneybean and green lentil.

Sample	Target dose (kGy)	Measured dose mean (kGy)
Chickpea	0.25	0.22 ± 0.01
	0.50	0.44 ± 0.10
	1.00	0.92 ± 0.04
Kidney bean	0.25	0.21 ± 0.04
	0.50	0.42 ± 0.09
	1.00	0.88 ± 0.09
Green lentil	0.25	0.21 ± 0.09
	0.50	0.46 ± 0.10
	1.00	0.91 ± 0.04