Radiation Technology to Enhance Food Quality and Ensure Food Safety in Syria

Mahfouz Al-Bachir [1*]; Ibrahim Othman[1]

1 Radiation Technology Department, Atomic Energy Commission of Syria, Damascus, P.O. Box 6091, Syrian Arab Republic.

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*Corresponding Author:
Mahfouz Al-Bachir
E-mail: ascientific@aec.org.sy

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ABSTRACT

Food irradiation program in Syria has been going on since 1985. The major goal of this program is to investigate the effect of ionizing irradiation on improving storability and insuring safety and preserving the quality of food. The food irradiation research focuses on sprout inhibition of onions and tubers, insect disinfestations of seeds and nuts, shelf life extension of prepared meal of both plant and animal food for human nutrition, and decontamination of spices and medical herbs. The results of the food irradiation program in Syria indicate that food irradiation is feasible for sprout inhibition, shelf life extension, disinfestations, and decontamination of food products. Regulations for food irradiation in Syria were put in place in 1986 with a maximum allowable dose of 10 kGy. Syrian Atomic Energy Commission (SAEC) has a multipurpose pilot scale facility (ROBO, Russia) 60Co, and linear electron accelerator facility (D-EPS-T30-30-002V, VIVARAD, France), which are used for pilot and semi- commercial irradiation of food, and about 2000 metric tons of food are irradiated yearly.

تقانة التشعيع لتحقيق جودة الغذاء وتعزيز سلامته في سوريا

محفوظ البشير*[1] و إبراهيم عثمان[1]

1 قسم تكنولوجيا الإشعاع، هيئة الطاقة الذرية في سوريا، دمشق، ص. ب 6091، الجمهورية العربية السورية.

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*الباحث المراسل: محفوظ البشير
بريد الكتروني:
ascientific@aec.org.sy

الكلمات الدالة

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المُستلخص

تمت مباشرة العمل ببرنامج تشعيع الأغذية في سوريا منذ عام 1986. و كان الهدف الأساسي من هذا البرنامج اختبار تأثير الأشعة المؤينة في تحسين قابلية التخزين وتحقق السلامة والمحافظة على الخصائص النوعية وجودة الغذاء. حيث ركزت البحوث المنفذة في هذا المجال على إعاقة الإنبات عند الأبصال والدرنات ومكافحة الحشرات التي يمكن أن تصيب الحبوب والمكسرات خلال التخزين، و إطالة فترة عرض الوجبات الجاهزة التي يدخل في تركيبها مواد غذائية ذات مصدر نباتي أو مواد غذائية ذات مصدر حيواني معدة للاستهلاك البشري، وتخليص النباتات الطبية والبهارات من حمولتها الميكروبية. وتعتبر المواد الغذائية المعالجة بجرع إشعاعية تصل حتى 10 كيلو غري قانونية ويسمح بتداولها تجاريا في سوريا منذ عام 1986، ويتوفر في هيئة الطاقة الذرية السورية وحدة تشعيع منبعها من الكوبالت 60 روسية الصنع ومسرع الكتروني فرنسي الصنع حيث يستخدم كلا الوحدتين في معالجة المواد الغذائية غلى مستوى تجاري، ويتم معالجة حوالي 200 م3 من المواد الغذائية سنويا في هذه الوحدات.

Introduction

Plant food for human nutrition typically have one or more pre-harvest insect pests that feed directly on the product and are capable of causing considerable damage and quality loss (Fernance et al., 2010; Reis et al., 2012). Gamma irradiation can be an effective alternative technology in post harvest pest control because of its ability to kill insects (Sirisoontaralak and Noomhorm, 2006), and inhibit mycotoxin biosynthesis during storage (Kabak, Dobson, & Var, 2006).

Ingredients including herbs and spices contain a high load of spores of bacteria and fungi (Sharma et al., 2006). The presence of invisible microorganisms, many of which could cause disease poses risks to human health, especially when spices or herbs are added to food after cooking (Sharma et al., 2006). Ionizing irradiation is now getting recognition through the world as phyto-sanitary treatment of plant materials. Irradiation decontamination of herbs and spice is currently the most popular application in food irradiation because their aromatic quality is well maintained after irradiation (Kim et al., 2009; Ramathilaga & Murugesan, 2011).

Microbiological contamination of meat is a concern, for both meat producers and consumers. In developed as well as developing countries, an increase in the incidence of food –borne diseases, especially of animal origin, has been noticed (Mayer-Miebach et al., 2005). Irradiation as a preservation method, has excellent potential in the elimination of pathogenic and spoilage microorganisms from meat and meat products (Mayer-Miebach et al., 2005; Bhatti et al., 2013).

Irradiation of food is widely recognized and is now legally accepted in about 55 countries with a maximum overall average of 10 kGy (IAEA, 2008). Irradiation decontamination of herbs and spices is very popular in food irradiation because this process maintains their aromatic quality. This process has already been approved in 55 countries and is currently practiced in more than 10 countries (Kume et al., 2009).

For many years, agriculture has been a major activity in the Syrian economy. The food production is enough for local consumption and some food products are available for exporting. The climate of the Mediterranean sea generally prevails in Syria. This climate enhance the physiology and biology food deterioration. As other developing countries, the new technology is not available yet and was not used well in Syria. Therefore, we need the new technology to solve the problem. Food irradiation program in Syria has been going on since 1985. The major goal of the program is to investigate the effect of ionizing irradiation on improving storability and safety and preserving the quality of food.

1. Type Of Food Studied in Syrian Food Irradiation Program (subjected to irradiation)

Food irradiation program was conducted with the following Syrian kind of food: Fruits of Surrany variety of olive (Al-Bachir, 2003), two local table grape varieties, namely; Baladi and Helwani (Al-Bachir, 1999/b), Golden Delicious and Starking varieties of apples (Al-Bachir, 1999/a), Senga sengana variety (var.) of strawberry (Al-Bachir & Farah, 1999zzzz), Slamoni var. of onion and Sponta var. of potato (Al-Bachir, Al-Sharabi, & Al-Midani, 1993), walnuts of the Baladi var. (Al-Bachir, 2004), Halebi var. of the pistachio (Al-Bachir, 2014/b), Baladi var. of almond (Al-Bachir, 2015/a), Baladi var. of peanut (Al-Bachir, & Othman, 2015), faba bean seeds (Mansour & Al-Bachir, 1995), seeds of anise (Al-Bachir, 2007/a), ground licorice roots (Al-Bachir & Lahham, 2003), licorice root products (Al-Bachir, A-Adawi, &Al-Kaed, 2004), powder of chamomile plant (Al-Bachir, 2015/b), ground spices (Al-Bachir, 2005), Jabaly Syrian goat meat (Al-Bachir & Zeinou, 2014), camel meat (Al-Bachir & Zeinou, 2009), chicken meat (Al-Bachir, 2013/b), luncheon meat (Al-Bachir & Mehio, 2001), Kubba (Al-Bachir, 2013/a), Borak (Al-Bachir, 2007/b), Sheesh Tawoq (Al-Bachir, 2010), chicken sausage (Al-Bachir & Othman, 2013), chicken kabab (Al-Bachir, Farah, & Othman, 2010), Shell eggs (Al-Bachir & Zeinou, 2006), and cheese (Al-Bachir & Farah, 2014), were used in the Syrian food irradiation program

2. Irradiation Processing

Samples from used food materials were exposed to gamma radiation in a 60CO package irradiator (ROBO, Russia) at room temperature. The absorbed dose was assured by alcoholic chlorobenzene dosimeter, and determined by the measurement of chloride ions or hydrogen ions by means Oscillotitrator (OK-302/2, Radelkisz, Budapest, Hungary) (Al-Bachir, 2004).

Apple fruits, table grapes and walnuts were exposed to gamma radiation at doses of 0.5, 1.0, 1.5. 2.0, and 2.5 kGy. Samples from pistachio, almond, peanuts, and olive fruits were exposed to gamma radiation at doses of 1, 2 and 3 kGy. Packed goat meat, camel meat, chicken meat, luncheon meat, Kubba, Borak, Sheesh Tawoq, chicken sausage, and chicken kabab were exposed to gamma radiation at doses of 0, 2, 4 and 6 kGy. Packed anise seeds, ground licorice root, licorice root products and powder of chamomile plant were treated with 0, 5, 10, 15 and 20 kGy of gamma rays.

Irradiated and non-irradiated samples were stored at appropriate conditions. Microbiological, physical, and chemical analyses were performed on controls and treated samples immediately after irradiation, and throughout storage periods. Sensory evaluation were done within two days of irradiation.

3. Evaluation of Irradiated Food

Food that included in the food irradiation program was subject to the microbial, chemical physical, sensorial and statistical evaluation.

3.1. Microbiological Analysis

Standard methods (AOAC, 2010) were used to estimate the total viable (mesophilic aerobic) plate counts (TPCs), on agar plate counts (APCs) (Oxoid, CM 325, UK) (48 h incubation at 30 oC), fecal coliform colony count on Violet Red Bile Agar (VRBA) (Oxoid, CM 485, UK) at 37 oC for 48 h. Yeast on Dichloran Rose-Bengal Chloramphenicol Agar (DRBC) (Merck, 1.00466, Germany) after incubation at 25 oC for 5 days. The survival level of Salmonella spp was determined by plate counting on Xylose Lysine Desoxycholate Agar (XLD) (Biolife, 402206, Italy) and the survival level of E. coli was determined by plate counting on Eosin Methylene Blue Agar (EMBA) (Oxoid, CM 69, UK), after 2 days of incubation at 37 oC (AOAC, 2010).

3.2. Chemical analysis

Standard methods (AOAC, 2010) were used to determine moisture and ash (drying for 6 h at 105 oC, and ashing for 4 h at 550 oC), crude fat (as extractable component in Soxhlet apparatus), and crude protein (as Kjeldahl nitrogen) pH values of the solutions of food produts were determined using an HI 8521 pH meter (Hanna Instruments, Woonsocket, RI, USA). Electrical conductivity (EC) values were determined using a Cyberscan Con 200 conductivity meter (Eutech Cybernetics Pte Ltd, Singapore). The total acidity was obtained by a direct titration with (0.1 N) NaOH. Total volatile basic nitrogen in the sample in term of mg VBN kg-1 food product (ppm) was determined (Al-Bachir, 2004).

3.3. Physical Analysis

The viscosity of the extracts was measured with HAAKE viscometer 6 R plus Model (RTM) using a R2 column at 200 rpm. (Al-Bachir & Lahham, 2003). The color of food product extract was measured using AvaSpec Spectrometer Version 1, 2 June 2003 (Avantes, Holland) (Al-Bachir, 2015/e).

Weight loss, spoilage and total loss of fruit was evaluated by the methods described by (Al-Bachir, 1998).

3.4. Sensory Evaluation

Sensory evaluation included color, texture, odor and taste was determined using a 5 point hedonic scale where:1 = extremely poor, 2 = poor, 3 = acceptable, 4 = good, 5: excellent) (Al-Bachir, 2004).

3.5. Statistical Analysis

Completely randomized design with three replicates were used in all experiments. Data were subjected to the analysis of variance test (ANOVA) using the SUPERANOVA computer package (Abacus Concepts Inc, Berkeley, CA, USA; 1998). A separation test on treatment means was conducted using Fisher's least significant differences (LSD) methods at 95% confidence level (Snedecor & Cochran, 1988).

4. Results of Syrian Food Irradiation Program.

4.1. Sprout Inhibition

Our investigation showed that, sprouting of tubers and onions produced in Syria started after 1.5 months of storage in well ventilated warehouses at ambient temperature. It is estimated that the sprouting rate reaches 100% after five months of storage, while treatment with 60 Gy dose at an equal period was shown to be 1% sprouting. This implies a waste factor of 50%. The irradiation process has the effect of reducing sprouting significantly. The required dose for sprout inhibition of Syrian products is 60 Gy for onion and 100 Gy for potato (Al-Bachir, Al-Sharabi, & Al-Midani, 1993).

4.2. Shelf-Life Extension Of Fruits

4.2.1. Apple Fruits

Gamma irradiation (0.5, 1.0 and 1.5 kGy) increased the weight loss of both apple varieties (Golden Delicious and Starking). After 45 days of storage, the weight loss of Golden Delicious apple treated with 0, 0.5, 1.0 and 1.5 kGy were 1.3, 1.8, 1.6 and 1.6% respectively. Application of gamma irradiation prevented the growth of Aspergillus niger and the formation of skin scald in 'Golden Delicious' fruits. Immediately after treatment, gamma irradiation increased the softening of fruits, changing their color from green to yellow and decreased the pH value of the juice (Al-Bachir, 1999/a).

4.2.2. Table Grapes

Gamma irradiation (0.5, 1.0, 1.5, 2.0, and 2.5 kGy) improved the storability of both grapes varieties (Baladi and Helwani). In addition, it prevented molding and prolonging the storage time. The optimum doses for improving the storability were 0.5 – 1.0 kGy for Helwani and 1.5 – 2.0 kGy for Baladi, and the storage periods can be extended by 50% using those optimal doses for both varieties (Al-Bachir, 1999/b). Gamma irradiation reduced the rotting of table grapes induced by Botrytis cinerea (Al-Bachir, 1998).

4.2.3. Strawberries

Gamma irradiation (1, 2 and 3 kGy) decreased the fungal spoilage and increased the shelf-life of strawberries fruits as compared with the control. Irradiation increased the marketing period of fruit from 2 days for the control to the 5 days on the treated with 3 kGy (Al-Bachir & Farah, 2000)

4.3. Shelf-life extension of fresh meat and eggs

4.3.1. Goat Meat

Irradiation (2, 4, and 6 kGy of gamma ray) was effective in reducing the microbial load and increasing the shelf-life of goat meat. Initially microbial load of control sample of goat meat were 106 microbe per gram and irradiated samples with 4 and 6 kGy had no detectable microorganisms on day 0 (less than 10 microbe per gram). The radiation doses required to reduce the microorganisms by 90 percent (D10) in goat meat were 294 and 400 Gy for the Salmonella and E. coli, respectively. No significant differences were observed in moisture, crude protein, crude fat, ash, pH value, fatty acids, total acidity, volatile basic nitrogen, and sensory properties (texture, flavor, color, and taste) of irradiated and non-irradiated goat meat. Lipid peroxidation measured in term of thiobarbituric acid-reactive substances (TBARS) increased on irradiation and chilled storage. Sensory evaluation showed no significant differences between irradiated and non-irradiated goat meat (Al-Bachir & Zeino, 2014).

4.3.2. Camel Meat

All doses of gamma irradiation (2, 4 and 6 kGy) reduced the total mesophilic aerobic plate counts (TPCs) and total coliforms of camel meat. Thus the microbiological shelf-life of camel meat was significantly extended from less than 2 weeks (control) to more than 6 weeks. No significant differences in moisture, protein, fat, thiobarbituric acid (TBA) values, total acidity and fatty acids of camel meat were observed due to irradiation. Sensory evaluation showed no significant differences between irradiated and non-irradiated camel meats (Al-Bachir & Zeino, 2009).

4.3.3. Chicken Meat

All used doses of gamma irradiation (2, 4 and 6 kGy) reduced the total mesophilic aerobic plate counts (TPCs) and total coliforms of chicken meat. Shelf-life extension periods estimated on the basis of a limit of 6 log CFU/g for TPCs were 2, 4, 9, and more than 13 weeks for samples irradiated at 0, 2, 4, and 6 kGy, respectively. Irradiation had little or no effect on general composition (moisture, protein, and fat contents), total acidity, lipid peroxide and total volatile basic nitrogen. Sensory evaluation showed no significant differences between irradiated and non-irradiated chicken meats (Al-Bachir, 2013/b).

4.3.4. Fresh Eggs

The radiation dose required to reduce the Salmonella load one log cycle (D10) in eggs was 448 Gy. Eggs irradiated with 1.5 kGy maybe suitable microbiologically to prepare safe mayonnaise. There are no significant differences in saturated fatty acids (C14: 0; C16: 0; C18:0) and TBA values between yolk lipid extracted from irradiated and that of non-irradiated eggs. Gamma irradiation reduced the viscosity of egg whites. Sensory evaluation showed no significant differences between mayonnaise prepared from irradiated and non-irradiated egg-yolk (Al-Bachir & Zeino, 2006).

4.4. Shelf-Life Extension of Prepared Meals

4.4.1. Luncheon Meat

Gamma irradiation (1, 2, 3 and 4 kGy) reduced the counts of microorganisms and increased the shelf-life of luncheon meat from 10 weeks for the control to 14 weeks for irradiated samples. Total acidity, lipid oxidation and the volatile basic nitrogen (VBN) increased after 2 weeks of irradiation. However after 10 weeks of storage the total acidity and volatile basic nitrogen were less than control. Sensory evaluation indicated that no significant differences (P> 0.05) were found between irradiated and non-irradiated samples in taste, and flavor (Al-Bachir & Mehio, 2001).

4.4.2. Kubba

The results indicate that 4 and 6 kGy doses of gamma irradiation decreased the total viable (mesophilic aerobic) plate counts and increased the shelf-life of Kubba. The reduction of plate counts was a log cycle of more than 1 or 2 for 4 and 6 kGy, respectively. Higher dose of gamma irradiation (6 kGy) decreased the protein and fats constituents of Kubba. The three chemical parameters, total acidity, lipid peroxide and volatile basic nitrogen, which were chosen as the indices of freshness, were all well within the acceptable limit for up to one week for Kubba treated with 0 and 2 kGy, and for up to 3 weeks at 1 - 4 0C for samples treated with 4 and 6 kGy. Sensory evaluation showed no significant differences between irradiated and non-irradiated samples (Al-Bachir, 2013/a).

4.4.3. Borak

Results of the proximate analysis of Borak showed that irradiation doses (2, 4 and 6 kGy) did not have a significant effect on moisture, protein and fat content of Borak. Gamma irradiation decreased the total counts of mesophilic aerobic bacteria, total coliform and yeast and increased the shelf-life of Borak. The reduction of total microbial load in the range of about 2, 4, or 6 log cycle for 2, 4 and 6 kGy, respectively. The radiation doses required to reduce the microorganisms load one log cycle (D10) in Borak were 456 and 510 Gy for the Salmonella and E. coli respectively. The three chemical parameters, total acidity, lipid peroxide and volatile basic nitrogen, which were chosen as the indices of freshness, were all well within the acceptable limits for up to 1, 3 and 6 weeks at 1 - 4 oC for samples treated with 0 or 2 , 4 and 6 kGy, respectively. Sensory evaluation showed no significant differences between irradiated and non-irradiated samples (Al-Bachir, 2007/b).

4.4.4. Sheesh Tawwook

The results indicate that 4 and 6 kGy doses of gamma irradiation decreased the total counts of mesophilic aerobic bacteria, total coliform and yeast. Thus the microbiological shelf-life of Sheesh Tawoq was significantly extended from 12 weeks (control) to more than 20 weeks (samples treated with 4 or 6 kGy). Irradiation doses did not have a significant effect on the major constituents of Sheesh Tawoq (moisture, protein and fats). The radiation doses required to reduce the microorganisms load one log cycle (D10) in Sheesh Tawoq were 435 and 385 Gy for the Salmonella and E. coli, respectively. The chemical parameters, total acidity and volatile basic nitrogen, were all well within the acceptable limit for up to 12 weeks for Sheesh Tawoq treated with 0 and 2 kGy, and for up to 20 weeks at 1-4 oC for samples treated with 4 and 6 kGy. Sensory evaluation showed no significant differences between irradiated and non-irradiated samples (Al-Bachir, 2010).

4.4.5. Chicken Sausage

Irradiation at 2, 4 and 6 kGy significantly reduced the counts of total viable (mesophilic aerobic) plate counts (TPCs), fecal coliform and yeast load and prolonged the refrigerated shelf-life of chicken sausage. At the beginning of the storage period non-irradiated chicken sausage had total viable plate count greater than 7 log cycle CFU/g, while in irradiated 2, 4 and 6 kGy it did not reach these number even after 12, 16 and 20 weeks of storage at 0 – 4 oC respectively. Irradiation significantly decreased their amount of total acidity, volatile basic nitrogen (VBN), and thiobarbituric acid reactive substances (TBARS), while storage increased the total acidity, VBN and TBARS for irradiated and non-irradiated samples. The percentage of protein slightly increased in irradiated samples with higher doses, while the percentage of fat significantly decreased. Gamma irradiation showed no significant effect on the sensory properties of chicken sausage (Al-Bachir & Othman, 2013).

4.4.6. Chicken Kabab

Gamma irradiation (2, 4 and 6 kGy) decreased the microbial load and increased the shelf-life of chicken kabab. The radiation doses required to reduce the microorganism load one log cycle (D10 value) in chicken kabab were 213 and 400 Gy for Salmonella and E. Coli respectively. Irradiation did not influence the major constituents of chicken kabab (moisture, protein and fats). No significant differences ($p>0.05$) were observed for total acidity between non-irradiated (control) and irradiated chicken kabab. Thiobarbitric acid TBA values (expressed as mg malonaldehyde (MDA)/kg chicken kabab) and volatile basic nitrogen (VBN) in chicken kabab were not affected by the irradiation. Sensory evaluation showed no significant differences between irradiated and non-irradiated samples (Al-Bachir, Farah, & Othman, 2010).

4.4.7. Cheese

All used doses of gamma irradiation (1, 2 and 3 kGy) reduced significantly the microbial load of Baladi cheese (manufactured from raw milk). Gamma irradiation decreased moisture, K^+, Ca^{++}, Na^+, ash and free fatty acids, and increased protein contents of Baladi cheese. Volatile basic nitrogen and firmness of irradiated cheese were increased after irradiation and decreased after 12 months of storage. Gamma irradiation had no effect on the sensory characteristics of Baladi cheese (Al-Bachir & Farah, 2004).

4.5. Disinfestations and Decontamination of Nuts and Seeds

4.5.1. Walnuts

Gamma irradiation reduced fungal load from 105 microbe per gram in control sample to up less than 10 microbe per gram on sample irradiated with 2 kGy. Used doses of gamma irradiation did not cause any significant change in proximate composition of walnuts. Gamma irradiation increased total acidity and decreased iodide value and volatile basic nitrogen (VBN) immediately after treatment. After 12 months of storage, gamma irradiation decreased total acidity and peroxide value and increased iodide value and VBN. No significant differences were observed between irradiated and non-irradiated samples in flavor and aroma immediately after irradiation. After 12 months of storage, higher doses (1.5 and 2.0 kGy) had a negative effect on sensory characteristics (Al-Bachir, 2004).

4.5.2. Pistachio

Used doses of irradiation significantly reduced the total bacterial plate counts (TBPCs) and total fungal counts up to undetectable level (less than 10 CFU g-1). Irradiation doses of 1, 2 and 3 kGy of gamma irradiation seem to be suitable for post harvest sanitation and decontamination treatment, since they did not cause significant changes in the sensorial properties (texture, odor, color and taste), chemical quality (free fatty acids and pH value) or in contents of moisture, proteins, sugars, lipid, and ash, with respect to the control samples (Al-Bachir, 2014/b). Gamma irradiation caused the alteration of fatty acids of pistachio oil which showed a decrease in oleic acid (C18:1) and an increase in linoleic acid (C18:2). All other fatty acids remained unaffected after irradiation. The higher used doses (2 and 3 kGy) decreased acidity value, peroxide value and iodine value, and increased specification number, with no effect on TBA value. Irradiation had a significant effect on color values of pistachio oil. Parameters L*, a* and b* increased at doses of 1 and 2 kGy (Al-Bachir, 2015/d).

4.5.3. Almonds

Gamma irradiation had no effect on chemical composition of almond nut kernels with the exception of total volatile basic nitrogen (TVBN) for irradiation dose of 3 kGy. During storage, the total fat and total protein were increased, but the total sugar was decreased. The TVBN increased due to irradiation doses and storage period. A trained sensory panel found that irradiation produced no significant change in texture, color, odor, and test attributes. Present analysis revealed that gamma irradiation could be successfully employed to preserve the overall quality to improve the shelf life to ensure the safety of almond nuts (Al-Bachir, 2015/a). Non-irradiated almond oil was characterized by high amount of unsaturated fatty acids. The fatty acid profile slightly changed due to irradiation. The major change in fatty acid composition was the decrease in the quantity of fatty acids (C16:0, C18:0 and C18:1) and the increase in the quantity of fatty acid (C18:2). Irradiation reduced acidity, peroxide, iodine and specifications values of almond lipid. Whereas, the TBA value was almost unaffected. Color parameters L*, a* and b* showed a small but, statistically significant ($p<0.05$) increase in all irradiated samples (Al-Bachir, 2014/c).

4.5.4. Peanuts

Gamma irradiation process had no effect on the proximate composition, and chemical attributes of peanut seeds. Irradiation was found to cause significant reduction in microbial load and no fungal colonies were detected in irradiated samples with 2 and 3 kGy. Bacterial and fungal load of irradiated peanut seeds and their comparison with control samples suggest that gamma irradiation treatment at low doses is an effective post-harvest treatment and quarantine control for fugal load. However, non-irradiated and irradiated peanut seeds did not show significant differences in the sensorial test (Al-Bachir, & Othman, 2016). Irradiation process had no effect on the chemical and physical qualities such as, fatty acid composition, peroxide value, iodine value specification number, TBA value and color of oil extracted from peanut seeds. On the contrary, the peroxide, acidity and TBA values of the peanut oil were decreased due to storage time (Al-Bachir, 2015/c).

4.5.5. Faba Bean Seeds

Our study indicate that ionizing irradiation (up to 300 Gy) could be an alternative to chemical fumigants for disinfestations and/or quarantine treatment of faba bean seeds infested with Bruchus dentipes Baudi. A dose of 90 Gy applied to faba bean seeds when the best population is still in the larval stage, during the first 3 months after harvest, is suggested. To minimize losses in seed quality, irradiation treatment should be done as early as possible after harvest (Mansour & Al-Bachir, 1995).

4.6. Decontamination of Medical Herbs and Spices

4.6.1. Licorice Root

Gamma irradiation reduced the counts of microorganisms, D10 of total count was about 2 KGy. The viscosity of suspension of irradiated roots (from 5 to 20 kGy) were significantly lower than those of non-irradiated samples. Also mineral charges (Na, Ca and K) and glycyrrhetinic acid concentration in juice produced from irradiated roots were lower than non-irradiated ones. Sensory evaluation indicated that no significant differences (P> 0.05) were found between juice produced from irradiated and unirradiated roots in color, taste, and odor (Al-Bachir and Lahham, 2004; Al-Bachir & Zeino, 2005). Total microbial count of licorice roots powder (control sample), including coliform, E. coli, and Klabsala spp. were relatively high. Irradiation reduced the total count by 4 logs and total coliform to negative (less than 1 log 10 CFU g-1). Klabsala Spp., E. coli, and Salmonella spp were not detected in irradiated sample (Al-Bachir & Al-Adawi, 2014/a; 2014/b). Similar finding showed that gamma irradiation with doses of 5, 10, 15 and 20 kGy had real effect on microbial load of licorice root products. D10 of total count and Klebsiella spp. Were about 1.4 and 0.7 KGy respectively (Al-Bachir et al., 2004).

4.6.2. Anise Seed

Gamma irradiation (from 5 to 20 kGy) reduced the aerobic plate counts of aniseed. However, doses greater than 10 kGy reduced aerobic population to less than 10 aerobic bacteria per gram. Immediately after irradiation, the total dissolved solids in extract of irradiated seeds were higher than those of un-irradiated ones. The total dissolved matter in extract of irradiated and un-irradiated seeds increased after 6 and 12 months of storage. There were no significant differences in inorganic dissolved solids between the water extract of irradiated and un-irradiated aniseeds. Sensory evaluation indicated that gamma irradiation improved sensory characteristics of aniseed water extract tested immediately after irradiation; however, after 12 months of storage, no significant differences (P> 0.05) were found in color, taste or flavor between extract of irradiated and un-irradiated seeds (Al-Bachir, 2007/a).

4.6.3. Chamomile Plant

Control samples of chamomile exhibited rather high microbiological contamination, exceeded the levels of 1.0 X 104 CFU g-1 reported by national and international authorities as the maximum permissible total count level. Irradiation with gamma ray was found to cause reduction in microbial load proportionate to the dose delivered. The dose of 10 kGy and 20 kGy significantly (p>0.05) reduced the total bacterial by 2 and 5 log cycle, respectively (Al-Bachir, 2015/b). Irradiation treatment did not affect significantly the dry weight yield. The viscosity increased in the extract of samples treated with 20 kGy. However, both irradiation doses (10 and 20 kGy) significantly increased the pH value, Mg concentration and L* value of color (lightness), and decrease the b* value of color (yellowness), but sensory qualities of all the chamomile powders samples were not significantly different depending on irradiation types and doses (Al-Bachir, 2014/a).

4.6.4. Spices and Packaging Materials

Gamma irradiation (with 10 kGy) decreased the microorganisms counts of spices, packaging materials and packed luncheon and increased the shelf-life of packaged luncheon products. No major differences in moisture, protein, fat, pH value, total acidity, lipid peroxide and volatile basic nitrogen were observed due to irradiation. Sensory evaluation showed that all the combination of treated luncheon were acceptable regarding sensory quality. However, the taste, odor, appearance and texture score of irradiated packaged luncheon were significantly lower than those of non-irradiated samples (Al-Bachir, 2005).

4.7. Other Advantages of Food Irradiation

4.7.1. Olive Fruits

The results showed that gamma irradiation (1, 2 and 3 kGy) increased the total and inorganic dissolved solid, Na, and K in washing wastewater, and in brine throughout de-bittering and storage periods. Gamma irradiation had an effect on EC and pH values of washing wastewater and brine (Al-Bachir, 2001; 2003).

Finally, the economic feasibility study of onion and potato irradiation in Syria was done (Al-Bachir et al., 1993).

4.8. Food Irradiation Legislation

Regulations for food irradiation in Syria were put in place in 1986 with a maximum allowable dose of 10 kGy. The authorized application of food irradiation for human consumption in Syria are: chicken (with up to 7 kGy for elimination of pathogens), fish and fish products (with up to 1 kGy for disinfestations of drayed products and up to 2.2 kGy for decontamination), cocoa (with up to 1 kGy for disinfestations and up to 5 kGy for decontamination) beans, condiments, dates, cereals and rice (with medium dos of 1 kGy for disinfestations), fish, dried fish products, mango (with up to 1 kGy for disinfestations and shelf-life extension), Strawberry (with up to 3 kGy for shelf-life extension) babaia (with medium dos of 1 kGy for disinfestations, improving the quality and delayed ripening), onions and potatoes (with up to 1.5 kGy for sprout inhibition), and spices herbs drayed fruits and vegetables (with up to 1 kGy for disinfestations and up to 10 kGy for decontamination). In 2000, we interpreted and introduced the ISO 15554 entitled: (Standard practice for dissymmetry in gamma irradiation facilities for food processing), which was adopted by national authorities. Also, at 2002, we interpreted and introduced the ISO 15562 entitled: (Standard practice for dosimetry in electron and bremsstrahlung irradiation facilities for food processing), which is waiting to adopting by national authorities. Licorice root is one of several food groups approved for irradiation in Syria for microbial control, and similarly, herbs are cleared up to 30 kGy in different countries (IAEA, 2008; SASMO, 2010).

4.9. Authorization of Food Irradiation Facilities

The radiation technology department in Syrian Atomic Energy Commission (SAEC) has a multipurpose pilot scale facility (ROBO, Russia) which about 240 kCui 60Co, and linear electron accelerator facility (D-EPS-T30-30-002V, VIVARAD, France) (beam energy 3 MeV (variable) and beam power 100 kW), which are used for pilot and semi- commercial irradiation of food, and about 2000 metric tons of food are irradiated yearly.

5.10. Social Feasibility for Food Irradiation

No studies or tests ever been conducted in Syria, to assess the acceptance or refusal of the irradiated foodstuffs. Local newspapers quote the subject concerning food irradiation from the international bulletins and publication such as FAO, WHO, and IAE A positive in general. However, in Syria there is no anti food irradiation group, and in general people believe in science results, therefore the Syrian consumers accept irradiated food.

Conclusion

In conclusion, this program demonstrates that the used doses of gamma irradiation causing significant reduction of loss, spoilage and microbial load leading to shelf-life extension of locally food products, and could maintain the safety and quality, without adversity effect of nutrition value, chemical and sensorial characteristics of its products. Food irradiation in Syria regulated legally since 1986 with a maximum allowable dose of 10 kGy (according to the codex general standard for irradiated food). Also, similarly herbs and spices are cleared up to 30 kGy. Accordingly, in the recent years, food irradiated is applied at commercial scale.

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