International journal of Advanced Biological and Biomedical Research
Available online at http:www.ijabbr.com
Volume 7, Issue 1 (2019) pp. 19-29

Review Article

Effects of using radiation processing in nutrition science and their restriction: a review

Mohsen Zarei

M.sc. Student of Animal Sciences, Faculty of Agriculture Razi University, Kermanshah, Iran
*Corresponding Author E-mail: m.zarei@pgs.razi.ac.ir

Received: 17 October 2018, Revised: 26 November 2018, Accepted: 12 December 2018

ABSTRACT

Isotopic and nuclear techniques play an important role in food and agriculture, health and industry. In the agricultural sciences and food technology sectors, recent research has elucidated the new potential application of radiation for microbial decontamination, food preservation, improve the nutritional quality of foods and effectively utilise its potential as human food or animal feed. The information presented will help researchers to identify techniques of relevance to them. Simplification of some of these techniques must be addressed so that they can be used more widely, especially in developing countries. This review suggest that a key challenge for the future is to use these techniques for improving efficiency of livestock production and decreasing environmental pollution.

Key words: Isotopic, Radiation processing, Nuclear techniques, Nutrition science.

Introduction

Research on the basic interaction of radiation with biological systems has contributed to human society through various applications in medicine, agriculture, pharmaceuticals and in other technological developments. In our world we faced to many restrictions in human and animal nutrition. In many cases we want to improve food or feed quality because high output or healthy body are required. For example Consumption of natural, fresh plant produce rich in phytochemicals and antioxidants has been reported to overcome some of the degenerative diseases that affect humans. In other hand a serious problem with plants is microbial contamination which affects health and has economic impacts. Therefore, decontamination of plant materials is important to increase the safety of medicinal plants. The current century has witnessed innovations and techniques that have been introduced and explored in the field of food preservation in human study. These innovations are a result of the ever-increasing demand from consumers all over the world for high quality foods, with major emphasis placed on quality and safety attributes. However, improper processing, handling, and long-term storage of produce might result in minimal availability of the health-promoting compounds. Food irradiation as a physical method for preservation has proved its efficacy over other common means of preservation, and is known to retain the quality of food and agricultural commodities. One of the main demands consumers make is for minimally processed, high nutrition/low energy natural foods with no or minimal chemical preservatives. medicinal plants can be decontaminated using heat, fumigation (ethylene oxide; ETO) and irradiation. Heat is not suitable for heat sensitive products. ETO is prohibited in many countries such as Japan and some European countries because it reacts with organic components leaving harmful residues. (Chmielewski & Migdal, 2005). The sources for ionizing radiation used to decontaminate microorganisms are high-energy electrons (electron beam; E-beam), X-rays or gamma rays (γ-rays). Likewise consumption of some animal feed and industrial by-products, especially its protein and energy, are less digestible than other cereals for human and monogastric animals (Chen *et al*., 1995; Fombang, Taylor, Mbofung, & Minnaar, 2005; Kondos & Foale, 1983), because of anti-nutritional factors such as tannins and phytic acid. Removal of these undesirable components is essential to improve the nutritional quality of foods and effectively utilise its potential as human food or animal feed. Food processing by employing radiation is well established as a physical, non-thermal mode of food preservation (cold-pasteurization) that processes foods at or nearly at ambient temperature. Irradiation of food products causes minimal modification in the flavor, color, nutrients, taste, and other quality attributes of food. However, the levels of modification (in flavor, color nutrients, taste etc.) might vary depending on the basic raw material used, irradiation dose delivered, and on the type of radiation source employed (gamma, X-ray, UV, electron beam) (Bhat & Sridhar, 2008; Bhat, Sridhar, & Yokotani, 2007; Mexis, Badeka, Chouliara, Riganakos, & Kontominas, 2009). Reports are available showing that ionizing radiation of food commodities, in the form of gamma rays or electron beams, is effective in overcoming quarantine barriers in international trade, as a mode of decontamination, disinfestation, and for improving nutritional attributes and shelf life (Hong *et al*., 2008; Lacroix & Ouattara, 2000; Teets, Sundararaman, & Were, 2008). During the last decade, several new nuclear techniques have emerged and also new uses of several old isotopic and nuclear techniques have been put forwarded. The purpose of this paper is to highlight the nuclear techniques that are being used in the field of food technology and nutrition science.

Radiation processing

Nuclear and related biotechnological techniques have played, and continue to play, a significant role in improving livestock productivity. In the past four decades, a vast knowledge has been accumulated on the chemical and biological effects of ionizing irradiation, which has contributed to promote its utilization (Diehl and Josephson, 1994; Olsen, 1998; Radomyski *et al*., 1994). The chemical changes resulting from the irradiation of proteins food have been the subject of considerable study (Delincee, 1983; Elias and Cohen, 1997; WHO, 1999). These studies demonstrated both fragmentation and aggregation of food proteins. Application of ionizing radiation treatment of foods on an industrial scale started at the beginning of the 1980s after the joint FAO/IAEA/WHO expert committee accepted the application of a 10 kGy overall average dose for foods (WHO, 1981). Also in 1981, the U.S. Food and Drug Administration (FDA) concluded that food irradiated at 50 kGy or less can be considered safe for human consumption (FDA, 1981). However, gamma irradiation of most human foods is prohibited in many countries. Most other countries that permit food irradiation also require labeling.

Isotopic methods

Isotopic techniques are used in many animal nutrition experiment for example these Isotopic methods have an important role in quantifying the supply of microbial protein post-ruminally to ruminants and in determining the true digestibility of feed proteins in monogastrics. Antinutritional factors such as tannins and saponins present in some feed resources can decrease nutrient uptake and cause toxicity when consumed at high levels. Isotope-based methods for quantifying some antinutrients are highly specific and sensitive. This method have many application such as microbial protein production in ruminants/ Energy availability from a feed in the rumen/ Determination of tannin level and activity/ Determination of saponins and other anti-protozoal compounds True protein digestibility in pigs/ Radioimmunoassays in animal nutrition-reproduction interactions and in food Safety/ Energy expenditure and body composition and etc.

Non-isotopic nuclear techniques

Gamma irradiation for enhancing nutrient availability

Several novel alternative plants are available that are good sources of protein, carbohydrate and other nutrients for use in livestock diets. But, these unconventional feed resources contain substantial amounts of plant secondary metabolites, which could have both adverse and beneficial effects depending on the level and nature of the plant secondary metabolites. The plant secondary metabolites that are found commonly in these feed resources are: protease inhibitors, tannins, saponins, lectins, phytate, oxalates and non-starch polysaccharides (Makkar and Becker, 1999; Francis *et al*., 2001). At high levels of plant secondary metabolites, the bioavailability of nutrients decreases. Several physical and chemical approaches have been used to remove plant secondary metabolites or inactivate their adverse activities. Ionisation radiation treatment could also be a possible method for inactivating these compounds. Gamma irradiation levels of up to 10 kGy have been found to be effective for inactivating antinutrients such as protease inhibitors, lectin, phytic acid, non-starch polysac-charides and oligosaccharides without altering the nutritional value of food/feed. Higher levels of irradiation, up to 600 kGy can be used to improve rumen degradability of dry matter and crude fibre in crop residues (Siddhuraju *et al*., 2002). Commercially available soyameal, widely used in livestock feeds, is generally steam treated to make it safe for livestock feeding. This heat treatment inactivates protease inhibitors and lectin present in soyameal. It would be interesting to compare the economics of soyameal treatment by steam and irradiation treatments and the industrial feasibility of using the latter.

Mutation breeding for producing feeds of desired traits

Induced mutations with gamma radiation, electron beam and fast neutrons produce random changes in the nuclearDNAor cytoplasmic organelles. These chromosomal or genomic mutations can be useful to plant breeders for selecting useful mutants (Ahloowalia *et al*., 2004) of forage plants.

Advanced nuclear techniques and their novel applications

Body and carcass composition can also be determined using another nuclear technique, dual energy X-ray absorptionmetry (Marcoux *et al*., 2003; Mitchell *et al*., 2003; Suster *et al*., 2004). This technique is based on a three-compartment model that divides the body into total body mineral, fat-free soft mass and fat tissue mass. The dual energy X-ray absorptionmetry uses a whole body scanner that has two dose X-rays at different sources that read bone and soft tissue mass simultaneously. It involves a small amount of radiation (0.6 mrems) and its use in pregnant animals requires careful evaluation; otherwise, it is safe and non-invasive. The computer tomography and magnetic resonance spectroscopy-based techniques have also been used for assessment of body composition studies (Kamba *et al*., 2001; Tylavsky *et al*., 2003). These techniques have largely been used in humans or in small animals for determining carcass composition, carcass value, and muscularity: for example, rabbits (Milisits *et al*., 2003) and fish (Hancz *et al*., 2003); birds such as chicken (Andrassy-Baka *et al*., 2003) and turkey (Brenoe andKolstad, 2000); pigs (Kolstad andVangen, 1996; Dunshea *et al*., 2003); lambs (Junkuszew and Ringdorfer, 2005) and sheep (Jones *et al*., 2004), but there is a need to validate them for large ruminants and to identify the investigations for which these methods have comparative advantages over other methods that require less capital and expertise. These techniques have many other potential applications, for example the use of hormonal (*e.g.*, use of somatotropin) and nutritional manipulations on body composition and meat quality. These non-invasive techniques provide new opportunities for animal breeders to determine body composition and slaughter value of live farm animals used for meat production, and to improve carcass composition and muscularity amongst the breeding objectives of their breeding programmes. In the last decades, high energy ions from accelerators and high quality neutron beams from reactors have been used in the analysis of the composition and structure of materials. Recently, electrostatic accelerators have evolved into specialized tools for accelerator mass spectrometry and ion beam analysis techniques. Accelerator mass spectrometry has applications in studies where measurement of long lived radionuclides such as 14C, tritium is required at isotope sensitivities as high as one part in 1015. This method utilizes a high energy isotope ratio mass spectrometer. Traditional isotope ratio mass spectrometers cannot differentiate ions having the same charge:mass ratio, but by accelerating the ions to MeV energy levels, accelerator mass spectrometry can distinguish ions with the same charge:mass ratio by measuring differences in energy loss inside the detector. This method eliminates the decay counting efficiencies of radionuclide measurement. It increases measurement efficiency by directly counting the individual ions of the isotope being measured. As a result, this method enables rapid analysis with greater sensitivity using much smaller samples when compared to other techniques such as liquid scintillation counting. Similarly synchrotron accelerators/X-rays microprobes have very high sensitivities, which allow the microscopic properties of material to be investigated. Microstructural features with dimensions in the range 10–1000 °A in biological samples can be studied using neutron beams. The information obtained using these techniques could compliment those obtained from conventional techniques such as optical, electron microscope, and mass spectrometers (Tuniz, 2003). Proton microprobe systems such as proton induced X-ray emission and proton induced gamma ray emission provide simultaneous and non-destructive determination of elements. These methods permit direct analysis of solid samples (Kumar and Raju, 2003). Trace elements in biological samples have also been determined using thermal ionisation mass spectrometry and induced coupled plasma mass spectrometry (ICP-MS). Thermal ionization mass spectrometry was found to be more precise and accurate than ICP-MS (Turnlund and Keyes, 2002). Prompt-gamma neutron activation analysis is an established nuclear analytical technique with important applications in in vivo studies of human body composition. Neutron beams from radionuclide neutron sources or accelerators are used to irradiate sections of the animal body. Prompt-gamma rays, produced by neutron capture reactions with tissue elements, having distinct peaks for nitrogen, hydrogen, chlorine etc., are detected by appropriate gamma ray detectors. It has also been used on small animals, for example rabbits, rats, fowls (Stamatelatos *et al*., 2003), allowing studies on in vivo analysis of the major body compartments of protein, extra-cellular and intra-cellular space. In the last two decades, the development of energy dispersive X-ray fluorescence spectroscopy has been intense. Lately, impressive developments have been made in digital technology, detector systems, image processing and data analysis. These developments have extended the applicability of this technique by enabling construction of low cost, reliable and portable spectrophotometers for determination of hazardous and essential trace elements in biological samples (Bamford *et al*., 2004).The synchrotron radiation-based Fourier Transform Infrared microspectroscopy technique is capable of exploring the molecular chemistry within the microstructures of a biological tissue without destroying the inherent structures at ultraspatial resolutions within cellular dimensions. This technique has the potential to study the availability of nutrients to animals from feed resources. This technique could be used to produce an image of intensities and the distribution of the biological components such as protein, lipids, lignin, structural and non-structural carbohydrates and their ratios in the microstructure of the plant within cellular dimensions. This would enable the intrinsic feed structure to be defined chemically and a comparison of feeds to be made according to spectroscopic properties, functional groups, spatial distribution and chemical intensity. This information about the chemical makeup of the ultrastructure could be examined in light of the conventional nutritional parameters, for example rumen degradability, post-rumen degradability of nutrients, and used for prediction of nutritive value of feeds or accessibility of various enzymes for digestion of nutrients (Yu, 2004). 13C, 3H and 1H nuclear magnetic resonance, fast atom bombardment mass spectroscopy, and mass ionisation spectroscopy have been used for the analysis, characterization and structure elucidation of compounds in environmental, clinical and biological materials (Gamble *et al*., 1996; Bacon *et al*., 1999; Stobiecki and Makkar, 2004). These recent techniques have applications in nutritional, environmental, and toxicological investigations, especially in understanding complex pathways in biological systems.

Effects of radiation treatments on phytochemicals composition

Irradiation can influence the levels of antioxidants/phytochemicals and the capacity of a specific plant to produce them at different levels. It has been reported that under certain favorable conditions, the concentration of plant phytochemicals might be enhanced. These conditions include exposure to radiation sources, wounding, storage at low temperatures, and/or exposure to extreme temperatures (Zobel, 1997). In terms of exposure to radiation sources, this depends on the dose applied (usually low and medium doses have insignificant effects on antioxidants), the sensitivity of the antioxidant or the phytochemicals towards irradiation, and the effect of irradiation itself on other food constituents that might be responsible for the production and/or the accumulation of phytochemicals/antioxidants in the plant.

Effect of radiation on digestion

In animal nutrition studies different effect of gamma irradiation on the digestion were observed. For example Taghinejad-Roudbaneh *et al*. (2010) indicate that electron beam-irradiation of canola meal at dose of 45 kGy increases the rumen undegradable CP content of canola meal without negative effects on in vitro CP digestibility. However, electron beam -irradiation at doses of 15 and 30 kGy had no effects on ruminal protein degradability but improved digestible rumen undegradable protein of canola meal. This difference was because of the different dose of irradiation. In the another study shawrang *et al.* (2008) showed that gamma irradiation of canola meal (at doses of 25, 50 and 75 kGy) could alter its ruminal protein degradation characteristics by cross-linking of the polypeptide chains. This processing resulted in decrease (linear effect, $P < 0.001$) of ruminal protein degradation and increase (linear effect, $P < 0.001$) of intestinal protein digestibility Gamma-irradiation of SBM by cross-linking and aggregation of the polypeptide chains resulted in decrease of effective protein degradation in the rumen and increase of intestinal CP digestibility. Therefore, g-irradiation at doses equal or higher than 25 kGy can be used as a cross-linking agent to improve protein properties of supplements in ruminant nutrition. (shawrang *et al.*, 2007). Behgar *et al*. (2011) indicated that there was no effect of gamma irradiation on the in vitro digestion of the pistachio hull. Irradiation decreased the digestion rate of the pistachio hull at the dose of 40 kGy when compared to the control. Ghanbari *et al*. investigate comparison between effects of electron beam and gamma ray irradiations on ruminal crude protein and amino acid degradation kinetics, and in vitro digestibility of cottonseed meal. They showed that ionizing radiations of electron beam (EB) and GR had significant effects ($P < 0.05$) on CP and AA ruminal degradability characteristics of CSM. Effective ruminal degradability (ERD) of CP was lower in EB and Gamma-irradiation (GR) irradiated CSM ($P < 0.05$) than in unirradiated CSM. GR and EB treatments had the same effects on ERD decreasing of CP (P40.05). Irradiation processing caused decrement in AA degradation after 16 h of ruminal incubation ($P < 0.05$). EB irradiation was more effective than GR irradiation in lessening the ruminal degradability of AA ($P < 0.05$). EB and GR treatments at a dose of 75 kGy increased in vitro digestibility of CSM numerically. This study showed that EB could cause CP and AA bypass rumen as well as GR.

Conclusions

Isotopic and nuclear techniques are important tools in animal production research. The principal advantage of stable isotopes over other tracers is that they are not radioactive and thus provide the ease of handling and transport. On the other hand, special precautions and laboratory conditions are required for using radio-isotopes, which could discourage some workers in using them. Although isotopic and nuclear techniques might be more expensive compared to the conventional techniques and probably as expensive as some of the molecular techniques in use, these techniques offer comparative advantages of high specificity, sensitivity and accuracy over non-nuclear techniques. Because of these advantages, isotopic and nuclear techniques help generate accurate data and provide unequivocal answers.These techniques coupled to the use of molecular tools have the potential to revolutionize the understanding of complex biological processes and make the livestock an efficient entity – highly productive with minimum wasteful discharges to the environment - helping to achieve sustainability of the global food chain. It is clear from the available literature and evidence that food irradiation is a promising preservation method with certain advantages. The main advantage is the short processing time, in addition to the minor effect irradiation has on the antioxidants in plant produce (with some limited exceptions, such as vitamin C).

References

Ahloowalia, BS, Maluszynski, M, Nichterlein, K, (2004). Global impact of mutation-derived varieties. Euphytica 135:187–204.

Andrassy-Baka, G, Romvari, R, Milisits, G, Suto, Z, Szabo, A, Locsmandi, L, horn P, (2003) Non-invasive body composition measurement of broiler chickens between 4–18 weeks of age by computer tomography. Archiv fur Tierzucht. forschungsinstitut fur die Biologie landwirtschaftlicher Nutztiere, Dummerstorf, germany 46(6):585–595.

Bacon, JR, Crain, JS, Vaeck, LV, Williams, JD, (1999). Atomic mass spectrometry. *J Anal At Spectrom*, 14:1633–1659.

Bamford, SA, Wegrzynek, D, Chinea-Cano, E, Markowicz, A, (2004). application of X-ray fluorescence techniques for the determination of hazardous and essential trace elements in environmental and biological materials. *Nukleonika*, 49:87–95.

Behgar M, Ghasemi S, Naserian A, Borzoie A, Fatollahi H, (2011). Gamma radiation effects on phenolics, antioxidants activity and in vitro digestion of pistachio (Pistachia vera) *hull Radiat Phys Chem*, 80:963-967.

Bhat, R, Sridhar, KR, (2008). Nutritional quality evaluation of electron beam irradiated (Nelumbo nucifera) *seeds. Food Chemistry*, 107:174e184.

Bhat, R, Sridhar, KR, Yokotani, KT (2007). Effect of ionizing radiation on antinutritional features of velvet bean seeds (Mucuna pruriens). *Food Chemistry*, 103:860e-866.

Brenoe, UT, Kolstad, K, (2000). Body composition and development measured repeatedly by computer tomography during growth in two types of turkeys. *Poult sci*, 79:546–552.

Chen, KH, Huber, JT, Simas, J, Theurer, CB, Yu, P, Chan, SC, et al. (1995). Effect of enzyme treatment or steam flaking of sorghum grain on lactation and digestion in dairy cows. *Journal of Dairy Science*, 78:1721–1727.

Chmielewski, AG, Migdal, W, (2005). Radiation decontamination of herbs and species. *Nukleonika*, 50:179-184.

Delincee, H,1983.Recent advances in radiation chemistry of proteins.In:Elias, PS,cohen, AJ, (Eds.), Recent Advances in Food Irradiation. Elsevier Biomedical press, Amsterdam, pp. 129–147.

Diehl, JF, Josephson, ES, (1994). Assessment of the wholesomeness of irradiated food (a review). *Acta Aliment*., 23:195–214.

Dunshea, FR, Suster, D, Kerton, DJ, Leury, BJ, 2003. Exogenous porcine somatotropin administered to neonatal pigs at high doses can alter lifetime fat but not lean tissue deposition. *Br J Nutr*, 89:795–801.

Elias, PS, Cohen, AJ, (1997). Radiation Chemistry of Major Food Components. elsevier Scientific, Amsterdam.

Fombang, EN, Taylor, JRN, Mbofung, CMF, Minnaar, A, (2005). Use of c-irradiation to alleviate the poor protein digestibility of sorghum porridge. *Food chemistry*, 91:695–703.

Food and Drug Administration, (1981). Irradiation in the production, processing, and handling of food; final rule. 21 CFR Part 179. Federal Register 51:13376–13399.

Francis, G, Makkar, HPS, Becker, K, (2001). Antinutritional factors present in plant-derived alternate fish feed ingredients and their effects in fish. Aquaculture 199:197–227.

Gamble, GR, Akin, DE, Makkar, HPS, Becker, K, (1996). Biological degradation of tannins in Sericea Lespedeza by the white rot fungi Ceriporiopsisw subvermispora and Cyathus stercoreus analyzed by solid state 13C NMR spectroscopy. *Appl Environ Microbiol*, 62:3600–3604.

Hancz, C, Romvari, R, Szabo, A, Molnar, T, Magyary, I, Horn, P, (2003). measurement of total body composition changes of common carp by computer tomography. *Aquacult Res*, 34(12):991–997.

Hong, YH, Park, JY, Park, JH, Chung, MS, Kwon, KS, Chung, K, et al. (2008). Inactivation of Enterobacter sakazakii, Bacillus cereus, and Salmonella typhimurium in powdered weaning food by electron-beam irradiation. *Radiation physics and Chemistry*, 77:1097e-1100.

Jones, HE, Lewis, RM, Young, MJ, Simm, G, (2004). Genetic parameters for carcass composition and muscularity in sheep measured by X-ray computer tomography, ultrasound and dissection. *Livestock Prod Sci*, 90(2/3):167–179.

Junkuszew, A, Ringdorfer, F, (2005). Computer tomography and ultrasound measurement as methods for prediction of the body composition of lambs. *Small rumin Res*, 56(1–3):121–125.

Kamba, M, Kimura, K, Koda, M, Ogawa, T, (2001). Proton magnetic resonance spectroscopy for assessment of human body composition. *Am J Clin Nutr*, 73:172–176.

Kolstad, K, Vangen, O, (1996). Breed differences in maintenance requirements of growing pigs when accounting for changes in body composition. *Livestock Prod sci*, 47:23–32.

Kondos, AC, Foale, MA, (1983). Comparison of the nutritional value of low and medium tannin sorghum grains for pigs. *Animal Feed Science technology*, 8:85–90.

Kumar, S, Raju, VS, (2003). Application of nuclear microprobe techniques in the analysis of biological materials. In: International Conference on Isotopic and nuclear Analytical Techniques for Health and Environment, IAEA-CN-103/039. IAEA, Vienna, Austria.

Lacroix, M, Ouattara, B, (2000). Combined industrial processes with irradiation to assure innocuity and preservation of food products e a review. *Food Research international*, 33:719e-724.

Makkar, HPS., Becker, K, (1999). Plant toxins and detoxification methods to improve feed quality of tropical seeds. *Asian-Australian J Anim Sci*, 12:467–480.

Marcoux, M, Bernier, JF, Pomar, C, (2003). Estimation of Canadian and european lean yields and composition of pig carcasses by dual-energy X-ray absorptiometry. *meat Sci*, 63:359–365.

Mexis, SF, Badeka, AV, Chouliara, E, Riganakos, KA, Kontominas, MG, (2009). Effect of g-irradiation on the physico-chemical and sensory properties of raw unpeeled almond kernels (Prunus dulcis). *Innovative Food Science and emerging Technologies*, 10:87e-92

Milisits, G, Levai, A, Andrassy-Baka, G, Romvari, R, (2003). In vivo examination of fat deposition in growing rabbits selected for high and low body fat content. agriculturae Conspectus Scientificus (Poljoprivredna Znanstvena Smotra) 68:145–149.

Mitchell, AD, Scholz, AM, Pursel, VG, (2003). Prediction of pork carcass composition based on cross-sectional region analysis of dual energy X-ray absorptiometry (DXA) scans. *Meat Sci*, 63:265–271.

Olsen, D, (1998). Irradiation of food. Scientific status summary. *Food Technol*., 52:56–62.

Radomyski, T, Murano, EA, Olson, DG, Murano, PS, (1994). Elimination of pathogens of significance in food by low-dose irradiation: a review. *J Food protect*, 57:73–86.

Shawrang, P, Nikkhah, A, Zare-Shahneh, A, Sadeghi, AA, Raisali, G, moradi-Shahrebabak, M, (2008). Effects of gamma irradiation on chemical composition and ruminal protein degradation of canola meal. *Radiation Physics chemistry*, 77:918–922.

Shawrang, P, Nikkhah, A, Zare-Shahneh, A, Sadeghi, AA, Raisali, G, moradi-Shahrebabak, M, (2007). Effects of gamma irradiation on protein degradation of soybean meal. *Animal Feed Science Technology*, 134:140–151.

Siddhuraju, P, Makkar, HPS., Becker, K, (2002). The effect of ionising radiation on antinutritional factors and the nutritional value of plant materials with reference to human and animal food: a review. *Food Chem*, 78:187–205.

Stobiecki, M, Makkar, HPS, (2004). Recent advances in analytical methods for identification and quantification of phenolic compounds. In: Muzquiz, M, Hill, GD, Burbano, C, Cuadrado, C, Pedrosa, MM, (Eds.), Recent Advances of research in Antinutritional Factors in Legume Seeds and Oilseeds. Wageningen press, The Netherlands, pp. 11–28.

Suster, D, Leury, BJ, Hofmeyr, CD, D'Souza, DN, Dunshea, FR, (2004). The accuracy of dual energy X-ray absorptiometry (DXA), weight and P2 back fat to predict half-carcass and primal-cut composition in pigs within and across research experiments. *Aust J Agric Res*, 55:973–982.

Taghinejad-Roudbaneh M, Ebrahimi SR, Azizi S, Shawrangm P, (2010). effects of electron beam irradiation on chemical composition, antinutritional factors, ruminal degradation and in vitro protein digestibility of canola meal, *radiat Phys chem*, 79:1264-1269.

Tamatelatos, IE, Kasvikli, K, Green, S, Gainey, M, Kalef-Ezra, J, Beddoe, A, (2003). International Conference on Isotopic and Nuclear Analytical Techniques for health and Environment IAEA-CN-103/074. IAEA, Vienna, Austria.

Teets, AS, Sundararaman, M, Were, LM, (2008). Electron beam irradiated almond skin powder inhibition of lipid oxidation in coked salted ground chicken breast. *Food Chemistry*, 111:934e-941.

Tuniz, C, (2003). Advanced nuclear techniques for health and environment. In: international Conference on Isotopic and Nuclear Analytical Techniques for Health and Environment, IAEA-CN-103/123. IAEA, Vienna, Austria.

Turnlund, JR, Keyes, WR, (2002). Isotope ratios of trace elements in samples from human nutrition studies determined by TIMS and ICP-MS: precision and accuracy compared. *Food Nutr Bullet*, 23:129–132.

Tylavsky, FA, Lohman, TG, Dockrell, M, Lang, T, Schoeller, DA, Wan, JY, fuerst, T, Cauley, JA, Nevitt, M, Harris, TB, (2003). Comparison of the effectiveness of 2 dual-energy X-ray absorptiometers with that of total body water and computed tomography in assessing changes in body composition during weight change. *Am J Clin Nutr*, 77:356–363.

WHO, 1981.Wholesomeness of irradiated food, Report ofa joint FAO/IAEA/WHO expert Committee. WHOTechnical Report Series 659, Geneva.

WHO, (1999). High-dose irradiation: wholesomeness of food irradiated with doses above 10 kGy, Report of a joint FAO/IAEA/WHO study group. WHO Technical report Series 890, World Health Organization, Geneva.

Yu, P, (2004). Applications of advances synchrotron radiation-based Fourier transform infrared (SR-FTIR) microspectroscopy to animal nutrition and feed science: a novel *approach Br J Nutr*, 92:869–885.

Zobel, AM, (1997). Coumarins in fruit and vegetables. In Toma´s-barbera´n FA, Robbins RJ, (Eds.), Photochemistry of fruit and vegetables (pp. 173e-204). Oxford, UK: Clanderon Press.

How to cite this article: Mohsen Zarei, Effects of using radiation processing in nutrition science and their restriction: a review. *International Journal of Advanced Biological and Biomedical Research*, 2019, 7(1), 19-29. http://www.ijabbr.com/article_33662.html