



Review Article

Radiation, Plant Proteins and Sustainability

Patricia Y. I. Takinami, Vanessa B. Uehara, Bruna S. Teixeira, Nelida L. del Mastro*

Center of Radiation Technology, Nuclear and Energy Research Institute, IPEN-CNEN/SP, Sao Paulo, Brazil

Email address:

nlmastro@ipen.br (N. L. d. Mastro)

*Corresponding author

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Abstract: The best sources of proteins for human nourishment come from animal origin. But, conventional meat production involves not only animal suffering but, also, prodigious amounts of water use and significant global warming gases produced per pound of meat. Sustainable plant proteins are good for human beings, as well as, for the planet. Specific natural resources like pulses, in particular, represent a very environmentally friendly and sustainable food source and are rich of high-quality and cost-effective protein ingredients. Ionizing radiation may contribute to food safety and food security. Also, irradiation could serve as an additional food processing method for inactivation or removal of certain antinutritional factors. In this work, the benefits of plant protein sources, particularly pulse protein foods, are highlighted. Moreover, a survey on database since 1970, about the relation among pulses, plant protein and ionizing radiation has been presented. Highlights: Pulses represent a very environmentally friendly and sustainable food source. Pulses are rich sources of high quality and cost effective protein ingredients. Ionizing radiation may contribute to food safety and food security and it could be applied for inactivation or removal of certain antinutritional factors.

Keywords: Pulses, Plant Protein, Ionizing Radiation, Antinutritional Factors

1. Introduction

Although the best sources of proteins come from animal origin, livestock farming incurs large and varied environmental burdens, dominated by beef. Replacing beef with efficient alternatives is, thus, potentially beneficial. To limit environmental impacts and improve agricultural sustainability, a next green movement, based on plant biology, is foreseen (Jez et al., 2016).

Plant-based diets have been associated with a reduced risk of obesity, diabetes (Satija et al., 2016), heart disease and some types of cancer, as well as increased longevity. Current evidences support the idea that the risk of cardiovascular diseases (CVD) may be reduced by a dietary pattern that provides plenty of plant sources of protein (Richter, Skulas-Ray, Champagne & Kris-Etherton, 2015; Marsh, Zeuschner & Saunders, 2012). Vegetarian diets are typically lower in fat, particularly saturated fat, and higher in dietary fiber.

Eshel et al. (2016) have shown that protein, mass and

energy from plant-based replacements to beef, in the USA diet, are readily achievable and can reduce, significantly, the resource use, improving the diet related health outcome. To have enough protein in the diet is possible without meat, dairy, eggs, poultry, fish, or anything else derived from an animal, provided a proper mixture of plant protein may be ingested in the diet. When legumes such as beans, lentils and peanuts are combined with grains like wheat, rice and corn, a complete protein is obtained. Nevertheless, the presence of secondary plant compounds in plant foods, such as tannins and hydrolysable phenolics, may interfere with the level of protein and fiber contents and should be taken into consideration.

Today, consumers seem to have an increasing interest in plant-based food. A recent American survey shows that one-quarter of meal preparers are regularly making more meatless meals and 61% declare that they serve beans/lentils as an alternative to a meat-based meal (Sloan, 2016).

From the point of view of sustainability, one example of

plant-based food is chickpea, the third most widely grown legume crop in the world, following soybean and bean, and it has the ability to capture and use atmospheric nitrogen, thus contributing to soil fertility.

Exposing materials to intense beams of gamma rays, electrons or neutrons may break molecular bonds and evolve new types of materials. Controlled amounts of beta particles, X-rays or gamma rays can be used to kill unwanted insects or microorganisms. This property is used for sterilizing hospital equipment, eradicating cancer cells, killing food pathogens and suppressing sprouting in vegetables. Ionizing radiation can be used as an effective intervention for post-harvest losses reduction; to provide higher crop production, eradicate pests and process the final food product to enhance its shelf life and make it safer for human consumption (Waltar, 2004). Also, ionizing radiation treatment could serve as a possible additional processing method for inactivation or removal of certain antinutritional factors.

This article has been constructed as it follows: a section based on why pulses, source of vegetal protein, deserve to have a higher participation in our diet; then, a data survey about the presence of pulses and ionizing radiation on a database; in the sequence, a compilation of important contributions that irradiation may provide, mainly on the inactivation of antinutritional factors.

2. Characteristics of Pulse Ingredients

Pulses are edible seeds of plants in the legume family, one of the few plant-based, non-allergenic proteins that include: beans, lentils, chickpeas and dry peas. They are nutritious, versatile, affordable and not new for mankind. Broad beans, chickpeas, fava beans, for instance, were already common in ancient Egypt with presence, also, in a large part of the Mediterranean lifestyle since then.

Pulse crops are cool season, annually grown legume crops, which are harvested for their seeds. Pulses represent a very environmentally friendly and sustainable food source and are rich sources of high-quality and cost-effective protein ingredients, high fiber, minerals (iron, zinc, phosphorous), containing high levels of B vitamins and folic acid. Pulse proteins can reproduce most or all of the functional properties of other food protein ingredients, depending upon the application. As they are gluten-free, non-allergenic and have low glycemic index, pulses can be included in gluten-free, vegetarian, diabetic and management weight diets.

The 2010 U.S. Dietary Guidelines for Americans recommended more frequent consumption of lentils, dry peas and beans. The 68th UN General Assembly declared 2016 the International Year of Pulses (IYP) (A/RES/68/231). To facilitate the implementation, the Food and Agriculture Organization of the United Nations (FAO) was nominated. The IYP 2016 aims to heighten public awareness of the nutritional benefits of pulses as part of sustainable food production, aiming at food security and nutrition. The Year is creating a unique opportunity to encourage connections throughout the food chain that would better apply pulse-based

proteins, increase global production of pulses, achieve better use of crop rotation, besides addressing the challenges in the trade of pulses.

Pulses grow by naturally producing their own fertilizer, using less renewable energy. They are invaluable agricultural commodities produced and imported in many regions of the world. Their nutritional characteristics have been associated with a reduction in the incidence of various cancers, HDL cholesterol, type-2 diabetes and heart disease (Roy, Boye & Simpson, 2010). They contain high amounts of lysine, leucine, aspartic acid, glutamic acid and arginine and provide well-balanced essential amino acids, when consumed with cereals and other foods rich in sulphur-containing amino acids and tryptophan. The protein content of most pulse legumes fall within the range of 17-30%. Apart from their nutritional properties, pulse proteins, also, possess functional properties that play an important role in food formulation and processing. Examples of such functional properties include solubility, water, fat binding capacity and foam. Various research studies indicate that some functional properties of pulse proteins may be comparable to those of other frequently used proteins, such as soy and whey. The functional properties of pulse proteins have been exploited in the preparation and development of products, such as bakery products, soups, extruded products and ready-to-eat snacks. The growing body of research on the health benefits, associated with the consumption of pulses, has increased interest in developing innovative technologies to expand the use of pulses in food products. At the same time, there are growing global food security challenges and protein malnutrition continues to be a problem in many countries around the world. Pulses, especially when blended with cereal proteins, may offer a promising alternative source for nutritional and functional proteins (Boye, Zare & Pletch, 2010).

Boye, Aksay, Roufik *et al.* (2010) made a comparison of the functional properties of pea, chickpea and lentil protein concentrates processed using ultrafiltration and isoelectric precipitation techniques. Yields for both processes on a protein basis ranged from 50.3% to 69.1% (w/w). All concentrates exhibited good functional properties. However, functional properties, such as solubility, water holding capacity and emulsifying properties, varied to some extent as a function of the type of pulse and manufacturing process. Nevertheless, the results highlighted the technological potential of pulse protein extracts for food industry.

3. Database Survey on Scientific Articles Published on Pulses and Ionizing Radiation

Any research on a database has the limitation of the arbitrary choice of keywords made by the authors and, very frequently, leads to paradoxes. Figure 1 presents the survey made on the Web of Science database, covering the number of articles published on plant protein and Figure 2, de number of articles on pulses, such as peas, beans, lentils or chickpeas, since 1970.

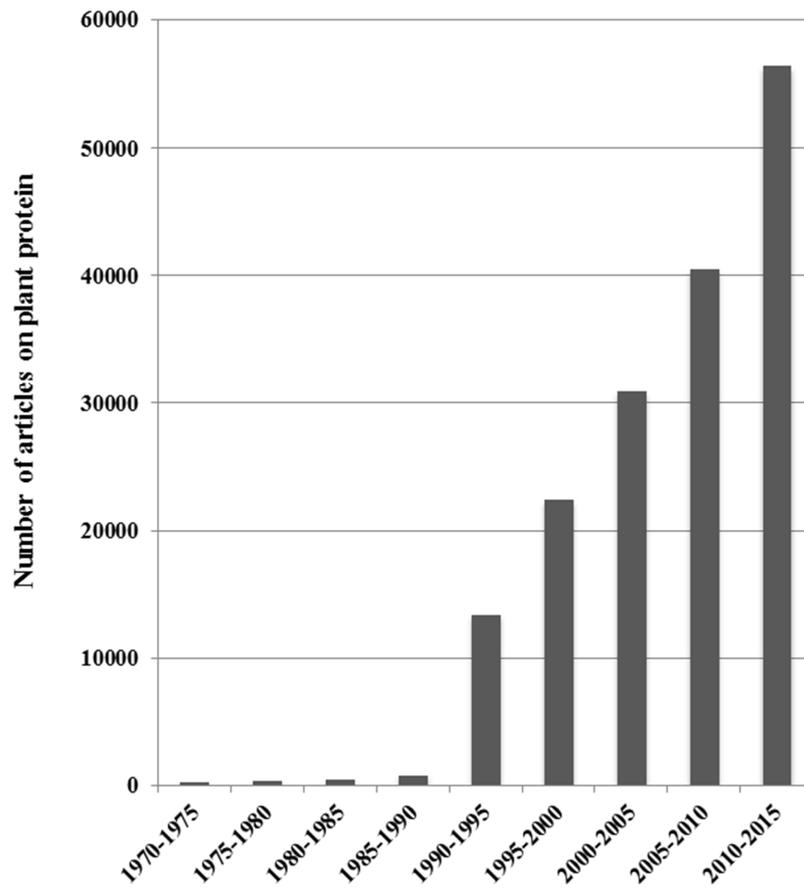


Figure 1. Survey on the Web of Science database, as for the number of articles published since 1970, when the tag employed was plant protein.

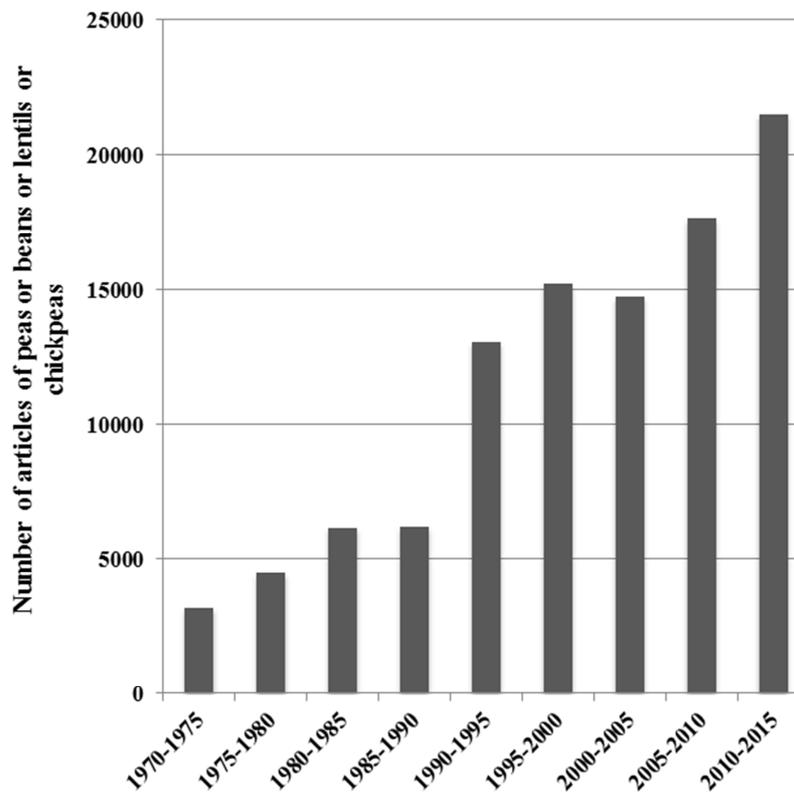


Figure 2. Survey on the Web of Science database, as for the number of articles published since 1970 when the tag employed was peas, beans, lentils or chickpeas.

It is possible to observe that in the 1990's, a remarkable and considerable increase of interest in researching this subject occurred, either as plant protein or peas, beans, lentils or chickpeas, in particular.

Figure 3 presents the survey of the number of articles published in the same period, using as tag just *ionizing radiation*. The interest in ionizing radiation research has increased in the last decades and the tendency has been, even, accentuated since the 1990's.

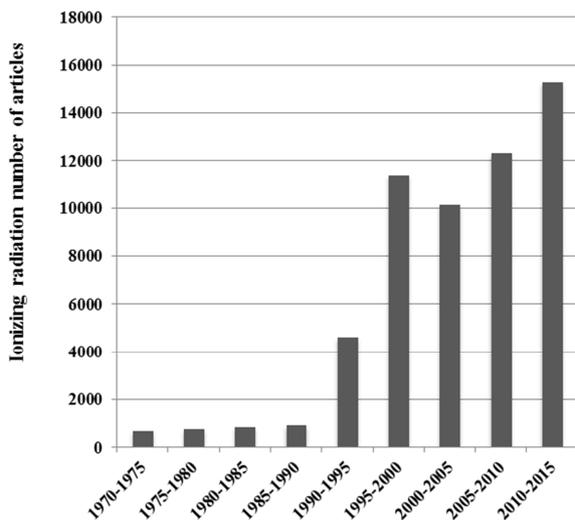


Figure 3. Survey on the Web of Science database in a number of articles that have been published since 1970, when the tag employed was ionizing radiation.

Figure 4 and Figure 5 present the results of a similar survey, but, crossing the tags *ionizing radiation + plant protein* and *ionizing radiation + pulses, such as peas, or beans or lentils or chickpeas*, respectively.

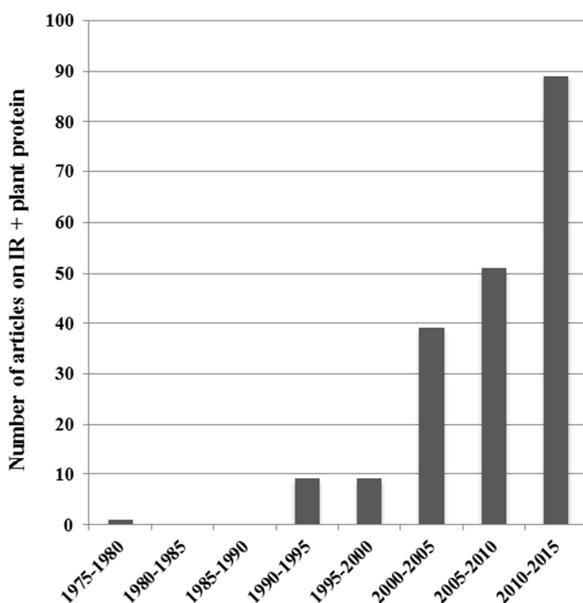


Figure 4. Survey on the Web of Science database, as to the number of articles published since 1970, when the tags employed were ionizing radiation + plant protein.

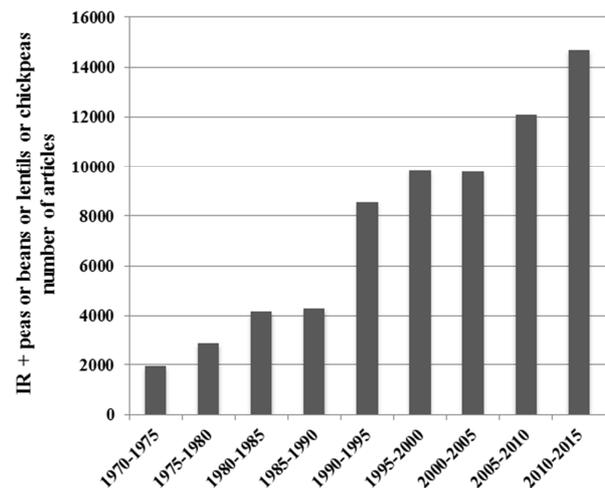


Figure 5. Survey on the Web of Science database, as for the number of articles published since 1970, when the tag employed was ionizing radiation + peas or beans or lentils or chickpeas.

Comparing the total published papers on ionizing radiation and the number of papers obtained, when crossing the 5 tags, it is possible to notice that most of them were, actually, dedicated to the effects on pulses.

4. Beneficial Action of Radiation on Pulses: Inactivation of Antinutritional Factors

The unit employed for radiation dose is the following: one gray (Gy), defined as the absorption of one joule of radiation energy per one kilogram of matter, in the International System of Units.

Begum *et al.* (2008) reported that ionizing radiation, as stress stimulator and coupled with somatic embryogenesis could be employed to build up desired variants of *Vigna radiata*, a protein-rich pulse. Induced mutagenesis through gamma radiation was tested in chickpea (cv. Amdoun) to improve resistance to the parasitic weed *Orobanche foetida*. Seeds of chickpea were exposed to increased doses up to 750 Gy. Germination rates and plant survival were scored 7 and 90 days after sowing, respectively. The 150 Gy dose was determined as the optimum dose limit, causing 50% reduction in the survival. The authors concluded that seed irradiation (LD 50) was efficient, in chickpea, to create variable initial material in mutation breeding of new resistant lines to *O. foetida* (Brahmi, Mabrouk, Charaabi & Belhadj, 2014).

Ionizing radiation affected the higher molecular weight seed storage chickpea proteins (Singh & Singh, 2015) and Melki, Mhamdi & Achouri (2011) described that a dose of 20 Gy was able to induce beneficial effects on chickpea, such as to enhance plant growth, root nodules and protein content of leaves and grains. A recent communication (Kumar *et al.*, 2016) reports that gamma rays, at low doses, stimulate the tolerance to salt stress in plants of pigeon pea (*Cajanus cajan* (L.) Millsp.

Radiation treatment could serve as a possible additional processing method for inactivation or removal of certain antinutritional factors (Abu-Tarboush, 1998; Siddhuraju, Makkar & Becker, 2002). The antinutritional factors in plants may be classified on the basis of their chemical structure, the specific actions they cause or their biosynthetic origin (Aletor, 1999; Soetan & Oyewole, 2009). They may be: proteins (such as lectins and protease inhibitors), which are sensitive to normal processing temperatures; other substances, which are stable or resistant to these temperatures, including, among many others, polyphenolic compounds (mainly condensed tannins), non-protein amino acids and galactomannan gums.

Pulses contain protein and non-protein antinutritional factors, which may cause deleterious effects on the host when the seeds or processed seeds are consumed raw. But, conversely, some studies have demonstrated that protein antinutritional compounds, such as lectins, protease inhibitors and the non-antinutritional component, angiotensin I-converting enzyme (ACE) inhibitor, may have beneficial properties. Lectins have been associated with the reduction of certain forms of cancer, activating innate defense mechanisms and managing obesity. Protease inhibitors, such as trypsin and chymotrypsin inhibitors, have demonstrated to reduce the incidence of certain cancers and, also, to have potent anti-inflammatory properties. Angiotensin I-converting enzyme (ACE) inhibitor has been associated with a reduction in hypertension (Roy, Boye & Simpson, 2010). This implies that antinutrients might not, always, be harmful even though they lack of nutritive value. Despite this fact, the balance between beneficial and hazardous effects of plant bioactives and antinutrients rely on their concentration, chemical structure, time of exposure and interaction with other dietary components. Hence, they may be considered as antinutritional factors with negative effects or non-nutritive compounds, with positive effects on health (Gemedé & Ratta, 2014).

Al-Kaisey, Alwan, Mohammad & Saeed, (2003) studied the effect of gamma irradiation on the level of antinutritional factors (trypsin inhibitor (TI), phytic acid and oligosaccharides) of broad bean. The seeds were subjected to gamma irradiation at 0, 2.5, 5, 7.5 and 10 kGy, respectively, using cobalt-60 gamma radiation. TI activity was reduced by 4.5%, 6.7%, 8.5% and 9.2%, at 2.5, 5, 7.5 and 10 kGy, respectively. Meanwhile, irradiation at 10.2, 12.3, 15.4 and 18.2 kGy reduced the phytic acid content. The flatulence causing oligosaccharides decreased, as the radiation dose increased. The chemical composition (protein, oil, ash and total carbohydrates) remained, almost, unchanged.

El-Niely (2007) studied the application of dose levels of 5, 7.5 and 10 kGy of ionizing radiation on nutritive characteristics of peas (*Pisum sativum* L), cowpeas (*Vigna unguiculata* L. Walp), lentils (*Lens culinaris* Med), kidney beans (*Phaseolus vulgaris* L), and chickpeas (*Cicer arietinum* L). Analyses included proximate composition, levels of antinutrients (phytic acid, tannins), available lysine (AL), in vitro protein digestibility (IVPD), and protein efficiency ratio (PER) in growing rats. The results showed that moisture, crude protein, crude fat, crude fiber and ash were unchanged

by the irradiation. Radiation processing reduced, significantly, ($p < 0.05$) the levels of phytic acid (PA), tannins (TN), and AL. IVPD, and PER were significantly enhanced in a dose-dependent manner, relative to unirradiated control samples, for all legumes. The data sets for each legume exhibited high correlation coefficients between radiation dose and PA, TN, AL, IVPD, and PER.

The impact of gamma irradiation on the antinutritional constituents of *Mucuna pruriens* seeds was assessed on exposing them to doses of 5.0, 7.5, 10, 15 and 30 kGy (Bhat, Sridhar & Tomita-Yokotani, 2007). There was significant dose-dependent increase in phenolics; tannin concentration did not differ significantly up to 7.5 kGy, while it increased, significantly, at higher doses. There was, also, significant decrease in the phytic acid and complete degradation was attained at 15 and 30 kGy. The 3,4-dihydroxyphenylalanine (L-DOPA) concentration showed a dose-dependent decline. A trace amount of hemagglutination activity was seen on human erythrocytes, in raw seeds, what was completely absent with irradiation (>5 kGy). As *Mucuna* seeds serve as food, feed or as pharmaceuticals, it may be necessary to set the ionizing radiation to a specific dose in order to retain optimum levels or to eliminate phenolics, tannins, phytic acid and L-DOPA.

Toledo, Canniatti-Brazaca, Arthur & Piedade (2007) studied the effects of gamma radiation - doses of 2, 4 and 8 kGy - on total phenolics, trypsin and tannin inhibitors in five cultivars of soybean grains. They found that all the antinutrients studied underwent reduction with the increase of the dose and that cooking process was, also, effective.

5. Concluding Remarks

Pulses deserve an increasing incorporation in the diet of western countries. UN General Assembly declaration of 2016, as the International Year of Pulses (IYP), offers a chance for the food industry, consumers and strategic planners to think carefully about the importance of these plant protein foods. Statistics about published number of articles in the last decades prospect the trend of increasing consumption of pulses, according to the increased knowledge of their benefits. Radiation application as a mean to reduce antinutritional factors represents a welcomed extra contribution for food safety. As irradiation is a physical and cold process, it may be ideal and emerge as an important technique to improve the nutritional quality of pulses and its products, besides facing present challenges of maintaining food security and minimizing environmental damage under shifting climate conditions.

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