2017 International Nuclear Atlantic Conference - INAC 2017
Belo Horizonte, MG, Brazil, October 22-27, 2017
ASSOCIAÇÃO BRASILEIRA DE ENERGIA NUCLEAR – ABEN

Agência Brasileira do ISBN
ISBN 978-85-99141-07-6

THE EFFECT OF GAMMA RADIATION ON CHIA (*Salvia hispanica L.*) EDIBLE FILM

Gabriel S. Chierentin, Bruna S. Teixeira and Nélida L. Del Mastro

Instituto de Pesquisas Energéticas e Nucleares (IPEN / CNEN - SP)
Av. Professor Lineu Prestes 2242
05508-000 São Paulo, SP
[1] gabrielsouza.ch@gmail.com

ABSTRACT

Edible films and coatings have received considerable attention in recent years for their advantages over synthetic films for edible packaging materials. Chia seeds (Salvia hispanica L.) have functional and important nutritional values: protein content (15–25%), fats (30–33%), carbohydrates (26–41%), dietary fiber (18–30%), and ash (4-5%). It also contains a high amount of vitamins, minerals, and antioxidants. Mucilage of chia, a natural exudates from chia seeds, is mainly composed of xylose, glucose and glucuronic acid forming a branched polysaccharide. In the present preliminary work whole chia seeds were irradiated in a ^{60}Co source Gammacell 220 (AECL) with doses of 0, 5 and 10 kGy, dose rate about 0.8 kGy h-1. The irradiated seeds were crushed and soaked in an aqueous solution (6% w/w) together with glycerol (1% w/w), under magnetic stirring for 15 minutes at room temperature and poured into casting plates. The plates were placed in an oven with forced air circulation at 35 °C for at least 20 h. Water uptake, moisture, solubility and water activity of the films were established. The most expressive result was a decrease in water uptake with the increase of the radiation dose. Solubility remained almost unaffected by radiation in doses of 5kGy and moisture analysis showed also a decrease with dose.

1. INTRODUCTION

Ionizing radiation has been used in a wide range of industrial applications, being the main application in the sterilization of medical products, pharmaceuticals, cosmetics and food processing [1]. It is also widely applicable in modifying the structure and properties of polymers [2]. Currently, 50 countries have legislation authorizing the use of radiation in food [3]. Food irradiation, as well as other processing techniques, induces certain changes that may modify the chemical composition and nutritional value of foods, especially carbohydrates, protein, amino acids and lipids [4].

Increasing environmental concerns associated with handling of plastic waste has emphasized the importance of developing biodegradable edible films from natural biopolymers. Biopolymer-based packaging materials normally are produced from proteins, polysaccharides, lipids or their blends, and may also serve as gas, moisture, aroma, and lipid barriers that enhance food quality by minimizing its deterioration and consequently improving its shelf life [5,6].

Chia seed (*Salvia hispanica L.)*, native to the Mexican region, has become increasingly important for human health and nutrition because of its high content of essential fatty acids, dietary fiber and protein [7]. It possesses a significant quantity of oil (about 40% total weight of the seed), almost 60% as a linolenic acid (ω-3) and also dietary fiber (over 30% of the total weight), both important components of the human diet, and proteins of high biological value (around 19% of the total weight). In addition, it contains natural antioxidants such as phenolic glycoside-Q and K, chlorogenic acid, caffeic acid, quercetin and kaempferol [8], with health benefits such as protection against some cardiovascular diseases and some types of cancer. Also, it contains vitamins and minerals [9,10]. When the chia seeds are soaked in water it expands and become very gelatinous in its texture because chia seed has a high amount of mucilage, a type of soluble fiber, that remains firmly attached to the seeds. In water, a transformation occurs where its compounds such as proteins, carbohydrates, and lipids are rearranged. The structure of chia polysaccharide exudate has qualities that find applications in the food industry [11].

The objective of this preliminary work was establishing the conditions to prepare an edible film based on irradiated chia seeds and to evaluate some important properties.

2. MATERIALS AND METHODS

Chia seeds were bought in a common market of São Paulo, São Paulo - Brazil. Glycerol and Na propionate reagent-grade were also employed. Irradiation was performed in a ^{60}Co source Gammacell 220, Atomic Energy of Canada Ltd (AECL) with doses of 0, 5 and 10 kGy. The dose rate was about 0.8 kGy h^{-1}. The irradiated seeds were stored at room temperature.

The film formation procedure was based on Dick method [12] with some adaptations. First, all whole seeds of each dose were crushed, in a conventional grinder producing chia flour. Chia flour was dispersed in distilled-water (6% w/v), glycerol (1% w/v) and Na propionate (1% w/v). The solution were magnetically stirred for 15 minutes and then dispersed in (18x20cm) plates and dried in an oven with force air circulation for at least 20h and up to 5 days.

Water absorption tests of films were performed based on the method described by Chiono et al. [13]. Samples of chia films (10 x 10 mm) were weighed (iw), placed in distilled water at room temperature for 24 h. After that, the swollen gels were removed from the water, dried with absorbent paper and weighted (fw). Each assay was performed in triplicate. Thus, the absorption of the gels was obtained by the following equation:

$$Wu\ (\%) = \frac{fw - iw}{iw} \times 100$$

Where Wu is the water absorption level (%); Fw: Final weigh; Iw: inicial weigh.

The moisture content of chia based films was determined based on Guerrero et al. [14] measuring the weight loss of the samples (10 x 10 mm) after drying in an oven with air circulation at 105 ± 1 ° C until constant weight.

The solubility of the films was determined with the methodology described by Colla et al. [15]. Film samples (10 x 10 mm) were weighed and dried in an oven with forced air circulation at 105 ± 1°C for 24 h. The samples were then placed in beakers with 50 mL of distilled water and stored at room temperature for 24 h with occasional gentle shaking. After

24 h, undissolved films were dried in a circulating air oven at 105 ± 1ºC for 24 h and weighed. Thus, the solubility of the films was calculated by the equation:

$$S\,(\%) = \frac{iw - fw}{iw} \times 100$$

Where S is the solubility level (%); Fw: Final weigh; Iw: inicial weigh.

The results were analyzed for analysis of variance (ANOVA). The software used was Statgraphics Plus 3.1 (Statistical Graphics Corp).

3. RESULTS AND DISCUSSION

Chia films were successfully prepared. Other authors [16] had already developed thin films based on mucilage of Salvia hispanica alone or in combination with other component in order to evaluate their physico-chemical properties. In the present preliminary work, the chia seed were previously irradiated and the effects of this treatment were registered, as can be seen in Table 1. No visual differences were perceived among the samples irradiated with 0, 5 and 10 kGy.

Table 1: Properties of chia films prepared with irradiated chia seeds as a function of irradiation dose

Analysis	Doses (kGy)		
	0	5	10
Water uptake level (%)	710.05 ± 47.66^{a}	540.57 ± 41.78^{b}	403.07 ± 22.93^{c}
Solubility (%)	24.11 ± 1.06^{a}	24.1 ± 0.87^{a}	21.27 ± 1.46^{b}
Moisture (%)	19.44 ± 0.64^{a}	16.12 ± 0.75^{b}	15.89 ± 1.12^{b}

Values represent average ± standard deviation. Same letters in the same line represent not significant difference ($P \leq 0.05$).

In water uptake determination the most expressive influence of gamma irradiation in the edible film was obtained. From 0 kGy to 5 kGy a significant decrease of approximately 24% was produced; comparing 0kGy and 10kGy a 43% of reduction in water uptake was obtained. Inamura et al [17] obtained similar results of water uptake level applying doses of 20kGy and 40kGy in edible film made by blend of potato starch and gelatin.

Solubility of the films was almost unaffected when the seeds were previously irradiated with 0 or 5kGy, however at a dose of 10kGy a decrease of about 12,5 % in reference to the control was noticed. Comparing the films with doses of 0 and 5kGy with Dick [12] film made only with chia flour (1:0 - chia flour: corn starch), the results were very similar.

Moisture content follows the tendency of decrease with the increase of irradiation dose. Oluwaseun et al [18] analyzing flour of pigeon pea seeds got decreasing values of moisture content according to increase of doses of gamma irradiation. Comparing with Dick [12] film

(1:0 - chia flour: corn starch), we obtained a higher value of moisture. Dick [17] reported that the decrease in moisture content in the chia flour/maize starch films with the addition of maize starch could be explained by the interactions between chia flour and maize starch. These interactions lowered the availability of the hydrophilic components (protein and fiber) in the flour, which, in turn, limited the chia flour interactions through hydrogen bonding (interactions with water molecules).

Depending on the adsorbed radiation dose various effects can be produced resulting in the polymerization/cross-linking or depolymerization/degradation of biomolecule components [19]. Radiation affects differently oil, protein and other important chia components, then, the net effect of radiation on chia seed remain to be established.

4. CONCLUSION

Gamma-irradiation affects proteins by causing conformational changes, oxidation of amino acids, rupture of covalent bonds and formation of protein free radicals that can be beneficial for specific further applications. On the other hand, radiation affects differently oil, protein and other important chia components, then, the net effect of radiation on these seed remain to be established. In the present preliminary work the conditions to prepare an edible film based on irradiated chia seeds were establishing. Some important properties of the films were also evaluated. As chia polysaccharide exudate has qualities that find applications in the food industry, present results are important and deserve to be considered on further researches and developments on the fabrication of chia based edible films.

ACKNOWLEDGMENTS

We thank irradiation assistance of Eng. Elizabeth Somessari.

REFERENCES

1. C.F. Oliveira, L.P Soares, A.M Alves. “Irradiação de Alimentos – Extensão da Vida Útil de Frutas e Legumes.” *Revista Acadêmica Saúde & Ambiente,* **7**, p. 52-53 (2012).
2. R.L. Clough. “High-energy radiation and polymers: A review of commercial processes and emerging applications.” *Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms*, **185**, n. 1–4, p. 8–33 (2001).
3. N.L.D. Mastro. “A radiação ionizante na promoção da alimentação adequada e saudável.” *Vigilância Sanitária em Debate*, **3**, n.2, p. 114-121, (2015).
4. D. Kilcast. “Effect of irradiation on vitamins.” *Food Chemistry*, **v.49**, p. 157-164 (1994).
5. J. P. Maran, V. Sivakumar, R. Sridhar, V.P. Immanuel, “Development of model for mechanical properties of tapioca starch based edible films.” *Industrial Crops and Products,* **42**, p. 159-168 (2013).

6. S. Kokoszka, F. Debeaufort, A. Hambleton, & A. Voilley. "Protein and glycerol contents affect physico-chemical properties of soy protein isolate-based edible films." *Innovative Food Science & Emerging Technologies*, **11**, 503–510 (2010).
7. R. Ayerza, W. COATES, "Protein content, oil content and fatty acid profiles as potential criteria to determine the origin of commercially grown chia (Salvia hispanica L.)." *Industrial Crops and Products*, **34**, p. 1366-1371 (2011).
8. C.E. Reyes, A. Tecante, M.A.V. López, "Dietary fibre content and antioxidant ctivity of phenolic compounds present in Mexican chia (Salvia hispanica L.) seeds." *Food Chemistry*. **v.107**, 656–663 (2008).
9. R. Ayerza, W. Coates. "Chia seeds: natural source of ω-3 fatty acids." *Annual Meeting of the Association for the Advancement of Industrial Crops*. Atlanta, Georgia. USA, **X**, p. 17 (2001).
10. R. Ayerza, W. Coates. "Composition of chia (Salvia hispanica) grown in six tropical and subtropical ecosystems of South America." *Tropical Science*, **44** (3), 131–135 (2004).
11. R. Craig. "Application for approval of whole chia (Salvia hispanica L.) seed and ground whole seed as novel food ingredient." *Company Representative Mr D Amstrong*, Northern Ireland. (2004).
12. M. Dick et al. "Edible films based on chia flour: Development and characterization." *Journal of Applied Polymer Science,* **133**, pp. 42455. issue 2 (2016)
13. V. Chiono, E. Pulieri, G. Vozzi. G. Ciardelli, A. Ahluwalia, P. Giusti. "Genipin-crosslinked chitosan gelatin blends for biomedical applications." *Journal of Materials Science: Materials in Medicine*, **19**, p. 889–898, (2008).
14. P. Guerrero, P.M. Stefani, R.A. Ruseckaite, K.D.L Caba. "Functional properties of films based on soy protein isolate and gelatin processed by compression molding." *Journal of Food Engeenier*, **105**, n. 1,p. 65-72, (2011).
15. E. Colla, P.J.A. Sobral, F.C. Menegalli. "Amaranthus cruentus flour edible films: influence of stearic acid addition, plasticizer concentration, and emulsion stirring speed on water vapor permeability and mechanical properties." *Journal of Agricultural and Food Chemistry*, **54**, n. 18 p. 6645-6653, (2006).
16. L.A. Muñoz, A. Cobos, O. Diaz, & J.M. Aguilera. "Chia seeds: microstructure, mucilage extraction and hydration." *Journal of Food Engineering*, **108**, 216-224 (2012).
17. P. Y. Inamura. "Irradiated gelatin-potato starch blends: evaluation of physicochemical properties." *International Nuclear Atlantic Conference - INAC 2015*. São Paulo, SP, Brazil, October 4-9 (2015).
18. P. B. Oluwaseun, C. T Akanbi. "Effect of gamma irradiation on physicochemical properties of stored pigeon pea (Cajanus cajan) flour." *Food Science & Nutrition*, **1**(5) pp. (2013).
19. N. L. D. Mastro. *"Radiation Influence on Edible Materials*." Chapter in the Book: Radiation Effects in Materials, Edited by Intech Open Science, Rijeka, Croatia (2016).