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Review Article

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Novel Applications of Radiation Technology on the Production of Biodegradable Packaging for the Food Industry

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ABSTRACT

The environmental damage human activities are cause is our most present concern. Plastics mainly petroleum-based packaging materials are widely employed in the manufacture of food packaging because of their performance and facility of production. That is leading to serious ecological problems for the environment as synthetic plastics are resistant to biodegradation. Biopolymers can be seeing as a solution to the problems posed by plastics as they easily degrade in the environment. Naturally occurring polymers produced by living organisms show no adverse effects on the environment or human being. For biodegradable food packaging it is required to employ biopolymers with good film formation capability and to employ a proper film formation method. In the present article, the employment of radiation technology in the production of films or coating for food packaging is presented as a novel application.

Introduction

The production of biodegradable packaging for the food industry requires the employment of environmentally friendly substances with properties such as renewability, biodegradability and biocompatibility. In nature we can find plenty of natural biodegradable and edible-film forming materials among the three kinds of biopolymers: polysaccharides (cellulose, starch, pectin, seaweed extracts), proteins (animal or plant protein) and lipids. Also, to transform a biopolymer into a food packaging it is necessary to employ a proper film formation method depending of the natural material chosen.

Important part of the present study has been performed by gathering information from online published articles collected under Web of Sciences, mainly to survey the number of articles published in different periods under specific tag words. It is actually a way to show and justify the title of the present article on new applications of radiation technology on the production of biodegradable packaging for the food industry.

Biodegradable Natural Polymers for Packaging

Food packaging materials must to fulfil a series of properties, depending the material that are supposed to preserve. As Marsh & Bugusu define, "the goal of food packaging is to contain food in a cost-effective way that satisfies industry requirements and consumer desires, maintains food safety, and minimizes environmental impact" [1].

Typical properties for the food packaging system are gas barrier property, mechanical, thermal, rheological, morphological, optical and physical properties. Many good articles and reviews were published on materials suitable for biodegradable packaging the use of different types of actives components used as natural additives was also reviewed recently by Kaur et al. [2-20] Shahidi F, Hossain A. [12]. Mangaraj et al in particular, summarize that the biopolymer based packaging materials may be divided into three main groups based on their origin and production: [21]

i. Polymers which are directly extracted or removed from biomass: starches, celluloses, proteins.
ii. Polymeric materials which are synthesized by a classical polymerization procedure using renewable biobased monomers such as poly (lactic acid) and oil-based monomers like poly-caprolactones.
iii. Polymers which are produced by microorganisms or genetically modified bacteria constitute this group. Ex: the polyhydroxy-alkanoates, bacterial cellulose.

The biodegradable polymers market is estimated to be valued at US$ 7.9 billion in 2023 (https://www.futuremarketinsights.com/reports/biodegradable-polymers-market).

Proteins are essential part of our diet. Animal meat consumption at the current rate is detrimental to our environment. Plant-based protein offers a more eco-friendly and sustainable substitute with reduced land use, lower greenhouse gas emissions, better

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water use efficacy, and reduced pollution levels [22]. In figure 1 is displayed the number of publications on plant proteins. The exponential growth of the plant protein subject as function of time in the last 3 decades could be related to the increase of interest in environmental aspects as well as public interest in having a more diversified diet, no restricted to animal origin proteins.

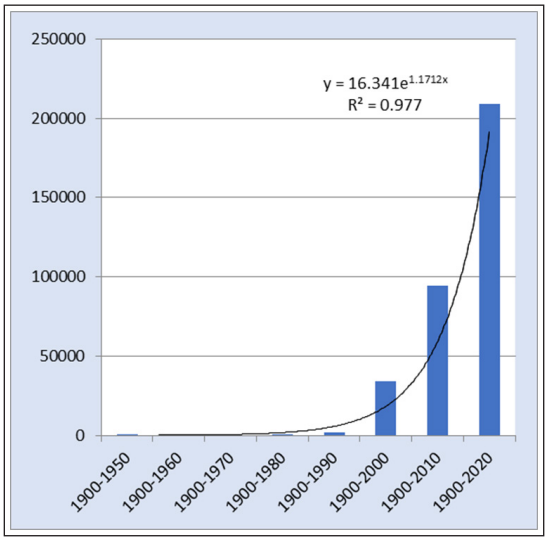


Figure 1: Number of publications on plant protein as a function of time

In Figure 2 is presented the number of publications on biodegradable packaging and bioplastics. Both terms attract attention as a subject of study starting in the last decades, with an increasing tendency.

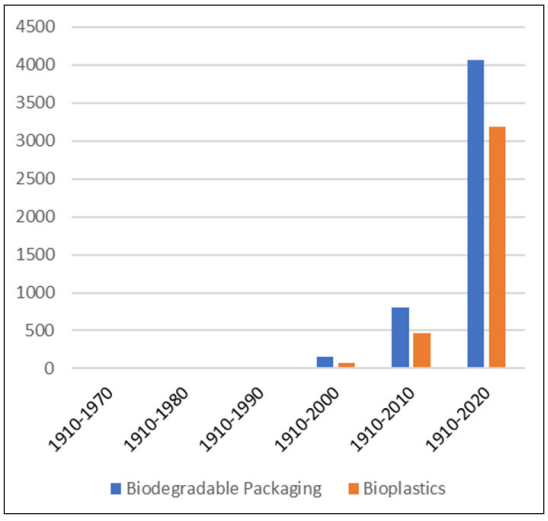


Figure 2: Number of publications on "biodegradable packaging" and on "bioplastics" as a function of time.

Among biodegradable materials edible films are of special importance. Azeredo, Otoni & Mattoso defined precisely what they are: macromolecular-based structures forming thin layers, usually polysaccharide and/or protein able to form a continuous and cohesive layer [23]. that are sometimes being considered as parts of both the packaging system (primary packaging) and the food itself. In Figure 3 is shown the number of online publications using as tag Edible Films. The interest in edible films as a subject of study appeared in the recent decades.

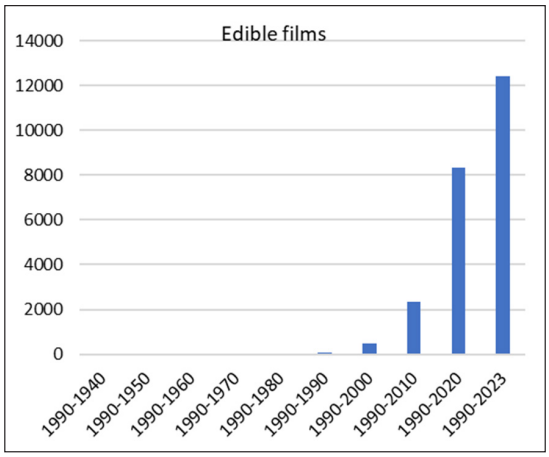


Figure 3: Number of articles published in ascended decades using the words: Edible films since 1990. The last column referred to a much shorter period but were registered to highlight the perspective of important growth in the present decade of 2020-2030.

Technologies for Food Packaging

Today are available for the food industry various non-thermal food processing/preservation technologies (ultra-high pressure, ionizing radiation, pulsed X-ray, ultrasound, pulsed light and pulsed electric fields, high-voltage arc discharge, magnetic fields. The packaging/products interactions that might result were and are still also studied [24-28].

Radiation Technology

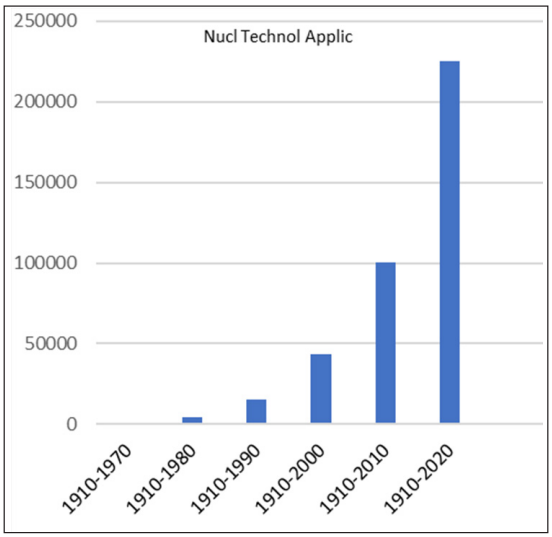
In physics, radiation is the emission or transmission of energy in the form of waves or particles through space or a material medium. It is a physical method of modification of materials that can be applied for many beneficial purposes. Chemical reactions can be initiated by radiation at any temperature, under any pressure and in any phase (gas, liquid or solid) without the use of catalysts. The irradiation of polymeric materials with ionizing radiation (gamma rays, X rays, accelerated electrons, ion beams) conducts to the formation of very reactive intermediates. These intermediates, via different reaction paths, induce rearrangements and/or formation of new bonds. The ultimate effects of these reactions can be the formation of oxidized products, grafts, scission of main chains (degradation) or cross-linking (https://www-pub.iaea.org/MTCD/Publications/PDF/TE_1420_Web.pdf).

The international atomic energy agency (IAEA), one of the agencies of the United Nations, and the American Nuclear Regulatory Commission, among others, considered that the use of irradiation brings benefit to humankind in medicine, academics, and industry, as well as for generating electricity (www.iaea.org, https://www.nrc.gov/about-nrc/radiation/around-us/uses-radiation.html#academic). Practical applications of radiation chemistry nowadays include many fields such as health care, food and agriculture and manufacturing [29]. In addition, radiation has useful applications in such areas as archaeology (carbon dating), space exploration, law enforcement, geology (including mining), and many others (https://www.nrc.gov/about-nrc/radiation/around-us/uses-radiation.html#academic).

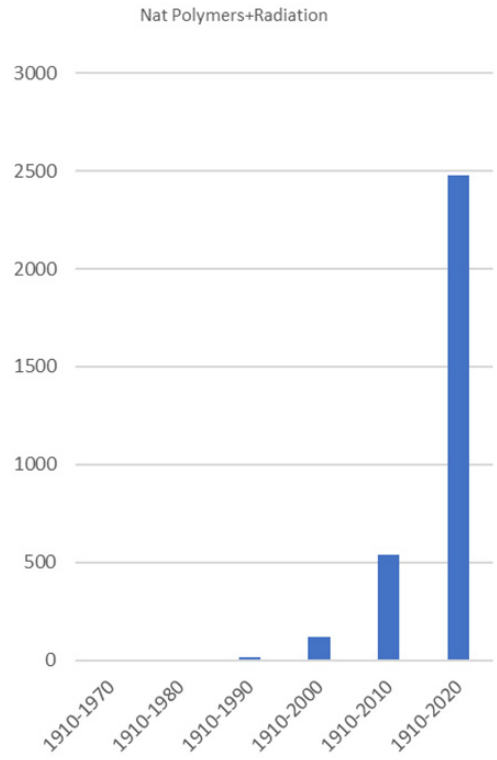
A lot of work has been and is still performed to evaluate the suitability of the ionizing irradiation on food packaging materials

or prepackaged foods [30-40]. As Chmielewski recognizes, the use of processing materials by radiation is at present a well-known technology and continues to advance constantly in many industrial sectors [41]. This fact is evident analyzing the number of publications on nuclear technology applications appeared since the first article was published online.

In Figure 4 is presented the resume of data surveyed on a) "nuclear technology applications" since the first publication found online, on b) "the natural polymers" + "radiation" and c) a comparison of both. Although the huge difference in magnitude, the number of publications that combines natural polymers plus radiation is insignificant when compared with the total number of nuclear technology applications, but both group of data clearly present a net tendency of increase.



a)



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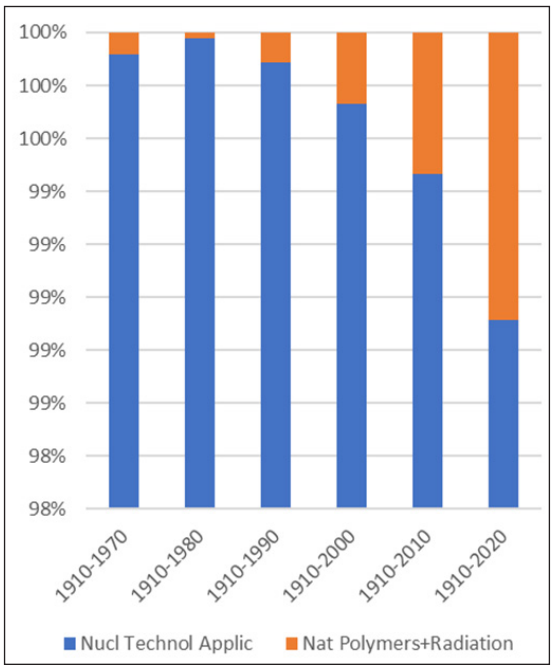

c)

Figure 4: From up to bottom: a) Data of the number of articles published on "nuclear technology application"; b) Data of the number of articles published on "natural polymers" + "radiation"; and c) a comparison of both plots.

As mentioned before, the interest in edible films is increasing according to the interest in publishing in the subject. Also, As Figure 5 makes evident, the use of irradiation applied in/for edible films or coating follows a similar tendency, i.e., radiation technology is increasingly used for the production of biodegradable packaging for the food industry, as mention already [42].

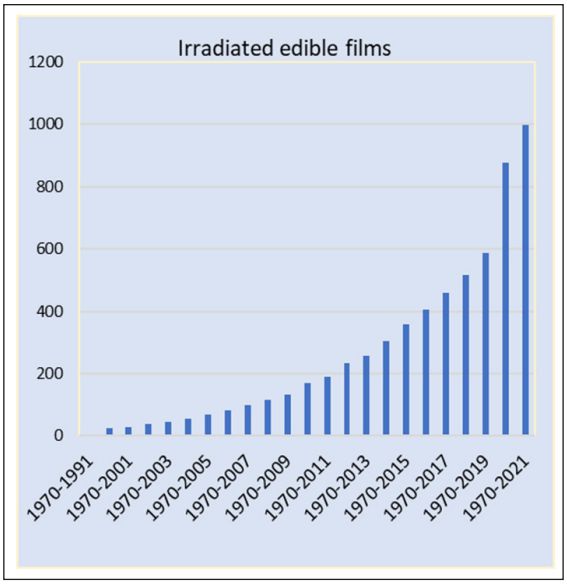

Figure 5: Number of publications on irradiated edible films as a function of time

Conclusion

The wide employment of synthetic plastics produced for norewable source in the food packaging industry results in environmental pollution. In the search of alternatives, the use of biodegradable polymers instead of synthetics appears

as an important contribution. For that reason, biodegradable polymers market is very valuable as most of the consumers start to think about sustainability when buying a product. Among biodegradable materials, edible films are of special importance as primary packaging material. Technological developments, traditional or novel ones are required for attending the increasingly demands of the food packaging industry. In the present article radiation technology is presented as a good and novel tool for the production of biodegradable packaging for the food industry taking in account the huge evidence derived from the substantial research work on beneficial radiation technologies applications.

Conflict of Interest Statement

The author has no conflict of interest to declare.

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