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THE INFLUENCE OF GAMMA IRRADIATION ON TEXTURE, COLOR AND VISCOSITY PROPERTIES OF POTATO STARCH

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ABSTRACT

Food choices, while influenced by taste and nutritional value, have also symbolic enjoyment meanings. The texture, appearance, and flavor are important acceptability factors for any meal component. In our every day enjoyment of eating, texture is often as important as flavor. Starch is the most important source of carbohydrate in human nutrition and is widely used in many applications throughout the food industry. As an additive for food processing, food starches are typically used as thickeners and stabilizers in foods such as puddings, custards, soups, sauces, gravies, pie fillings, and salad dressings, and to make noodles and pastas. Potato starch is extracted from the root tubers of the potato plant. Radiation processing can be applied on foods for different purposes. It can also produce some modifications that are important to know. The aim of this research was to analyze the influence of gamma irradiation on texture, color and viscosity of potato starch. Starch samples were irradiated in a ^{60}Co source Gammacell 220 with doses of 0, 5, 10 and 15 kGy. The results obtained showed that texture became inversely proportional to the applied radiation dose. Increasing doses promoted a slight rise in the parameter b* (yellow color) while the parameter L was not significantly affected. On the other hand, the viscosity of potato starch aqueous preparations decreased with the radiation dose, attributable to some degradation of starch molecules.

Keywords: Gamma irradiation. ^{60} Co. Texture. Color. Viscosity Potato starch.

1. INTRODUCTION

Starch is a biopolymer that is produced by plants and serves as a store of carbon and energy. Unlike other plant polysaccharides, such as cellulose and pectic substances, starch has no structural function in the plant. Starch becomes a structuring agent in food owing to its transformation during food processing. Since the thickening and gel-forming properties of starch arise during hydrothermal processing, it is considered a secondary texturogen [1]. Frequently the starches may need to be modified to improve the physico-chemical and functional characteristics to adapt to the areas of application.

Potato starch is an abundant and cheap raw material widely applied in various food, pharmaceutical and technical industries. Gelling properties of starch and viscosity and stability of it's gels appear to be the crucial factors that affect possible application of starch in a number of industrial products. Accordingly, development of starch modification and analysis appears to be the important task [2].

Rheological properties of starch are key factors determining their industrial usage. Some authors [3] suggested that the integrity of swollen starch granules was the major factor determining the rheological properties of a starch paste or gel. They reported that the formation of gel structure was governed by the rigidity of swollen granules and that the hot-water soluble component could strengthen the elasticity of the starch gel or paste. Maximal swelling might also be related to the molecular weight and the shape of the amylopectin [4].

The textural properties of products depend on characteristics of starch granules in absorbing water and expanding themselves during heating [5]. The content of amylose and amylopectin determines the swelling power of starch granule [6,4].

Gamma-irradiation is an ionic, non-thermal process that has been used as method for food preservation and functional modification of polymer. The capability of gamma-irradiation to degrade glycosidic bonds results in conversion of large starch molecules into smaller fragments. These changes may affect the physicochemical properties of irradiated foods [7,8]. Understanding the influence of γ-irradiation on starch properties contributes to a better utilization of this physical technique for food quality control. Another scenario is that γ-irradiation can be used for starch modification to create novel functionality for diverse food and non-food applications [7,9].

Starch modification by gamma radiation may change the physicochemical and rheological properties of irradiated starch-rich products, resulting in decreased swelling power [10], viscosity and consistency of starch paste [11].
Following the recent tendency of going on deeper in the research on the influence of γ-irradiation on starch from diverse botanical origins [12], the aim of this study was to determine the changes induced by γ-radiation on the rheological, color and textural properties of potato starch.

2. MATERIAL AND METHODS

2.1. Material and gamma irradiation

A commercial potato starch obtained at local market was employed. Starch samples were packed in plastic polyethylene bags and gamma irradiation was conducted in a cobalt-60 (^{60}Co) irradiator Gammacell 220 (AECL). Samples were irradiated with doses of 0 (unirradiated), 5, 10 and 15 kGy at the dose rate of 0.997 kGy/h.

2.2. Preparation of samples

For viscosity analysis samples were prepared with 5% (w/w) of starch $(C_6H_{10}O_5)_n$, 3% (w/w) glycerol ($C_3H_8O_3$), 0.5 % calcium propionate ($C_6H_{10}CaO_4$) and supplemented with distilled water; then, were heated to gelatinization.

For film analysis the samples were prepared as described above to obtain gelatinization. Subsequently, 60 g of gel was added to glass plates lined with plastics of 15 cm in diameter driven polyethylene and drying in an oven at 25°C for 72 h.

2.3. Texture analysis

The starch pastes/gels obtained after the gelatinization were poured into glass plate lined with polyethylene plastics. The samples were then stored at room temperature (25°C) for 3 days. After the films formed were cut into squares of 30x30 mm and were analyzed using a texture analyzer Stable Micro Systems TA-XT2 with capacity of compression of 50 kg. The films were measured for their compressibility, using a cylindrical stainless steel probe, 35 mm in diameter (P/35).The pre-testing, testing and post-test speeds were set at 2, 1 and 10 mm/sec, respectively. They were analyzed approximately 15 samples from each irradiation dose applied.

2.4. Color

Color of the starch was determined using *Chroma meter* colorimeter, model CR-400 (Konica Minolta Camera Co., Osaka, Japão) and the software used for data treatment was SpectraMagic NX. A white standard board was used for calibration. The results were expressed according to the CIELAB system, which measures the three dimensions of color: L^*(lightness), a^*(redness to greenness) and b^*(yellowness to blueness) values were measured. They were analyzed 15 samples for each dose irradiated starch. All analyzes were performed in triplicate.

2.5. Viscosity measurements

Radiation effects on starch samples were measured following viscosity at 50°C using a Brookfield viscometer, model LV-DVIII with small sample adapter (SSA), spindle SC4-14, with Rheocalc software and Neslab water bath model RTE-210, precision ± 0,1°C.

2.6. Statistical Analysis

Statistical analysis was applied according to Analysis of Variance (ANOVA). When appropriate, the difference among means was determined using Tukey's multiple comparisons. Statistical significance was set at the 5% level of probability.

3. RESULTS AND DISCUSSION

3.1.Texture analysis

Gamma radiation treatment caused a little decrease in F_{max} of the 10 and 15 kGy (Fig.1). The decrease in resistance with increasing irradiation dose is a direct consequence of reduced starch viscosity, due to depolymerization of constitutive macromolecules into shorter molecules. He et al. [13] reported the mechanical properties of potato starch are relatively better than most of other kind of starch.

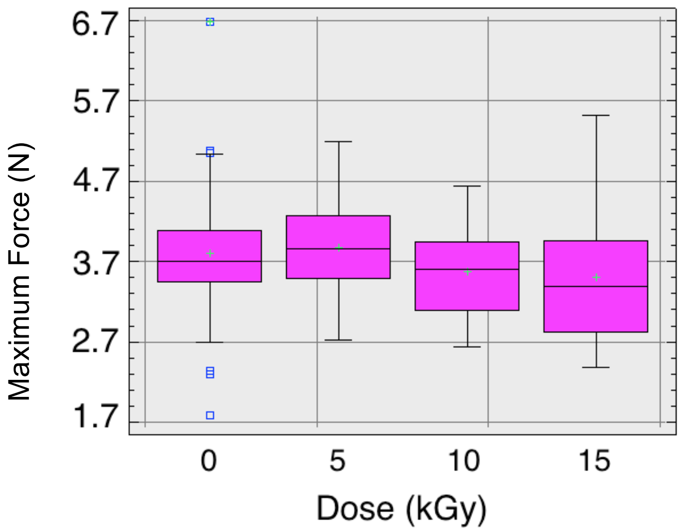

Figure 1: Relationship between Maximum Force(N) and dose (kGy) of potato starch.

3.2.Color

Resultant color values of potato starch samples are presented in Table 1. The brightness, parameter *L**, was closer white and was not affected by radiation in any of the dose levels. There was an increase of the *b** parameter with increasing doses; there was an enhancement of the yellow color. In parameter *a** the samples became greener with the doses. The γ- irradiation in the applied doses changed the color of potato starch.

Table 1: Color parameters of irradiated potato starches

	Irradiation dose			
Color Parameter	0 kGy	5 kGy	10 kGy	15 kGy
*L**	95.65 ± 0.54^{a}	95.62 ± 0.49^{a}	95.51 ± 0.43^{a}	95.62 ± 0.51^{a}
*a**	-0.07 ± 0.04^{d}	-0.18 ± 0.06^{c}	-0.43 ± 0.06^{b}	-0.58 ± 0.11^{a}
*b**	3.19 ± 0.26^{d}	3.61 ± 0.20^{c}	4.54 ± 0.36^{b}	5.23 ± 0.53^{a}

Values expressed are mean±standard deviation

Means in the same row with different superscript are significantly different at $p\leq0.05$.

The altered color of starch may be attributed to the Maillard reaction between sugars and protein residues [14] or transformation of residual phenolics [15], rather than caramelization as suggested previously [16] since little heat is generated by radiation. Others authors working with broad bean starch found also that radiation up to 15 kGy had little effect on the lightness, decreased the redness, and increased the yellowness.

3.3.Viscosity

In this work potato starch samples behaved as non-Newtonian fluids because the viscosity changes with the applied rotation speed (rpm) (Fig.2). Samples were measured either increasing speed or decreasing it, with no apparent differences.

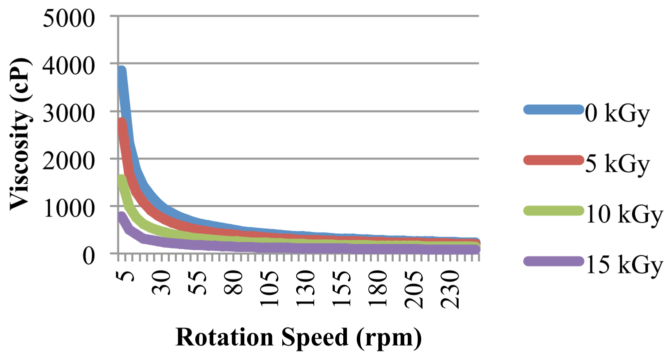

Figure 2: Relationship between viscosity and speed of all potato starch samples.

When a fluid have a drop in viscosity when the shear rate increases, as show in Figure 3, the fluid is called pseudoplastic.

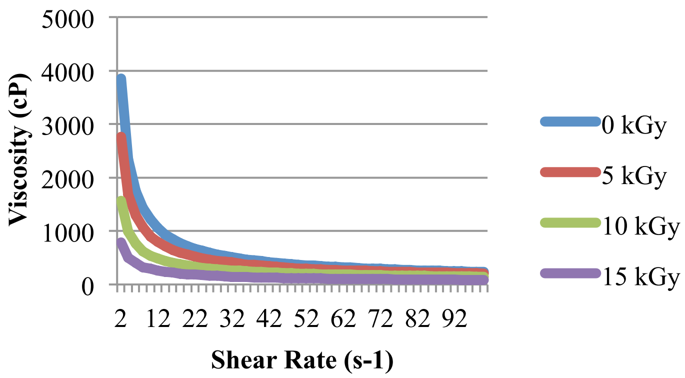

Figure 3: Relationship between viscosity and shear rate of all potato starch samples.

Many substances such as emulsions, suspensions or high technical and commercial importance dispersions belong to this group. These fluids at rest have a disordered state, and when subjected to shear stress, the molecules tend to orient in the direction of the applied force. Consequently, the apparent viscosity will be lower [17].

The gamma irradiation can be considered a macromolecule modification technology [18]. Figure 4 displays the relationship between viscosity and time of the potato starch samples, submitted to 0, 5, 10 and 15kGy.

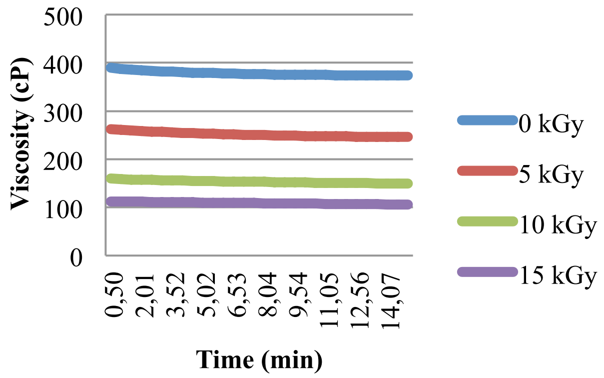

Figure 4: Means of viscosity measurements (cP) of potato starch as a function of time (min) at 250 rpm at 50°C.

As can be noticed, viscosity remains independent of time, as standard deviations remained smaller than 5%. In general terms, the viscosity decreased with the ionizing radiation doses applied as shown in Figure 5.

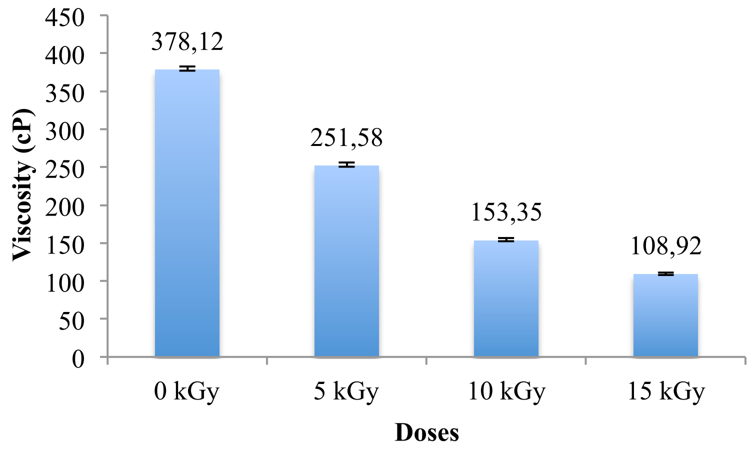

Figure 5: Means and standard deviations of viscosity (cP) of potato starch as a function of radiation dose (kGy) at 250 rpm at 50°C.

The application of ionizing radiation (gamma or electron beam) is reported to generate free radicals that are capable of inducing molecular changes and fragmentation of starch [19-21,15]. This unique property has been suggested to be one of the main mechanisms underlying physicochemical changes in starchy food, like reduction of viscosity and high water solubility [14].

During radiation treatments (as with gamma rays), the glycoside bonds (at chain endings) are broken down in starch granules, which is later accompanied by the decomposition of macromolecules and the creation of macromolecules with smaller chains [22-25]. Studies have also shown that there is a decrease in the crystalline phase content as well as in the distribution order of amylose and amylopectin in starch granules [26]. Radiation treatment was also reported to be able to promote starch cross-linking under oxygen atmosphere [27].

Some authors [28] evaluated the viscosity of corn and cassava starches along with other technological properties of agar-agar and kappa-carrageenan to look for the possible efficacy of employing gamma irradiation (0 and 2 kGy) as a microbial decontaminating treatment. Present results corroborated such referenced results that revealed a decrease in the starch viscosity after irradiation along with a significant loss in the viscosity of puddings prepared from irradiated starches.

The shear stress versus shear rate curves determined at increasing strain rates were modeled by the power law equation (Fig.6). Consequently, n (flow behavior index) and K (consistency index) were determined (Table 3). This model is convenient for analysis of rheological behavior of a wide range of fluids that are Newtonian ($n = 1$), shear-thinning ($0 < n < 1$) or shear-thickening ($n > 1$).

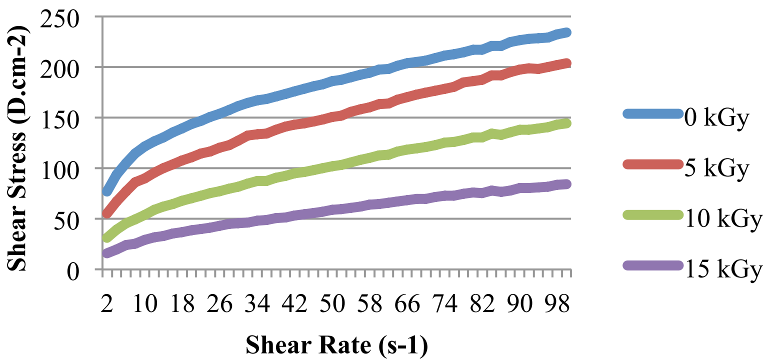

Figure 6: Shear rate x Shear stress at 50 °C.

One may characterize the rheological fluid. To this end, it is necessary processing of data in a form to transform the values obtained on a logarithmic scale.

Table 2: Linear equation obtained from graphics ln (shear stress) x ln (shear rate) at 50 °C

Dose	linear equation
0 kGy	y = 0.0196x + 4.4599
5 kGy	y = 0.016x + 4.7589
10 kGy	y = 0.0233x + 3.9546
15 kGy	y = 0.0256x + 3.3228

From the linear equation it is possible to study the behavior of the fluid. Table 2 presents the linear equations adjustment to logarithmic scale to the shear stress and shear rate.

Table 3: Rheological parameters obtained from ln (shear stress) x ln (shear rate.

Rheological parameters	Doses			
	0 kGy	5 kGy	10 kGy	15 kGy
n	0.0196	0.0160	0.0233	0.0256
ln k	4.4599	4.7589	3.9546	3.3228
k_c	86.4780	116.6100	52.1750	27.737

Shear-thinning behavior, which emphasizes the sensitivity of the solution to shear, indicates the presence of physical interactions and/or entanglements between structural unites (i.e. macromolecular chains) that disappears progressively when shear rate increases. Jane and Chen [29] assumed that the long-branch chains of the amylopectin interact to greater extent with amylose via entanglement than do the other amylopectins.

When checking the values described in Table 3, it is noted that the index n_c obtained flow behavior showed variation between the doses studied. This index indicates how much fluid flow behavior deviates from the Newtonian behavior. Fluids with values near to unity exhibit behavior close to a Newtonian fluid.

The consistency index K_c indicates the degree of fluid resistance to the flow of fluid: the greater the value of K_c, the greater its flow resistance and, therefore, the greater its apparent viscosity. According to Table 3, it is observed that the higher the dose, the lower the value of K_c fluid thus less resistance to flow.

4. CONCLUSION

Gamma irradiation of potato starch caused significant changes in physico-chemical and functional properties. The power law equation can be precisely and successfully applied in viscosity of potato starch gels. The viscosity of the starch has been reduced proportionally to the applied radiation dose. Gamma irradiation affected also color of potato starch samples.

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