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Effects of ionizing radiation on rheological properties of seasoned cassava bacon flour defatted

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ABSTRACT.

The action of ionizing radiation in food occurs due to interactions of energy that modify chemical structures and is currently seen as a technological alternative in the improvement of the paste food in front of the food industries. Seasoned flour, or "farofa", a typical Brazilian dish, presents its greatest challenge related to oxidative stability, due to its high lipid content. The objective of this study was to evaluate the effects of ionizing radiation on the rheological properties of bacon seasoned cassava flour or bacon "farofa" (BF) and defatted bacon "farofa" (DBF). The samples were obtained at the local market in São Paulo-SP / Brazil, so flour was defatted with hexane and irradiated at the IPEN-CNEN Radiation Technology Center (CTR) in an electron beam machine at doses of 0 (control) and 5 kGy (sanitary purposes), and analyzed for their binding properties using RVA-Rapid Visco Ana-lyzer (viscosity profile) and mass texture (texturometer). The results demonstrated that the application of the irradiation with electron beam to 5KGy has affected the rheological prop-erties of the farofas comparing to the controlled sample, reducing every parameter of viscosity pro-file on the RVA and paste texture.resulting in products easier to chewing during the consumption.

Keywords: food irradiation, seasoned flour, viscosity profile.

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1. INTRODUCTION

The interest in green chemistry in the food chain is growing and the irradiation technology is considered a viable alternative, because it is known that it is a process which does not use chemicals, leaves no residue in food and stands out for controlling insect infestation in grains and flour during storage and also for modifying the physical and functional properties of foods [1-2-3].

Ionizing irradiation is a physical process that involves exposing food, packaged or not, to one of these three types of ionizing energy: gamma rays Cobalt-60 or Cesium-137 (Co^{60} or Cs^{137}), X-rays and an accelerated electron beam [4]. Using a dose according to its purpose: disinfection, reduction of microbial load, sterilization, delaying ripening and improvement of technological properties [5]. The application of electron beam irradiation has been further explored, as it is an irradiation method that does not require radioactive isotope (since, in the future, obtaining the source of Cobalt-60 (Co^{60}) will be more difficult) and for not generating radioactive risk, thus making it a viable alternative [6-7].

In this context, the processes of modifying foods rich in starch through ionizing irradiation are observed by several studies with the purpose of changing their properties [8-9]. It can provide a fundamental basis for understanding and efficiency for the food industries, mainly in the production sector of flour and its derivatives, whether in technological, organoleptic, functional, thermal and physical-chemical properties [10].

Seasoned flour, or "farofa", a typical Brazilian dish, originally from the colonial period and currently sold on the market, presents its greatest challenge related to oxidative stability, due to its high lipid content (9.12%) [11-12]. The interaction of ionizing radiation with foods rich in lipids can generate free radicals causing lipid oxidation. However, these problems can be solved by combining them with other technologies. According to Santos, et. al. (2003) the irradiation produced by electron beams or X-rays has a low tendency to penetration power compared to gamma irradiation, besides being efficient in reducing starch swelling capacity, a technology used by foods with low density [13].

In the literature, when relating oxidative stability to the effect of ionizing radiation in flours, reported by Sá & Villavicencio (2017) it was found that doses starting from 5 kGy, showed direct action of ionizing radiation with oxidative stability, changing their features [14]. However, when analyzing the close composition and the functional properties of the flours, it presents varied results on the effect of irradiation and its doses.

The efficiency of the technology in foods containing starch is already known, since it is of wide industrial interest, for it is intended to modify its technological properties, but there are few studies related to the interaction of the oxidative stability of the flour so that the amylose-lipid can directly interfere with technological, functional and thermal characteristics. The objective of this study was to evaluate the effects of ionizing radiation on the rheological properties of bacon seasoned cassava flour or bacon "farofa" (BF) and defatted bacon "farofa" (DBF).

2. MATERIALS AND METHODS

2.1 Samples and Experimental Design

Bacon “farofa” was purchased at a local market in São Paulo, Brazil. The sampling procedure was performed using two different lots, so they were homogenized and divided in 2 experimental parts. One transferred to two polyethylene packages (100 g and 1 cm thick each) and the other part subjected to the removal of the lipid constituent through the extraction of total lipids by the Soxhlet, according to the methodology described by the Adolfo Lutz Institute (2008), with repeated washes of hexane at approximately 69ºC for 8 hours, so they were dried, homogenized and transferred to two polyethylene packages [15].

2.2 Samples Irradiation

The irradiation process for the samples of "farofa" as presented in item 2.1 were carried out at the Energy and Nuclear Research Institute - IPEN / CNEN (São Paulo, Brazil) in an electron beam accelerator (IBA Industrial Inc., Edgewood, NY, USA), at room temperature with an applied dose of 5.0 kGy (dose rate 3.99 kGy / s, energy: 1.5 MeV, beam current: 1.0 mA, tray speed 6 m/ min), related dose per passage in the tray (1 kGy). The alanine and alanine pellet Blister dosimeter (aerial) were used to measure the radiation dose.

2.3 Instrumental analysis

2.3.1. Pasting properties

The pasting properties of the samples were measured using a Rapid Viscosity Analyzer (RVA-4500 model from Perten Instruments, Warriewood, Australia) using the software Thermocline for Windows version 3 performed at the Institute of Food Technology in Campinas, Brazil. Samples were analyzed in triplicates, suspension of samples (2.5 g of "farofa" in 25 mL of water), corrected for 14% of humidity. The scheduling was performed according to the methodology described by Pereira & Leonele (2009), where: time / temperature 50°C for 1 minute, heating from 50 to 95°C at a rate of 6°C / min., maintenance at 95°C for 2 min and 30 sec and cooling at 95 ° C at a rate of 6 / min. The viscosity was expressed in Rapid Visco Unit (RVU) [16]. The parameters analyzed were: Pasting temperature; Peak viscosity time; Maximum or peak viscosity; Minimal viscosity; Final viscosity; Breakdown and Setback.

2.2.2. Texture analyzer

The pasta hardness was determined using Stable Micro Systems TA-XT2i texture analyzer, version 6.10 and 7.10, 1997, held at the Institute of Food Technology in Campinas, Brazil. The gel obtained from the RVA analysis was kept in its own aluminum cup, temperature of 23°C until its complete cooling and the pasta hardness readings were carried out. The pre-test, test and post-test velocities were, respectively, 0.5 mm / s, 1.0 mm/s, and 10 mm/s, with a 5 mm sample penetration distance, using an acrylic probe cylindrical of P20.

2.3. Statistical Analysis

The results were analyzed using the program GraphPad Prism (version 7.0), which were also used for the elaboration of tables and graphs. The comparisons among the data were performed using two-way ANOVA and Bonferroni post-analysis, with a statistical significance limit of $p < 0.05$.

3. RESULTS AND DISCUSSION

3.1 Pasting properties

The main parameters of the rheological properties: peak viscosity, final viscosity, breakdown and setback. Analyzed using the viscoamylogram values of the two types, the bacon “farofa” and the defatted bacon “farofa”, irradiated with 5 kGy and the controls (non-irradiated) shown in Table 1.

Table 1: Pasting properties of bacon “farofa” (BF) and defatted bacon “farofa” (DBF) control (non-irradiated) and irradiated with 5 kGy.

Sample		Parameters			
		Peak viscosity	**Breakdown**	**Final viscosity**	**Setback**
BF	**Control**	411.00±7.78[a]	208.00 ±3,11[a]	1171.00 ±24,44[a]	966.00±19,78[a]
	5 kGy	53.33± 3.11[b]	4.67±0.98[b]	74.67±2,89[b]	26.00 ± 0,67[b]
DBF	**Control**	335.00±10.67[a]	133.00±4,67[a]	1075.00±34,22[a]	869.00±32.22[a]
	5kGy	62.5±4.89[b]	5.00±0.00[b]	113.5±0.44[b]	51.00±0.67[b]

[1] Mean value followed by their standard deviation.[2] For each parameter, different capital letters on the same line mean statistical difference by the Tukey test ($p > 0.05$).

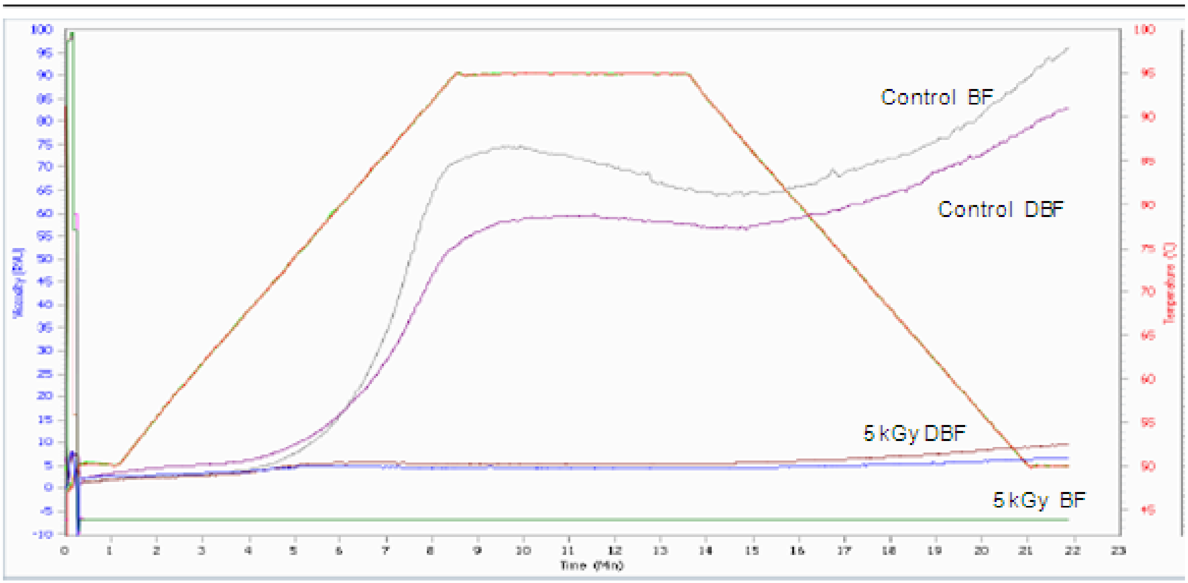
It was observed that the properties of the pastes, regardless of the presence of lipids, underwent significant changes with the effect of ionizing radiation. It should be noted that through the results, the reduction in viscosity was considerable between the irradiated 5kGy sample and the control sample (not irradiated), which was expected, as some studies report this reduction due to the interactions of ionizing radiation with amylose, causing the rupture of the polymer binding starch in smaller chains.

The importance of the pasta properties is correlated to the use of processing applicabilities in the food industry. The viscosity peak (VP) reflects on the starch capacity to bond to water related to the heating time, when the starch granule reaches the gelatinization temperature, the viscosity rises rapidly. This phenomenon is considered irreversible. The (VP) is used to evaluate the thickening and the solubility of the starch granule [16].

The results of the study showed that the irradiation directly interfered with the decrease of (VP) in relation to the controlled (not irradiated), when analyzing the BF sample it showed a decrease of approximately 8 turn in relation to the control (411.00 to 53.33 RVU), whereas the effect of radiation in the DBF sample showed a reduction of 5 turn in relation to the controlled (335.00 to 62.50 RVU). Comparing the control samples, VP was statistically higher for BF compared to DBF, possibly the lipids protected or reinforced the starch granule, leading to greater swelling.

The viscosity profile showed a typical shape of a starch products source (VP) for the controlled, and, on the sample irradiated with 5 kGy a low and stable viscosity has been shown during the whole heating and cooling process of the analysis, which is something typically from a hydrolyzed or dextrinized starch (Figure1).

Figure 1: Viscoamylograph profile (RVA)of the bacon "farofa" and defatted bacon "farofa" control (non-irradiated) and irradiated with 5 kGy.



Comparing to other studies, this modification of the morphology of the starch was also observed when analyzed in terms of the irradiation effect, values who have been reported by

Barroso, et.al (2019) [17], (173.10 to 147.00 RVU) in arrowroot starch irradiated with 5 kGy. The potential explanation for the (VP) reducing is described by Hyun-Jung Chung, et.al (2010) due to the irradiation (gamma or electron beam) being related to the downgrading of being related to the degradation amylopectin and amylose present on the starch, reducing the capacity of the water connection and difficulting the interaction with the starch granules [18].

As the temperature rises, it causes the interaction between the amylose chains and the linear starch chains, preventing the dissolution of amylose, reducing the recombination degree of the starch chains, on this phase, the viscosity "breaks" when related to the viscosity peak [19]. The break happens because of the difference between the viscosity peak and the minimum viscosity under the temperature of 95°C, which happens because of the swollen/gelatinized starch granule bursts because of the heating and the shearing process.

The control samples (not irradiated) showed a high drop in viscosity, regardless of the presence of lipids, both in the sample BF (208.00 RVU) and in the DBF (133.00 RVU), typical of native starches, emphasizing a weakness in the morphology of the granules. When analyzing the effect of the presence of the lipid fraction, it was observed that BFD showed less break compared to BF. In the case of BF, the break was more intense due to the presence of lipids. As for the samples irradiated with 5 kGy, they present a small rupture value in the samples (4.67 RVU) and (5.00 RVU) respectively, showing almost an absence of the breakdown of viscosity (Figure 1), possibly due to the granule depolymerisation.

The final viscosity is associated to the behavior of the gel during the cooling, allowing to evaluate the resulting characteristics of the modification of the starch granule structure during the processing Chung and Liu 2010, resulting on the tendency of the amylopectin and amylose chains dissociating and reorganizing again [18]. As seen, the downward trend for the 5kGy irradiated sample was really low compared to the control for BF (26.00; 966.00) and DBF (52.00; 869.00 RVU), respectively; Barroso, et.al (2019) presents similar results for arrowroot starch [17]; for Ocloo, et.al (2014) tiger nut wheat [20]. This decrease occurs due to the crystallization capacity and the rupture of molecular structures through the effects of irradiation.

The final viscosity is considered as an indicative behavior of the viscosity that the gel will remain in its final process, the desired parameter for the food industry is a less viscous gel Cereda, (2005)[21] in some cases. In the study, it was demonstrated that the final viscosity of the samples showed different behaviors in relation to the radiation effect, where there was a decrease in the values compared to the irradiation samples, for the BF samples 1171.00 to 74.67 in contrast the DBF was of 1075.00 RVU to 114.00 RVU, these results are in accordance with the values presented in the literature [17-18].

3.2 Analysis of the texture profile

The texture pastes properties obtained during the RVA analysis of bacon "farofa" (BF) and defatted bacon "farofa" (DBF) samples not irradiated (control) and irradiated at 5 kGy are presented in Figure 2. The texture parameters analyzed were: hardness, chewing and cohesion are important for the preparation of new food products, such as: creams, soups, pasta.

Figure 2: Texture profile (TPA) of the bacon "farofa" and defatted bacon "farofa" control (non-irradiated) and irradiated with 5 kGy.

To the texture profile of BF and DBF samples it was demonstrated that the influence of the irradiation effect on the starch present in the cassava flour matrix was directly affected, reducing the values. Some studies such as [20-21] describe that this interaction can be affected by several indicators, such as: starch structure, composition wheat chemistry, relationship between amylose and amylopectin and molecular interaction with water. The defatted also affected the texture profile, reducing the parameters values.

The texture profile analysis (TPA) simulates the mastication process through the mechanics properties of food [23], which the measurements are based on resistance of the sample to deformation force, cutting, shearing, punching or extrusion. [24].

Through statistical analysis ($p < 0.05$), the resulting values of the hardness parameters have shown a considerable gap between the means of strength applied due on the irradiation effect. To Liu et al. (2016) studied the effect of heat-moisture treatment on molecular interactions and physicochemical properties of tapioca starch and observed that the gel hardness is used to evaluate the texture contribution of starches in food applications [25].

The capacity of chewing is defined as the product of Hardness x Cohesion x Gumminess it is measured in terms of the needed energy to chew a solid food [26].

As for the cohesion, elasticity and chewing attributes, there has not been found the essential strength to compress the gel. This shows that, for these questions, the interaction of the electron beam has lead to molecular changes and fragmentation of the starch, as seen on the study Negrão, et.al (2019) with the bacon and traditional "farofa" with a lipid level of 8% [27].

4 CONCLUSION

According to the results obtained, under the conditions used, the application of electron radiation to 5KGy affected the rheological properties of the "*farofas*" compared to the control samples.

The irradiation process at 5 KGy depolymerized the starch granules of the bacon farofas demonstrated by the reduced viscosity and texture profile, resulting in products that are easier to chew during the consumption.

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