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EFFECTS OF IONIZING RADIATION ON RHEOLOGICAL PROPERTIES OF SEASONED FLOUR DEGREASED

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ABSTRACT

The seasoned flour is a typical Brazilian dish having its origin registered in the colonial period and its elaboration presents a high added value, in order to provide a food with higher nutritional value: carbohydrate (78.9%), lipids (13.6%), protein (2.1%) and dietary fibers (7.8%). 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. The objective of this work was to characterize the effects of ionizing radiation on the rheological properties of degreased seasoned flours. The samples were obtained from the local market of São Paulo-SP/Brazil. They were irradiated at the IPEN-CNEN Radiation Technology Center (CTR) in an electron beam machine at doses of 0 (control) and 5 kGy (applied for microbiological aspects). The flour was degreased using hexane and analyzed for its bonding properties using RVA-Rapid Visco Analyzer (viscosity profile) and pasta stability (texturometer). The results demonstrated that irradiated farofa traditional and bacon there were significantly lower than the control. This is due to the interactions of the ionizing radiation with the amylose, which can be attributed to the viscosity loss in relation to the use of the dose, also observed similar tendency in the texture stability parameters. It was concluded that the irradiation presented significant interference in the rheological properties, expected results for the industries.

1. INTRODUCTION

Flour, or *farofa,* is a typical Brazilian dish. Its origin dates from the colonial period and is currently marketed in the restricted market, with a high nutritional value (78.9%), lipids (13.6%), protein (2.1%) and dietary fiber (7.8%), is destined to the middle and upper income classes of the Brazilian population, which is widely consumed in the north and northeast of the country [1]. Its central base is produced through cassava flour or corn flour. Cassava meal gains space in cooking, because it presents a rich carbohydrate raw material [2] [3].

Due to the growth and interest of the "green" chemical industries, the physical modification stands out, because it is a process that does not use chemical products and leaves no residues in the food, because in contrast, the modification by the chemical process using some chemicals agents [4]. In this sense, the modifications processes of the starchy foods are observed by the changes in the physical-chemical, morphological, thermal, rheological and technological properties of the starches, being able to provide a fundamental base in the understanding and efficiency for the alimentary industries, mainly in the producing sector flour[5][6].

Changes in the physical-chemical properties of foods can be accomplished through the irradiation process [7]. This is a physical process involving the exposure of food, packed or not, to one of three types of ionizing energy: Cobalt-60 or Césio-137 (Co^{60} or Cs^{137}) gamma rays, X-rays from an electron accelerator, and accelerated electron beam used in a special room or chamber processing, for a set time [8]. The doses are according to their purpose: disinfection, reduction of microbial load, sterilization, retardation of ripening improvement of technological properties [9].

The application of electron beam irradiation has been more exploited because it is a method of irradiation that does not require a radioactive isotope (since in the future obtaining the source of Cobalt-60 (Co^{60}) will be more difficult) and since it does not generate risk radioactive, thus making a viable alternative [10] [11].

Currently, several scientific studies have investigated the changes in the effect of irradiation on the technological, organoleptic, functional, thermal and physicochemical properties of wheat and starch flour [12]. The efficiency of irradiation technology is already known, and the control of insect infestation in wheat grains and wheat flour during storage [13] [14].The challenge now is to research the use of different doses of radiation as a purpose of improving the technological properties of flour [15].

Seasoned flours, due to their high lipid content (13%), have as their main problem the oxidative stability that can be affected by the presence of oxygen, free radicals and light. The interaction of ionizing radiation with foods rich in lipids generates free radicals causing lipid oxidation. However, these problems can be solved by combining irradiation with other technologies. According to Santos, et. al. (2003)[16] 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.

The effect of ionizing radiation on starch-containing foods is of broad industrial interest, since they are intended to modify their technological properties, but there are few studies related to the interaction of oxidative stability of flour so that the amylose-lipid complex can directly interfere with the technological, functional and thermal characteristics. The objective of this work was to mark the effects of ionizing radiation on the rheological properties of degreased tempered flours.

2. MATERIALS AND METHODS

2.1. Samples and Irradiation

Farofa (bacon) was purchased at a local market in Sao Paulo, Brazil. The process of degreasing the *farofa* for the removal of the lipid constituent occurred through the extraction of the total lipids, which were extracted and quantified by Soxhlet, according to the methodology described by the Adolfo Lutz Institute (2008)[17], with repeated hexane solvent washes. The temperature of 69ºC of boiling hexane, and then dried and homogenized and transferred to polyethylene bags containing 100 g. The samples were then irradiated at the Institute of Energy and Nuclear Research - IPEN / CNEN (Sao Paulo, Brazil) using an electron beam accelerator (IBA Industrial Inc., Edgewood, NY, USA) at room temperature with a selected dose of 5 kGy of the dose range applied in food, that is, low dose up to 1kGy for phytosanitary, and medium doses up to 10 kGy technological purposes. Non-irradiated samples were used as control.

2.2 Instrumental analysis

2.2.1. 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)[18],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). 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

Figure 1 shows the main viscoamylogram points of the defatted bacon *farofa* values: peak viscosity, final viscosity, rupture and tendency to retrograde movement and also its statistical analysis. It should be noted that the results showed a considerable difference between the irradiated 5kGy sample and the controlled (non-irradiated) sample, which was expected, as some studies report this reduction due to interactions of ionizing radiation with amylose, causing the rupture of starch polymer binding in smaller chains. They were also observed in the other parameters, being smaller for the irradiated 5kGy sample.

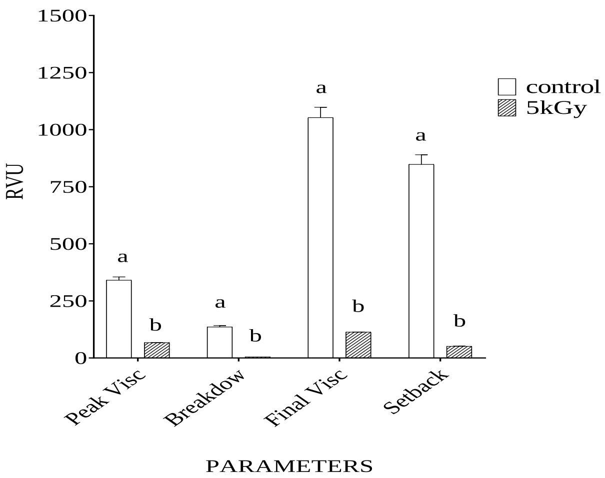

Figure1: Pasting properties of *farofas* Bacon degreased control irradiaded with 5 kGy

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 [19].

The results of the study have shown that the irradiation interfered directly on the decrease of (VP) compared to the controlled (non-irradiated), presenting a decrease of 5 times related to the controlled (335.00 to 67.00 RVU). The viscosity profile showed a typical shape of a starch products source (VP) for the controlled, and, on the sample irradiated with 5kGy 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. (Figure 2).

Comparing to other studies, thismodification of the morphology of the starch were also observed when analyzed in terms of the irradiation effect, values who have been reported byBarroso, *et.al* (2019)[20], (173.10 to 147.00 RVU) in arrowroot starch irradiated with 5 kGy. The potential explanation for the (VP) reducing is described byHyun-Jung Chung, *et.al* (2010)[21]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.

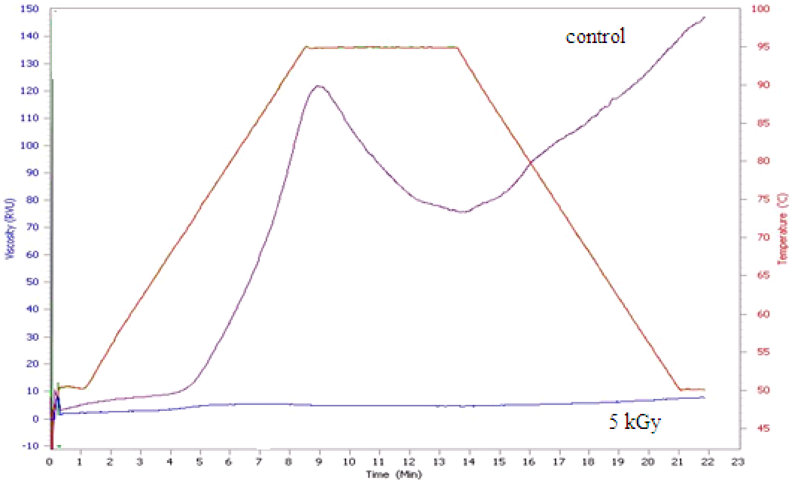

Figure 2: Viscoamylograph profile (RVA) of "farofa" bacon degreased controlirradiated 5 kGy

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 [22].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 controlled sample (non-irradiated) has presented an elevated viscosity break (133.00 RVU), which is typical of the native starches, emphasizing a weakness of the granule morphology. As for the sample irradiated with 5 kGy, it has presented a small breaking value (5.00 RVU), showing almost an absence of the viscosity breach (Figure 2), possibly due to the breach and depolymerisation of the granule.

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[21], resulting on the tendency of the amylopectin and amylose chains dissociating and reorganizing again. As seen, the tendency to downgrading for the sample irradiated 5kGy was really low comparing to the controlled (52.00; 869.00 RVU) respectively, Barroso, *et.al* (2019) [20] has similar results for the arrowroot starch; to Ocloo, *et.al* (2014)[23] tiger nuts wheat. This decrease happens because of the crystallization capacity and the rupture of molecular structures through the irradiation effects.

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) [24]in some cases. In the study, it was shown that the final viscosity of the samples presented distinct behaviors in relation to the radiation effect, where has been a decrease of the values compared to the irradiation, from 1075.00 RVU to 114.00 RVU, these results are according to the values presented by the literature [21] [23].

3.2 Analysis of the texture profile of the degreased bacon *farofa* texture

The texture properties of the obtained pastes during the analysis of RVA from the samples of (BFD) are listed on Table 1. The analyzed texture parameters were: hardness, elasticity, chewiness and cohesiveness are important for the elaboration of new food products, such as: creams, soups, dough. When the controlled sample (non-irradiated) and irradiated with 5 kGy were compared, there was a tendency of decrease or even lack of viscosity of the pastes for the evaluated parameters.

Chart 1: Texture profile (TPA) of the degreased bacon *farofa* controlled (non-irradiated) and irradiated with 5 kGy.

Bacon *farofa* (BFD)				
Dose (kGy)	Hardness (N)	Cohesiveness	Gumminess	Chewiness
0	0.35 ± 0.03[a]	0.66 ± 0.01	0.24± 0.02	0.23 ±0.01
5	0.23 ± 0.00[b]	-	-	-

[1]Mean values followed by their standard deviation. The averages followed by the same letter do not differ statistically from each other by the Tukey test (p> 0.05).

As for the texture profile of the DBF sample, it was demonstrated that the influence of the irradiation effect on the starch was directly affected, some studies as [25], [26] describe that this interaction can be affected by several indicators, such as: starch structure, chemical composition of the wheat, the relation between amylose and amylopectin and the molecular interaction with the water.

On the texture profile analysis (TPA), the capacity of chewing is defined as the product of hardness x cohesion x elasticity, and it is measured in terms of the needed energy to chewing a solid food [27]. Through statistical analysis (p <0,05), the resulting values of the hardness parameters have shown a considerable gap between the means of strength applied on the irradiation effect.

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)[28] with the bacon and traditional "farofa" with a lipid level of 8%.

4. CONCLUSIONS

The application of the irradiation with electron beam to 5KGy has affected the rheological properties of the *farofas* comparing to the controlled sample, reducing every parameter of viscosity profile on the RVA and paste texture.

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