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Starch Digestibility and Functional Properties of Rice Starch Subjected to Gamma Radiation

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Abstract: This study investigated the effect of gamma radiation on the digestibility and functional properties of rice starch. Rice cultivars IRGA417 and IAC202 were used for isolation of starch by the alkaline method. Starch samples were irradiated with 1, 2 and 5 kGy doses of ^{60}Co at a rate of 0.4 kGy/h. A control sample, which was not irradiated, was used for comparison. Irradiated and control starches were characterized by *in vitro* starch digestibility, total dietary fiber, color, water absorption index, water solubility index, syneresis, swelling factor, amylose leaching, pasting properties and gel firmness. Irradiations changed starch digestibility differently in either cultivar. Increasing radiation doses promoted increase in the color parameter *b** (yellow), elevation in the capacity to absorb water, and solubility in water as well as the amylose leached from granules for both cultivars. Pasting properties showed a decrease that was proportional to the dose applied, caused by the depolymerization of starch molecules. Gel firmness of the starch from IAC202 was inversely proportional to the radiation dose applied, whereas for IRGA417, there was a reduction at 5 kGy dose. Rice starches can be modified by irradiation to exhibit different functional characteristics and they can be used by the food industries in products such as soups, desserts, flans, puddings and others.

Key words: *Oryza sativa*; irradiation; viscosity; swelling; amylose; starch; digestibility

Rice is consumed by people in many countries and is the basis of diet for more than half of the world's population (Beinner et al, 2010). Brazil is the largest producer of rice among the Western countries (FAO, 2014), with the primary consumption of polished grains. During rice processing, about 14% of the grains are broken resulting in a by-product with a low commercial value, which can be used for starch extraction as an alternative to add value, thereby transforming it into an ingredient with an increased industrial and commercial interest (Zavareze et al, 2009).

Starch is used to bring consistency to food, but the regular starches can have limitations such as low resistance to shear and high tendency toward retrogradation and syneresis (Liu et al, 2012). Because of these limitations in the properties of starches, the concerned industries look for modified starches that can meet their needs. Thus, starches from different botanical sources are modified to obtain the desirable functional properties in the industries.

Gamma radiation is a physical method of modifying starch (Bao et al, 2005), with advantages such as not significantly raising the temperature of the product, requiring the minimal sample preparation, being fast, and not dependent on a catalyst (Bhat and Karim, 2009; Gani et al, 2012).

Ionizing radiation generates free radicals that are

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able to induce molecular changes and fragmentation of starch. During the irradiation treatment, glycosidic bonds are broken, promoting the decomposition of amylose and amylopectin into smaller molecules (Bhat and Karim, 2009; Chung and Liu, 2009).

Another factor that has been considered lately when selecting starch as an ingredient is its digestibility, due to health implications. Depending on the rate at which the starch is digested *in vitro*, it may be classified into rapidly digestible starch (RDS), digested between 0 and 20 min; slowly digestible starch (SDS), digested between 20 and 120 min; and resistant starch (RS), undigested even after 120 min (Englyst et al, 1992). The SDS and RS fractions have several health benefits; however, foods containing high levels of RDS, when ingested in large quantities, can cause health hazards, such as development of diabetes (Englyst et al, 2007; Zhang and Hamaker, 2009).

In general, starches subjected to gamma radiation present reductions in paste viscosity, molecular weights of amylose and amylopectin, and increases in solubility and carboxyl content (Bao et al, 2005; Chung and Liu, 2009, 2010; Gani et al, 2012; Liu et al, 2012; Falade and Kolawole, 2013; Othman et al, 2015; Reddy et al, 2015). However, other properties such as granule crystalline structure, granule morphology, amylose content, thermal properties and amylopectin fine structure show distinct behaviors depending on the botanical source of starch and irradiation conditions (Chung and Liu, 2009; Liu et al, 2012).

The irradiation can cause reduction in the starch digestibility due to the formation of β-bonds, carboxyl groups and structural modifications (Chung and Liu, 2009; Lee et al, 2013). The β-bonds reduce digestibility because they are partially digested by the amylolytic enzymes (Rombo et al, 2004), whereas the carboxyl groups of the irradiated starch inhibit the enzymatic attack, leading to an increase in RS content compared to the native starch (Chung et al, 2009). Structural modifications restrict the access of the enzymes to the starch molecules. However, other researchers have also observed increased starch digestibility with irradiation, attributing this fact to the loss of the granular structure and to the molecular fragmentation of the starch, which facilitates the access of the amylolytic enzymes (Bhat and Karim, 2009).

The objective of this study was to investigate the effect of gamma radiation on the digestibility and functional properties of rice starch.

MATERIALS AND METHODS

Raw materials

Polished rice grains of cultivar IAC202 were acquired from the Instituto Agronômico de Campinas (IAC) and IRGA417 was courtesy of Instituto Rio Grandense do Arroz (IRGA). These cultivars were selected because they are used on a large commercial scale.

Starch isolation

The rice starch was isolated according to the alkaline method of Patindol et al (2003) with modifications. Polished rice grains were soaked in 0.1% NaOH in the ratio of 1:2 for 24 h. After that, the grains were ground and sieved (63 μm). The sieved slurry was centrifuged at 1 500 × *g* for 15 min, the supernatant was discarded, and the protein upper layer (yellowish) carefully removed with a stainless steel spatula. The decanted material was suspended in 0.1% NaOH solution, centrifuged at 1 500 × *g* for 15 min, the supernatant was discarded and the upper layer removed carefully. The decanted starch was suspended in distilled water, and the pH was adjusted to 6.5 with 0.2 mol/L HCl, and then the sample was centrifuged at 1 500 × *g* for 15 min. The supernatant was discarded and decanted starch was suspended in distilled water and centrifuged at 1 500 × *g* for 15 min. This procedure of suspending the decanted starch in distilled water and centrifuging was repeated three times. Starch was dried in air circulating oven at 40 ºC, ground in mortar with pestle, sieved (150 μm) and stored in a sealed glass flask.

Starch irradiation

The starch samples (200 g, approximately 9% moisture) were packed in high density polyethylene bags and subjected to 1, 2 and 5 kGy gamma radiation at a dose rate of 0.4 kGy/h in ^{60}Co gamma irradiator (Gammacell, 220 Excel, GC-220E, Nordion Inc., Ottawa, Canada) at room temperature. The irradiation treatments were performed at the Center for Nuclear Energy in Agriculture, University of São Paulo, Piracicaba, Brazil. A non-irradiated sample (dose 0) was used as a control.

Starch digestibility

In vitro starch digestibility was analyzed in raw and cooked starch samples according to Englyst et al (1992) with modification. An enzyme solution was