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Starch Digestibility and Physicochemical and Cooking Properties of Irradiated Rice Grains

Luís Fernando POLESI[1], Manoel Divino da MATTA JUNIOR[2], Silene Bruder Silveira SARMENTO[2], Solange Guidolin CANNIATTI-BRAZACA[2]

(*[1]Department of Food Engineering, Federal University of Rondônia, Ariquemes 76872-848, Rondônia, Brazil; [2]Department of Agroindustry, Food and Nutrition, College of Agriculture Luiz de Queiroz, University of São Paulo, Piracicaba 13418-900, São Paulo, Brazil*)

Abstract: This study evaluated the starch digestibility, physicochemical properties and cooking characteristics of polished rice (varieties IRGA417 and IAC202) subjected to the doses of 0 (as the control), 1, 2 and 5 kGy of gamma radiation. The highest dose decreased the apparent amylose content, peak viscosity, water absorption and volume expansion. Irradiation increased the solid loss by 119% and 187% for IAC202 and IRGA417, respectively, when comparing the higher dose with the control. For IAC202, irradiation decreased the rapidly digestible starch and increased the slowly digestible starch (SDS) and resistant starch (RS). IRGA417 showed an elevation of SDS and a reduction in RS. And 1 kGy dose of gamma radiation generated the highest level of RS for both the two varieties and presented the smallest changes in other physicochemical and cooking properties.

Key words: *Oryza sativa*; gamma radiation; ^{60}Co; amylose; starch; digestibility; cooking property

Rice is one of the most produced and consumed grains in the world, characterized as the primary source of food for over half of the world's population. Rice is also an important source of energy for human consumption because of its high concentration of starch and source of proteins, vitamins and minerals (Walter et al, 2008). Starch is a polysaccharide that is composed of two macromolecules, amylose and amylopectin. Amylose is an essentially linear macromolecule and composed of α-1,4-linked glucose units, with less than 0.1% branching. Amylopectin is branched and consists of α-1,4- and α-1,6-linked glucose units (Bello-Pérez et al, 2006).

Starch can be classified based on the length of time for digestion *in vitro*. Rapidly digestible starch (RDS) is converted to glucose within 20 min, slowly digestible starch (SDS) is converted to glucose within 20 to 120 min, and resistant starch (RS) resists the action of digestive enzymes for at least 120 min (Englyst et al, 1992). RDSs can cause an abrupt increase in blood glucose level after intake, while SDSs are completely digested in the small intestine, promoting a slow rate of increase in blood glucose compared to RDSs. RSs are not digested in the small intestine by the action of digestive enzymes but instead are fermented in the large intestine by the action of intestinal microflora (Chung and Liu, 2009).

The potential health benefits of SDS are associated with stable glucose metabolism, diabetes control, mental performance and satiety (Lehmann and Robin, 2007). The health benefits of RS include the prevention of colon cancer, prevention of the hyperglycemic effect, a substrate for the growth of probiotics and microorganisms, reduction of gallstone formation, hypocholesterolemic effect, inhibition of fat accumulation and increased absorption of minerals (Sajilata et al, 2006).

Irradiation is used in rice mainly to control insect infestation, reduce microbial load and quality loss during storage and ensure sanitary quality. Food

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Corresponding author: Luís Fernando POLESI (lfpolesi@yahoo.com.br)

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irradiation is more practical and hygienic because it can be performed in the package because of the high penetration power of gamma rays (Bao et al, 2005; Zuleta et al, 2006).

Gamma radiation modifies the starches presenting in foods because it generates free radicals that are capable of inducing molecular alterations, mainly fragmentation, of the starch macromolecules. The irradiation process leads to the formation of cross-links, β-bonds, carboxyl groups and structural changes, which can reduce the digestibility of starch (Bhat and Karim, 2009; Chung and Liu, 2009). Other researchers have observed increases in starch digestibility, attributing this fact to the loss of the granular structure and molecular fragmentation of starch, which facilitate access to amylolytic enzymes (Bhat and Karim, 2009; Yoon et al, 2010). These modifications that alter digestibility also interfere with the cooking properties of rice, which are largely controlled by starch (Wootton et al, 1988; Sirisoontaralak and Noomhorm, 2006). Thus, the objective of this study was to evaluate the starch digestibility, physicochemical and cooking properties of rice grains subjected to the gamma radiation.

MATERIALS AND METHODS

Rice materials

Brazilian rice varieties IAC202 (containing 9.7% moisture, 6.6% protein, 0.2% lipid and 0.2% ash), provided by Instituto Agronomico de Campinas (IAC), Brazil, and IRGA417 (containing 10% moisture, 7.5% protein, 0.3% lipid and 0.3% ash), provided by the Instituto Rio Grandense do Arroz (IRGA), Brazil, were used. Both varieties are white, long-grain and polished rice.

Irradiation of rice grains

Polyethylene bags containing 500 g rice grains were subjected to gamma radiation doses of 0 (as the control), 1, 2 and 5 kGy at a dose rate of 0.4 kGy/h in ^{60}Co gamma irradiator (Gammacell, 220 Excel, GC-220E, Nordion Inc., Ottawa, ON, Canada). These doses were based on pre-tests (data not shown) and were necessary to ensure higher shelf life by insect disinfestation. Irradiation was performed in triplicate (3 packs of 500 g for each dose). The samples were analyzed immediately after irradiation, without storing them for long periods.

Apparent amylose content (AAC)

AAC was determined according to the method of Martínez and Cuevas (1989) with adaptations according to Zavareze et al (2009).

Starch digestibility

Starch digestibility was performed on raw and cooked rice. Approximately 0.5 g milled rice was used for the first determination, and 3 g raw rice grains were used for the second determination, which were placed in a Petri dish (60 mm) containing 6 mL distilled water and cooked for 20 min in water vapor. After cooking, the samples were left to stand for 5 min prior to the evaluation of digestibility. Starch digestibility was performed according to the method of Englyst et al (1992) with adaptations. For raw sample, 0.5 g milled rice was added into 0.1 mol/L sodium acetate buffer (pH 5.2) containing 4 mmol/L $CaCl_2$ (20 mL) and kept in a shaking water bath at 37 ºC for 5 min to homogenize the temperature. For cooked sample, 1.0 g freshly cooked rice and 10 mL of 0.1 mol/L sodium acetate buffer (pH 5.2) containing 4 mmol/L $CaCl_2$ were added in a 50 mL test tube. The sample was homogenized and transferred to a beaker (100 mL), and the tube was rinsed twice with 5 mL of 0.1 mol/L sodium acetate buffer. The temperature was homogenized at 37 ºC for 5 min. From this point, the procedures were carried out according to Englyst et al (1992).

Total dietary fiber

Total dietary fiber was determined using the enzymatic-gravimetric method AOAC985.29 (AOAC, 2006).

Pasting properties

Pasting properties of the milled rice were evaluated using a Rapid Visco Analyzer (RVA-S4A, Newport Scientific, Warriewood, NSW, Australia) according to AACC method 61-02 (AACC, 2000).

Cooking properties

The minimal cooking time (MCT), water absorption (WA), solid loss (SL) and volume expansion (VE) of rice grains were determined according to the methods described by Bassinello et al (2004) and Cui et al (2010) with some modifications. For MCT test, 4 g rice grains were added into 135 mL boiling distilled water. After 10 min, a few grains were removed, placed on a glass plate and pressed firmly against