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Effect of Gamma Irradiation on Some Rice Varieties Properties

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Abstract

This study aimed to evaluate the effect of gamma irradiation at dose levels of 0, 1, 3 and 5kGy on the chemical composition, starch digestibility, pasting properties and cooking properties of two varieties of polished rice (Sakha104 and basmati). The results showed that the highest dose of gamma irradiation decreased the apparent amylose content, peak viscosity water absorption and minimum cooking time; while the fat absorption and solid loss were slightly increased. Irradiation showed increases in rabidly digestible starch (RDS) and slowly digestible starch (SDS), with consequent reductions in resistant starch (RS) for Sakha104variety. Furthermore, basmati rice displays a linear behavior over the range of radiation doses for RDS and SDS with a reduction in RS.

Key words: rice varieties; gamma radiation; chemical composition; pasting properties; starch digestibility; cooking properties,

Introduction

Rice is the staple food of more than half of the world's population – more than 3.5 billion people depend on rice for more than 20% of their daily calories **(FAO, 2020)**. Rice provides about 75% of the calorie and 55% of the protein in the average daily diet of the people **(Anonymous, 2002)**.

Irradiation is used in rice mainly to control insect infestation, reduce microbial load , quality loss during storage and ensure sanitary quality. Food 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 and Zuleta *et al.*, 2006)**. Gamma radiation was 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 crosslinks, α-bonds, carboxyl groups and structural changes, which can reduce the digestibility of starch **(Bhat and Karim, 2009 and 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 and Yoon *et al.*, 2010)**.

Gewaily *et al.* (2018) found that the chemical composition of white rice seeds (Sakha 104 variety) for moisture content, crude protein, ether extract, ash, crude fiber and available carbohydrate were: 10.55, 6.77, 0.46, 0.65, 1.82 and 79.74%, respectively (on wet weight basis).

Guimarães *et al.* (2012) studied the chemical composition of rice subjected to different doses of Co^{60} gamma radiation (0 kGy, 6.5 kGy and 7.5 kGy) by determination the moisture, protein, lipid, fibers, total carbohydrates and caloric value. The result showed that, doses of 6.5 kGy and 7.5 kGy had no significant effect (p>0.05) on the chemical composition of rice. They found that the samples of polished white rice contained moisture (12.01%), protein (7.32%), ash (0.48%), raw fiber average amount (0.3%) and total carbohydrate (78%).

Bhattacharjee *et al*. (2002) reported that the proximate chemical composition of Basmati 257 variety was 9.04% moisture, 9.13% protein, 2.38% crude lipids, 1.15% ash, 0.95% crude fiber and 77.35% total carbohydrate (on wet weight basis).

Galal *et al*. (2019) found that the chemical composition of white rice grains (Basmati) contained 11.87±0.53% moisture, 6.72±0.44% crude protein, 1.35±o.23% crude fiber, 1.27±0.29% ash and 1.24±0.33% fat.

Kumar *et al.* (2017) studied the effect of different doses of gamma radiation (from 5 to 20 kGy on the apparent amylose content (AAC) of brown rice starch. AAC showed decreasing trend significantly with an increase in irradiation dose. For native starch, AAC was found to be 26.22% which decreased to 17.91% for 20 kGy treated sample.

Gul *et al.* (2016) studied the effect of gamma radiation at dose levels of 0, 2 and 10 kGy on the pasting properties of starches isolated from two recently released rice cultivars. They found a significant difference in pasting properties by irradiation. Final viscosity of the starch paste decreased significantly after irradiation from 4218 to 323.1cP for starch separated from PR 121 and 4550 to 398cP for PR 116.

Irradiation caused a decrease in the viscosity of the starch pastes in both rice cultivars, which was proportional to the dose. Peak viscosity showed reduction with increasing doses of gamma radiation. Breakdown viscosity showed the highest values at 1 kGy for IAC202 and 2 kGy for IRGA417. Nevertheless, when the breakdown is compared to the peak viscosity, it is possible to observe an increase of the breakdown viscosity with the increasing doses.

Also, pasting temperature reduced with irradiation for IAC202 and increased for IRGA417 **(Polesi et al. 2018)**.

The aim of this study is to evaluate the effect of gamma irradiation on the chemical composition, starch digestibility, pasting properties and cooking properties of two varieties of polished rice (Sakha104 and basmati)

Materials and Methods

Egyptian rice variety (Sakha 104) and Indian rice variety (Basmati) provided by the EL-RAYES HERBAL SHOP (EGYPT), were used. Both varieties are white and polished rice were procured from local market in Cairo Government.

Irradiation process:

Polyethylene bags containing 500 g rice grains were irradiated by gamma radiation doses of 0 (as the control), 1, 3 and 5 kGy at a dose rate of 5.5 Gy/sec in Cobalt-60 at the National Center for Radiation Research and Technology, Nasr City, Cairo (NCRRT). The irradiation facility used was Egypt industrial mega gamma-1, model "AECL JS 6500 Irradiator" provided with two automatic conveyors. The samples were analyzed immediately after irradiation, without storing them for long periods.

Chemical composition analysis:

Moisture, fat, protein, and ash, was determined according to **(AOAC, 2010)** methods, while total Carbohydrate content was determined by difference.

Apparent amylose content (AAC):

Amylose content was determined in reference to the standard curve and expressed on percent basis **(Jain *et al*., 2012)**.

Scanning electron microscopy (SEM):

The microstructure of the surface, cross section, and longitudinal sections were observed using an electron microscope (JEOL-JSM-5500LV) at 20 kV by using high vacuum mode and the micrographs were viewed, recorded and downloaded **(Hsu *et al*., 2015)**.

Pasting properties:

To describe the changes of The Rapid Visco Analyzer (RVA) profile caused by gamma irradiation, the starch viscosity was determined by BROOKFIELD (Model-DVш HEAD UNIT, MA 02072 U.S.A.) The temperature was first maintained at 50oC for 1 min to have a uniform temperature and then raised to 95°C at a rate of 12°C/min. The sample was maintained at 95°C for 2.5 min, and then cooled to 50°C at a rate of 12°C/min. After the sample was maintained at 50°C for 1.5 min, the determination of pasting behavior was concluded. The paddle will rotate at 960 rpm for the first 10 s, then at 160 rpm for the remainder of the test. The parameters of starch pasting curve were used as follows: peak viscosity (PKV), hot pasting viscosity (HPV), cool pasting viscosity (CPV). The viscosity unit was RVU (rapid visco units) **(Yu and Wang, 2007)**.

In vitro starch digestibility:

In vitro starch digestibility was determined according to the procedure of **Englyst *et al*. (1992)** with some modifications.

The digestibility measurement was consistent with that described by **Englyst *et al.* (1992)** rapidly digestible starch (RDS) as the starch that was hydrolyzed with in 20 m in of incubation, slowly digestible starch (SDS) as the starch digested during the period between 20 and 120 min, and resistant starch (RS) as the starch that was not hydrolyzed with in120 min described by **Chung *et al.* (2010)**.

Cooking methods:

Boiling method (traditional method):

One hundred gram of milled rice was cleaned from dirt and foreign objects then washed with clear water (two times) and drained 2 minutes. Put the rice in pan pot and added 150 ml of distilled water. The rice was cooked in a covered pot until boiling. Then stirring done 10 times after water boiling (100°C). The cooking times of method were 10 minutes as described by **Syafutri *et al*. (2016)**.

Steaming method (modern cooking method):

The cooking procedure was automatically controlled by the cooker which automatically switched off when cooking was done. For comparison, the experiment was repeated for three times as described by **Parka and Han (2016)**.

Cooking properties:

The minimal cooking time (MCT), water absorption (WA), cooking solid loss (SL) and fat absorption capacity were determined according the method described by **Bassinello *et al*. (2004) and Cui *et al*. (2010)**.

Statistical analysis:

The statistical analysis was carried out using two-way ANOVA using SPSS, ver. 22 (IBM Corp. Released 2013). Data were treated as a complete randomization design according to **Steel *et al.* (1997)**. Multiple comparisons were carried out applying Duncun test. The significance level was set at < 0.05.

Results and Discussion

1. Chemical composition of rice:

Data in Table (1) showed that the chemical composition of raw white rice Sakha104 and Basmati before and after irradiation. The effect gamma irradiation on the proximate composition of rice such as moisture, ash, fat, crude protein and total carbohydrates of Sakha104 and basmati rice are summarized in Table (1). Native control rice moisture, protein, fat, ash and total carbohydrates of 9.72±0.04, 6.18±0.09, 1.11±0.00, 1.45±0.01 and 91.26±0.10, for Sakha104, respectively and 9.72±0.25, 7.31±0.01, 0.96± 0.08, 1.76±0.01 and 89.97±0.07 for Basmati rice, respectively. Gamma irradiation was non significantly influence the moisture, fat and ash contents of the Sakha104 type. But, there was a significant difference in moisture content between the sample of Sakha104 and Basmati rice after irradiated. While there were significant differences in crude protein and total carbohydrates between control and other doses in the same type. On the other hand, fat and ash contents of basmati rice were not significantly different following gamma irradiation treatment (P>0.05). Significant variations were observed between the control and irradiated samples in moisture, crude protein and total carbohydrates contents in the same type. Similar to our results, **Lee and Kim (2018)** reported that the proximate chemical composition of brown rice flour was not changed significantly following gamma irradiation treatment.

Table 1. Effect of gamma irradiation on chemical composition of two rice varieties.

Dose (kGy)	Moisture (%)		Crude protein* (%)		Ether extract* (%)		Ash* (%)		Total carbohydrate (%)*@	
	Sakha104	Basmati	Sakha104	Basmati	Sakha104	Basmati	Sakha104	Basmati	Sakha104	Basmati
0	9.72 ±0.04^{cA}	9.72 ±0.25^{aA}	6.18 ±0.09^{bB}	7.31 ±0.01^{bA}	1.11 ±0.00^{aA}	0.96 ±0.08^{aB}	1.45 ±0.01^{aB}	1.76 ±0.01^{aA}	91.26 ±0.10^{bA}	89.97 ±0.07^{abB}
1	9.73 ±0.05^{bcA}	9.45 ±0.12^{bB}	7.10 ±0.53^{aA}	7.24 ±0.07^{bA}	0.96 ±0.04^{bA}	0.96 ±0.04^{aA}	1.47 ±0.01^{aB}	1.77 ±0.02^{aA}	90.46 ±0.52^{abA}	90.04 ±0.11^{abB}
3	9.99 ±0.08^{abA}	9.18 ±0.12^{cB}	7.40 ±0.33^{aB}	8.36 ±0.05^{aA}	1.04 ±0.10^{abA}	1.03 ±0.04^{aA}	1.47 ±0.02^{aB}	1.77 ±0.02^{aA}	90.09 ±0.26^{bA}	88.85 ±0.09^{bB}
5	10.03 ±0.12^{aA}	9.37 ±0.10^{bcB}	5.80 ±0.01^{cB}	6.96 ±0.02^{bA}	0.96 ±0.04^{bA}	0.96 ±0.04^{aA}	1.45 ±0.02^{aB}	1.76 ±0.02^{aA}	91.78 ±0.04^{aA}	90.33 ±0.02^{aB}
LSD at 0.05	Dose	Var.	Dose	Var.	Dose	Var.	Dose	Var.	Dose	Var.
	0.26	0.19	0.48	0.34	0.11	0.08	0.03	0.02	0.46	0.32

*: On dry weight basis @: Total charbohydrate calculated by different.

a, b & c: There is no significant difference (P>0.05) between any two means, within the same column have the same superscript letter.

A, B & C: There is no significant difference (P>0.05) between any two means for the same attribute, within the same row have the same superscript letter.

2. Apparent amylose content (AAC):

Apparent amylose content of the irradiated and non-irradiated rice samples are showed in Table (2). The results proved that the apparent amylose content (AAC) were with a significant decreasing trend with increasing the irradiation dose. AAC of non-irradiated rice was 21.69%, while AAC was reduced to 20.51, 19.22 and 17.62% at 1, 3 and 5 kGy doses, respectively for Sakha104 rice starch. For basmati rice the AAC was significantly decreased from 19.80 in control sample to 19.23, 18.02 and 17.001%, at 1, 3 and 5 kGy doses, respectively. The decrease of AAC could be due to the breakage or cleavage of partly branched long chains in amylopectin caused by gamma irradiation **(Yu and Wang, 2007)**. These results are in agreement with those reported by **Polesi *et al.* (2016)** who reported that the amylose content of a rice starch significantly increased following exposure to 5kGy irradiation. Also, **Gul *et al.* (2016)** reported that the AAC of rice starch tended to decrease with gamma radiation up to 10 kGy. The apparent amylose content of the native starch granules varies with the botanical origin, climatic conditions, and soil type **(Morrison *et al*., 1984)**.

The effect of gamma irradiation pretreatment on AAC was associated with the structure of starch. As we known, amylose is an essentially linear polymer of α-(1–4)-linked-D-glucopyranosyl units with up to 0.1% α-(1–6) linkages, with degree of polymerization of 800–4920. Amylopectin consist of α-(1–4)- linked-D-glucosyl chains and is highly branched with 5–6% α-(1–6)-bonds, with degree of polymerisation of 8200–12,800. Evidently, the content and degree of polymerization of amylopectin were so higher than that of amylose. This kind of decrease of AAC might avail human to digest rice starch, for the decreased starch molecule causing easier to hydrolyse by starch enzyme **(Chiang and Yeh, 2002 and Vandeputte and Delcour, 2004)**.

Table 2. Apparent amylose content of gamma irradiation two rice varieties .

Variety	Dose (kGy)			
	0	1	3	5
Egyptian rice (sakha104)	**21.69^{aA}**	**20.51^{aA}**	**19.22^{aB}**	**17.62^{aC}**
Basmati rice	**19.80^{bA}**	**19.23^{bA}**	**18.02^{bB}**	**17.00^{aB}**
Mean of dose	**20.75 ± 0.95^{A}**	**19.87 ± 0.64^{A}**	**18.62 ± 0.6^{B}**	**17.31 ± 0.31^{C}**
LSD at 0.05 for	**Variety**	**0.83**	**Dose**	**1.17**

a, b & c: There is no significant difference (P>0.05) between any two means, within the same column have the same superscript letter.
A, B & C: There is no significant difference (P>0.05) between any two means for the same attribute, within the same row have the same superscript letter.

3. Morphological properties of starch granules

The scanning electron microscope (SEM) photographs of starch granules revealed polygonal or irregular shapes in both irradiated and non-irradiated starch varieties (Sakha104 and basmati rice) (Figs. 1 and 2). However, surface cracking of starch granules was observed to increase with increasing irradiation dose. The cracks on the surface could be considered the effect of highly energetic and penetrating gamma radiations. The deformation of granular structure appeared to be dose dependent; however, the two varieties were not affected equally. Similar results were found by **Chung and Liu (2009)**. The changes in size of starch granules represented effect of irradiation on microstructure of rice grain. The size of starch granules of non-irradiated rice grain was large, and little small sized granules could be found. With increase of dose, the amount of small sized granules was increased. Similar phenomena could be found at the inner endosperm. This kind of breakage resulted in increased number of small sized starch granules. All the rice starch samples showed small polygonal granules with a smooth surface, but some have dents or hollows at one end. The difference in granule morphology may be attributed to the biological origin, biochemistry of the amyloplast and physiology of the plant **(Sandhu *et al.*, 2004).**

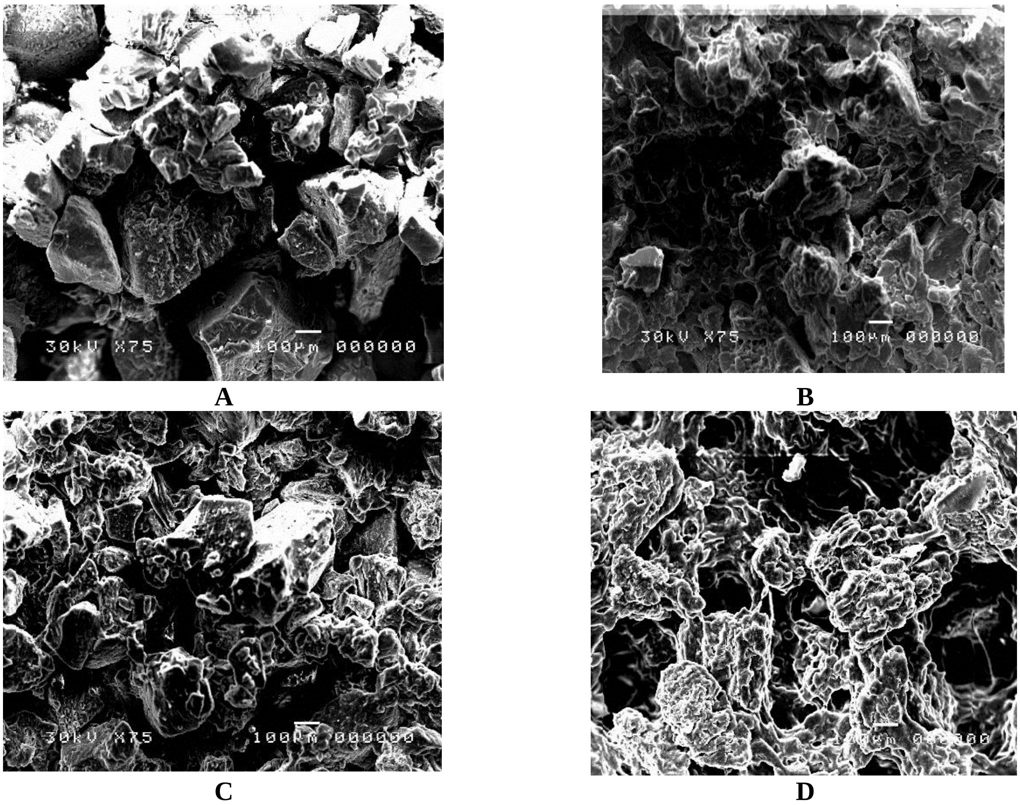

Fig. (1): Scanning Electron Micrographs: Effect of irradiation dose on the starch structure of outer Sakha104 rice endosperm: (A) 0 kGy; (B) 1 kGy; (C) 3 kGy and (D) 5 kGy.

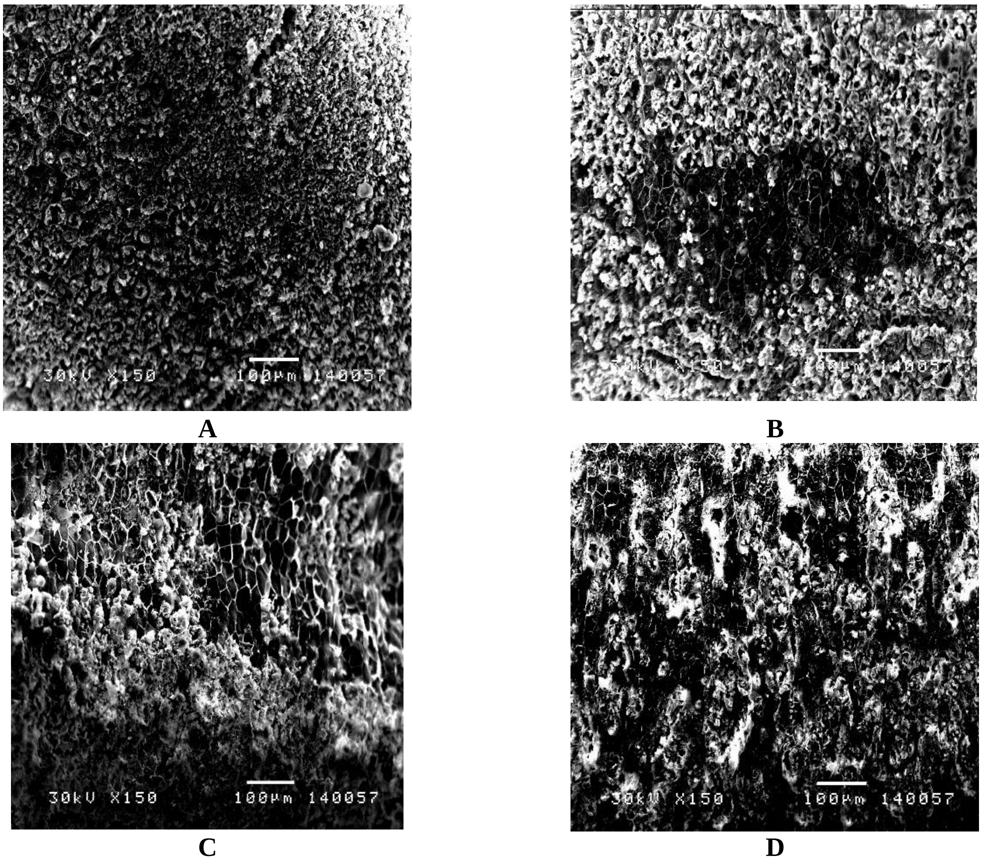

Fig. (2): Scanning Electron Micrographs: Effect of irradiation dose on the starch structure of outer Basmati rice endosperm: (A) 0 kGy; (B) 1 kGy; (C) 3 kGy and (D) 5 kGy.

4. Pasting properties of rice flour:

Two major parameters of starch pasting hot pasting viscosity (HPV), cool pasting viscosity (CPV), were measured by Brookfield at different velocity and the results presented in Tables (3 and 4). The results showed that, there was a reduction in rice viscosity with increasing doses of gamma radiation for both the two rice varieties. The comparison of CPV (50ºC) shows that this critical parameter was reduced from 122 to 86; 56 to 46; 38 to 33 and 34 to 29 at 25, 50, 75 and 100 rpm, respectively in Sakha104 variety. While, it was reduced from 82 to 34 ;50 to 48; 34 to 32 and 25 to 24 at 25, 50, 75 and 100 rpm, respectively in basmati variety.as shown in Table (3).

On the other hand, the HPV of Sakha104 type was reduced from 22400 to 18800; 15360 to 12280; 12240 to 9800 and 9870 to 8110 at 25, 50, 75 and 100 rpm, respectively. Furthermore, it reduced from 19400 to 4800; 12700 to 3200; 10000 to 2586 and 8690 to 2310 at 25, 50, 75 and 100 rpm, respectively in basmati type.

It was therefore likely that the observed decrease in HPV and CPV were due to the decreased of size of starch granules caused by gamma irradiation. With the increasing dose, an increasing numbers of starch granules ruptured before Rapid Visco Analyzer (RVA) processing, and the average size of starch granules in rice grain was decreased. These changes caused the decrease of rupture of swollen granules and the swelling degree of starch granule, and directly caused the decrease of HPV and CPV **(Vandeputte *et al*., 2003)**.

A reduction in rice viscosity with increasing doses of gamma radiation had been noticed in earlier studies by **(Sirisoontaralak and Noomhorm, 2006; Bao *et al,* 2005 and Yu and Wang, 2007).** These researchers attributed the reduction of viscosity to the breakdown that occurs in the starch macromolecules, with consequent reduction in the degree of polymerization and the degradation of granules. The degradation of starch macromolecules by the breaking of inter- and intra-molecular bonds promotes a reduction in the expansion capacity of granules and, consequently, a reduction of viscosity **(Chung and Liu, 2009 and Polesi *et al.,* 2016)**. The increase in the pasting temperature may be associated with the reduction in the amorphous regions of the starch granules, increasing the crystalline proportion, which is not so easily disrupted upon heating.

Table 3. Pasting properties of gamma irradiation two rice flour suspensions at cool viscosity (CPV) (50^{o}C).

Variety	Velocity (rpm)	Dose (kGy)			
		0	1	3	5
Egyptian rice (Sakha104)	25	122^{aA}	88^{aC}	108^{aB}	86^{aC}
	50	56^{bA}	48^{bB}	48^{bB}	46^{bB}
	75	38^{cA}	31^{cA}	35^{cA}	33^{cA}
	100	34^{cA}	24^{cB}	32^{cA}	29^{cAB}
Basmati rice	25	82^{aB}	60^{aC}	90^{aA}	34^{aAB}
	50	50^{bA}	32^{bB}	46^{bA}	48^{bA}
	75	34^{cA}	32^{bA}	27^{cA}	32^{cA}
	100	25^{dA}	24^{cA}	22^{cA}	24^{dA}
Mean of dose		0 55.06^{A}	1 42.35^{C}	3 51.04^{AB}	5 47.69^{B}
Mean of velocity		25 90.00^{A}	50 46.75^{B}	75 32.83^{C}	100 26.56^{C}
Mean of variety		Sakha104 53.57^{A}	Basmati 44.50^{B}		

a, b & c: There is no significant difference (P>0.05) between any two means, within the same column have the same superscript letter for each variety.

A, B & C: There is no significant difference (P>0.05) between any two means for the same attribute, within the same row have the same superscript letter.

Table 4. Pasting properties of gamma irradiation two rice flour suspensions at hot viscosity (HPV) (95^{o}C).

Variety	Velocity (rpm)	Dose (kGy)			
		0	1	3	5
Egyptian rice (Sakha104)	25	22400^{aB}	23280^{aB}	29920^{aA}	18800^{aC}
	50	15360^{bB}	15100^{bB}	21810^{bA}	12280^{bC}
	75	12240^{cB}	11600^{cB}	17302^{cA}	9800^{cC}
	100	9870^{dB}	9490^{dB}	14945^{dA}	8110^{dC}
Basmati rice	25	19400^{aA}	14160^{aB}	10920^{aC}	4800^{aD}
	50	12700^{bA}	9540^{bB}	6510^{bC}	3200^{bD}
	75	10000^{cA}	7280^{cB}	3560^{cC}	2586^{bD}
	100	8690^{dA}	5940^{dB}	2910^{dC}	2310^{bC}
Mean of dose		0 13833^{A}	1 12063^{B}	3 13485^{A}	5 7736^{C}
Mean of velocity		25 17960^{A}	50 12063^{B}	75 9296^{C}	100 7783^{D}
Mean of variety		Sakha104 15769^{A}	Basmati 7782^{B}		

a, b & c: There is no significant difference (P>0.05) between any two means, within the same column have the same superscript letter for each variety.

A, B & C: There is no significant difference (P>0.05) between any two means for the same attribute, within the same row have the same superscript letter.

5. Starch digestibility:

Raw rice of the two varieties promoted high levels of slowly digestible starch (SDS), intermediate levels of rabidly digestible starch (RDS) and low levels of resistant starch (RS) (Tables 5, 6 and 7). Irradiation showed increases trend which were 33.5, 33.9, 35.7 and 36.8; for RDS and 43.2, 44.0, 47.5 50.8 for SDS at doses of 0, 1, 3 and 5kGy, respectively;. Furthermore, basmati rice displays a linear behavior over the range of radiation doses for RDS and SDS as shown in tables (5) (6). While, RS showed a reduction for raw rice in the two varieties.

The cooking process of rice samples, in itself, appeared significant changes in the starch digestibility of grains. The cooked rice of both the two varieties showed higher levels of RDS and lower levels of SDS, as expected, as a consequence of starch gelatinization. RS in cooked samples was decreased with increasing the irradiation doses for basmati rice. For Sakha104, cooking was increased RS in the control and irradiated samples compared to raw samples. SDS tended to increase for both the two varieties with the increasing of the irradiation dose. Considering the health benefits of SDS and RS, irradiation may improve the polished white rice from the point of view of starch digestibility.

The starch digestibility of rice during consumption (cooked) is an important parameter. The increase in RDS after starch cooking is may be because the granular structure is lost and amylose is leached when the starch is gelatinized and more starch molecules are readily available for the enzyme, making it more susceptible according to **Polesi *et al.* (2018)**.

This result is in agreement with those obtained **Polesi *et al.* (2017)** who found that RS decreased with increasing the irradiation dose. Similarly, **Chung and Liu (2009) and Chung *et al*. (2010)** observed a decrease of RS in irradiated corn starch and waxy maize starch.

Table 5. Rabidly digestible starch of raw and cooked samples of gamma irradiated two rice varieties**.**

Variety	Condition	Dose (kGy)			
		0	1	3	5
Egyptian rice (Sakha104)	Raw	33.5^{bC}	33.9^{bC}	35.7^{bB}	36.8^{bA}
	Cooked	72.8^{aC}	72.8^{aC}	75.2^{aB}	77.5^{aA}
Basmati rice	Raw	31.9^{bD}	33.5^{bC}	36.2^{bB}	39.1^{bA}
	Cooked	76.7^{aD}	78.0^{aC}	81.6^{aB}	83.8^{aA}
Mean of dose		0	1	3	5
		53.73^{C}	54.55^{C}	57.16^{B}	59.30^{A}
Mean of velocity		Raw	Cooked		
		35.08^{B}	77.29^{A}		
Mean of variety		Sakha104	Basmati		
		54.78^{B}	57.59^{A}		

a, b & c: There is no significant difference (P>0.05) between any two means, within the same column have the same superscript letter for each variety.

A, B & C: There is no significant difference (P>0.05) between any two means for the same attribute, within the same row have the same superscript letter.

Table 6. Slowly digestible starch of raw and cooked samples of gamma irradiated two rice varieties**.**

Variety	Condition	Dose (kGy)			
		0	1	3	5
Egyptian rice (Sakha104)	Raw	43.2^{aC}	44.0^{aC}	47.5^{aB}	50.8^{aA}
	Cooked	5.8^{bB}	6.2^{bB}	8.0^{bB}	11.9^{bA}
Basmati rice	Raw	46.4^{aB}	46.9^{aB}	48.0^{aAB}	50.7^{aA}
	Cooked	8.2^{bC}	9.2^{bC}	12.3^{bB}	15.0^{bA}
Mean of dose		0	1	3	5
		25.91^{C}	26.58^{BC}	28.95^{B}	32.10^{A}
Mean of velocity		Raw	Cooked		
		47.19^{A}	9.58^{B}		
Mean of variety		Sakha104	Basmati		
		27.18^{B}	29.59^{A}		

a, b & c: There is no significant difference (P>0.05) between any two means, within the same column have the same superscript letter for each variety.

A, B & C: There is no significant difference (P>0.05) between any two means for the same attribute, within the same row have the same superscript letter.

Table 7. Resistant starch of raw and cooked samples of gamma irradiated two rice varieties.

Variety	Condition	Dose (kGy)			
		0	1	3	5
Egyptian rice (Sakha104)	Raw	12.6^{bA}	12.1^{bA}	9.1^{bB}	6.5^{aC}
	Cooked	15.0^{aA}	16.0^{aA}	11.7^{aB}	7.8^{aC}
Basmati rice	Raw	12.1^{aA}	12.9^{aA}	12.0^{aA}	8.9^{aB}
	Cooked	12.8^{aA}	11.2^{bAB}	9.4^{bB}	7.0^{bC}
Mean of dose		0	1	3	5
		13.13A	13.05A	10.55B	7.55C
Mean of velocity		Raw	Cooked		
		10.78A	11.36A		
Mean of variety		Sakha104	Basmati		
		11.35A	10.79A		

a, b & c: There is no significant difference (P>0.05) between any two means, within the same column have the same superscript letter for each variety.

A, B & C: There is no significant difference (P>0.05) between any two means for the same attribute, within the same row have the same superscript letter.

Starch digestibility is related to, among other factors, the crystallinity of the starch granules, as the crystalline regions prevent or hinder the access of digestive enzymes to the glucose chains. Gamma radiation may disrupt the both amorphous and crystalline regions of the granule depending on the dose applied. Furthermore, the dose rate may influence starch modifications. Lower doses, in addition to disrupting molecules, may induce the recombination of fragmented structures **(Chung and Liu, 2009)**. The cleavage of glycosidic bonds increases the access of digestive enzymes to starch molecules and facilitates digestibility. On the other hand, the cleaved chains may have higher mobility to align in a packed matrix, which will be less accessible to enzymes **(Yoon *et al*., 2010).** Therefore, the differences in starch crystallinity associated with the formation of β-bonds, carboxyl groups and cross-linking, that may occur in starch during irradiation **(Chung and Liu, 2009)**, can justify the differences observed between doses and varieties in this study.

1.6. Cooking properties

Based on an analysis of the cooking properties of rice grains (Table 8), the minimum cooking time (MCT) decreased with the increasing of irradiation dose in the two rice varieties. MCT of control sample was 21.12 min and reduced to 12.30, 8.51 and 7.57 min for the treated samples for, Sakha104; while it was 27.00, 16.21, 10.30 and 8.15 min for control, 1, 3 and 5 kGy, respectively in basmati rice variety.

The results of water absorption (WA) of native as well as irradiated rice starches are shown in (Table 5). The increasing doses of gamma irradiation caused a slightly decrease in WA in both rice variety. The WA of Sakha104 rice sample was 5.00 ml in control sample and reduced to 4.50, 4.50 and 4.20 ml in treated samples by 1, 3 and 5 kGy doses, respectively. In the case of basmati rice WA was 3.70 ml, while after irradiation treatment by 1, 3 and 5 kGy reduced to 3.30, 2.80 and 2.80 ml, respectively.

After cooking in excess water, the total solids leaked in cooking water was increased by increasing the irradiation dose compared to the control sample. SL in Sakha104 was 0.21 g and increased to 0.38, 0.52 and 0.57 g in the treated samples by 1, 3 and 5 kGy, respectively. While basmati variety, the SL was 0.12 g and increased to 0.15, 0.15 and 0.18 g in the treated samples by 1, 3 and 5 kGy, respectively. Fat absorption (FA) of native and irradiated rice samples was presented in table 5. The results observed that, FA of Sakha104 control sample was 0.20 g, while it increased to 0.40, 0.80 and 1.20 g in the treated samples by 1, 3 and 5 kGy respectively.

The increase in FA of irradiated flours may be attributed to unmasking of non-polar protein residues as a result of protein denaturation induced by irradiation **(Lee and Song, 2002)**,and the degradation and crosslinking of starch due to irradiation resulting in its enhanced ability to physically entrap more oil **(Sathe *et al*., 1982). Sultan *et al.* (2018)** reported that the effect of gamma irradiation on FA of brown rice flour was insignificant at lower doses of irradiation. However, significant increase in FA was observed with increase in irradiation dose. Also **Bashir and Aggarwal (2017)** showed a significant increase in FA at dose ≥ 2.5 kGy.

Table 8. Cooking properties of gamma irradiated two rice varieties**.**

Parameters	Variety	Dose (kGy)			
		0	1	3	5
MCT (min)	**Sakha104**	**21.12^{bA}**	**12.30^{bB}**	**8.51^{aB}**	**7.57^{aB}**
	Basmati	**27.00^{aA}**	**16.21^{aB}**	**10.30^{aC}**	**8.15^{aC}**
WA (ml)	**Sakha104**	**5.00^{aA}**	**4.50^{aB}**	**4.50^{aB}**	**4.20^{aB}**
	Basmati	**3.70^{bA}**	**3.30^{bA}**	**2.80^{bC}**	**2.80^{bC}**
SL (g)	**Sakha104**	**0.21^{aB}**	**0.38^{aAB}**	**0.52^{aAB}**	**0.57^{aA}**
	Basmati	**0.12^{aA}**	**0.15^{bA}**	**0.15^{bA}**	**0.18^{bA}**
FA (g)	**Sakha104**	**0.20^{bC}**	**0.40^{bBC}**	**0.80^{aAB}**	**1.20^{aA}**
	Basmati	**0.70^{aB}**	**1.10^{aAB}**	**1.10^{aAB}**	**1.40^{aA}**

a, b & c: There is no significant difference (P>0.05) between any two means, within the same column have the same superscript letter for each parameter.

A, B & C: There is no significant difference (P>0.05) between any two means for the same attribute, within the same row have the same superscript letter.

The reduction in WA and the increasing in FA are likely due to the degradation of starch granular structure and a decrease in the degree of polymerization of amylose and amylopectin **(Polesi *et al*., 2016)**, which also cause reduction in viscosity. Irradiation reduces the expansion power of starch granules by decreasing the crystalline regions of starch **(Singh *et al*., 2011)**.

An increase in SL due to rice irradiation was also observed by **Sirisoontaralak and Noomhorm (2006)**, who attributed this behavior to the increased solubility of starch by the degradation of amylose and amylopectin molecules into smaller fragments. Together, these facts also explain the reduction observed in the WA and increasing in the FA values.

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تأثير أشعة جاما على خصائص بعض أصناف الأرز

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هدفت هذه الدراسة إلى تقييم تأثير أشعة جاما عند جرعات صفر، 1، 3 و5 كيلوجراى على التركيب الكيميائي، هضم النشا، خصائص اللزوجة وخصائص الطبخ لصنفين من الأرز (سخا 104 وبسمتي). أظهرت النتائج أنه مع زيادة الجرعة الإشعاعية حدث إنخفاض فى كل من محتوى الأميلوز الكلى الظاهري، اللزوجة، إمتصاص الماء و زمن الطبخ. بينما أدى إلى حدوث زيادة طفيفة فى إمتصاص الدهن وفقدان المواد الصلبة فى ماء الطبخ. كما أدت المعاملة بأشعة جاما إلى زيادة معدل السرعة فى هضم النشا والبطئ فى هضم النشا، مع حدوث إنخفاض في النشا المقاوم في صنف سخا 104. كما أظهرت النتائج أنه بالنسبة للأرز البسمتي كانت هناك علاقة خطية بين زيادة الجرعة الإشعاعية و معدلات السرعة فى هضم النشا والبطئ فى هضم النشا مع حدوث إنخفاض في معدل النشا المقاوم.