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Effect of gamma irradiation on physicochemical, functional and pasting properties of some locally-produced rice (*Oryza spp*) cultivars in Ghana

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HIGHLIGHTS

- Effect of gamma irradiation on properties of some rice cultivars in Ghana was investigated.
- Gamma irradiation decreased pH and swelling power, whereas solubility increased.
- Gamma irradiation did not change the XRD pattern of the rice cultivars.
- Gamma irradiation decreased peak time for BAL and VNT rice cultivars.
- Gamma irradiation decreased PV, HPV, BDV, FV and SBV for all the rice cultivars.

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ABSTRACT

Rice (*Oryza sativa L.)* is a staple crop in Ghana and much of West Africa, where it serves as an important convenience food for urban consumers. The objective of this study was to determine the effect of gamma irradiation as insect disinfestation technique on some physicochemical, functional and pasting properties of selected locally-produced rice cultivars in Ghana. Four local rice cultivars and an imported (commercial) type were purchased, cleaned and irradiated at doses of 0.0, 0.25, 0.50, 0.75, 1.0 and 1.5 kGy. The irradiated rice cultivars were milled and their physicochemical, functional and pasting properties determined. There were reductions in pH and swelling power, as well as increase in solubility of rice cultivars after gamma irradiation. Gamma irradiation did not change the XRD pattern of the rice cultivars. Gamma irradiation significantly ($P < 0.05$) decreased peak time for BAL and VNT rice cultivars. Gamma irradiation significantly ($P < 0.05$) decreased PV, HPV, BDV, FV and SBV for all the rice cultivars. This study shows that flours from gamma irradiated rice cultivars have potential in food formulations that require low viscosity.

1. Introduction

Rice (*Oryza sativa L.)* has become a staple in Ghana and much of West Africa where it serves as an essential convenience food for urban people (Tomlins et al., 2007). Rice recorded the highest deficit (210,700 metric tonnes) on the domestic food supply and demand position for Ghana in 2008, with a per capita consumption of 15.1 kg/annum and an estimated national consumption of 353,300 metric tonnes (Ayittey and Banini, 2009). In Ghana, rice is utilized in a broad range of food products; the most common include 'jollof rice', 'rice balls', rice porridge, fried rice and plain-cooked rice. Although rice forms a major part of the Ghanaian diet, locally grown rice is not patronized due to its variable quality. Several factors account for the variability in rice quality, and the most prominent factors being poor sensory and physical qualities (Tomlins et al., 2005). These quality defects arise not only from inappropriate post-harvest handling, but also from poor planting materials and poor agronomic practices (Gayin et al., 2009).

Due to its chemical composition and production chain, rice is susceptible to infestation by insects which reduces the economic

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Table 1
Effect of gamma irradiation on some physicochemical and functional properties of rice cultivars.[†]

Cultivar/ Type	Dose (kGy)	Moisture (%)	pH	Bulk density (g/ml)	Solubility (%)	Swelling power (g/g)	Water Absorption capacity (ml/g)	Oil absorption capacity (ml/g)
BAL	0	$12.7^{de} \pm 0.1$	$6.10^{l} \pm 0.00$	$0.91^{efgh} \pm 0.02$	$7.3^{abcdefg} \pm 1.0$	$8.6^{fg} \pm 0.6$	$1.5^{efg} \pm 0.1$	$1.2^{bc} \pm 0.2$
	0.25	$12.7^{de} \pm 0.1$	$6.70^{r} \pm 0.00$	$0.89^{cdef} \pm 0.01$	$8.2^{abcdefgh} \pm 3.2$	$8.5^{fg} \pm 0.4$	$1.4^{def} \pm 0.0$	$1.2^{bc} \pm 0.2$
	0.50	$12.5^{de} \pm 0.2$	$6.04^{i} \pm 0.00$	$0.85^{bc} \pm 0.04$	$9.6^{efghi} \pm 1.5$	$8.8^{g} \pm 0.4$	$1.4^{def} \pm 0.0$	$1.3^{cd} \pm 0.1$
	0.75	$12.4^{de} \pm 0.1$	$6.05^{j} \pm 0.00$	$0.89^{cdef} \pm 0.07$	$9.0^{defgh} \pm 2.0$	$8.2^{efg} \pm 0.7$	$1.4^{def} \pm 0.0$	$1.3^{cd} \pm 0.2$
	1.0	$12.8^{e} \pm 0.1$	$6.05^{j} \pm 0.00$	$0.91^{efgh} \pm 0.03$	$9.3^{defghi} \pm 2.6$	$7.8^{def} \pm 0.1$	$1.3^{cde} \pm 0.1$	$1.3^{cd} \pm 0.2$
	1.5	$12.6^{de} \pm 0.1$	$6.05^{j} \pm 0.00$	$0.82^{ab} \pm 0.03$	$7.0^{abcdef} \pm 0.6$	$7.9^{defg} \pm 0.2$	$1.2^{bcd} \pm 0.0$	$1.4^{de} \pm 0.1$
VNT	0	$11.8^{abcde} \pm 0.0$	$5.95^{h} \pm 0.00$	$0.89^{cdef} \pm 0.05$	$6.8^{abcde} \pm 0.1$	$7.5^{cde} \pm 0.6$	$1.3^{cde} \pm 0.1$	$1.4^{de} \pm 0.1$
	0.25	$12.3^{de} \pm 0.1$	$5.93^{g} \pm 0.00$	$0.86^{bcd} \pm 0.02$	$6.9^{abcdef} \pm 0.4$	$7.7^{def} \pm 0.8$	$1.4^{def} \pm 0.2$	$1.4^{de} \pm 0.1$
	0.50	$12.3^{de} \pm 0.0$	$5.92^{f} \pm 0.00$	$0.88^{cde} \pm 0.02$	$12.0^{ijk} \pm 2.0$	$7.0^{bcd} \pm 0.4$	$1.4^{def} \pm 0.1$	$1.1^{ab} \pm 0.1$
	0.75	$11.7^{abcd} \pm 0.1$	$5.93^{g} \pm 0.00$	$0.91^{efgh} \pm 0.01$	$15.0^{lmn} \pm 1.2$	$7.9^{defg} \pm 0.5$	$1.2^{bcd} \pm 0.1$	$1.2^{bc} \pm 0.1$
	1.0	$11.7^{abcd} \pm 0.1$	$5.92^{f} \pm 0.00$	$0.85^{bc} \pm 0.02$	$16.3^{mn} \pm 0.5$	$7.8^{def} \pm 0.2$	$1.4^{def} \pm 0.0$	$1.2^{bc} \pm 0.2$
	1.5	$12.1^{cde} \pm 0.1$	$5.93^{fg} \pm 0.00$	$0.88^{cde} \pm 0.02$	$6.0^{ab} \pm 1.0$	$7.9^{defg} \pm 0.8$	$1.3^{cde} \pm 0.1$	$1.1^{ab} \pm 0.1$
VNS	0	$12.6^{de} \pm 0.1$	$6.10^{l} \pm 0.00$	$0.96^{i} \pm 0.02$	$19.8^{o} \pm 2.0$	$6.6^{bc} \pm 0.4$	$1.1^{abc} \pm 0.1$	$1.4^{de} \pm 0.1$
	0.25	$12.5^{de} \pm 0.0$	$6.11^{m} \pm 0.00$	$0.91^{efgh} \pm 0.01$	$13.1^{jkl} \pm 2.4$	$5.6^{a} \pm 1.3$	$1.2^{bcd} \pm 0.1$	$1.4^{de} \pm 0.1$
	0.50	$12.3^{de} \pm 0.1$	$6.10^{l} \pm 0.00$	$0.86^{bcd} \pm 0.01$	$8.6^{bcdefgh} \pm 0.4$	$6.1^{ab} \pm 0.5$	$1.2^{bcd} \pm 0.2$	$1.3^{cd} \pm 0.1$
	0.75	$12.5^{de} \pm 0.1$	$5.81^{d} \pm 0.00$	$0.87^{cde} \pm 0.02$	$14.1^{klm} \pm 1.8$	$6.6^{bc} \pm 0.2$	$1.2^{bcd} \pm 0.0$	$1.4^{de} \pm 0.0$
	1.0	$12.0^{bcde} \pm 0.0$	$6.04^{i} \pm 0.00$	$0.90^{defg} \pm 0.02$	$8.8^{cdefgh} \pm 1.4$	$7.1^{cd} \pm 0.5$	$1.1^{abc} \pm 0.1$	$1.4^{de} \pm 0.1$
	1.5	$12.5^{de} \pm 0.1$	$6.08^{k} \pm 0.00$	$0.86^{bcd} \pm 0.02$	$10.0^{ghi} \pm 1.0$	$7.0^{bcd} \pm 0.2$	$1.0^{a} \pm 0.1$	$1.4^{de} \pm 0.0$
VWR	0	$12.6^{de} \pm 0.0$	$6.31^{p} \pm 0.00$	$0.87^{cde} \pm 0.02$	$5.4^{a} \pm 0.3$	$7.9^{defg} \pm 0.1$	$1.1^{abc} \pm 0.1$	$1.2^{bc} \pm 0.1$
	0.25	$14.5^{f} \pm 3.5$	$6.29^{o} \pm 0.00$	$0.88^{cde} \pm 0.02$	$8.0^{abcdefgh} \pm 1.6$	$10.3^{h} \pm 0.2$	$1.2^{bcd} \pm 0.0$	$1.0^{a} \pm 0.2$
	0.50	$12.7^{de} \pm 0.0$	$6.23^{n} \pm 0.00$	$0.78^{a} \pm 0.03$	$6.7^{abcd} \pm 0.1$	$8.6^{fg} \pm 0.3$	$1.1^{abc} \pm 0.1$	$1.3^{cd} \pm 0.3$
	0.75	$12.3^{de} \pm 0.1$	$6.32^{q} \pm 0.00$	$0.81^{a} \pm 0.03$	$8.9^{defgh} \pm 1.6$	$8.5^{fg} \pm 0.8$	$1.2^{bcd} \pm 0.1$	$1.3^{cd} \pm 0.1$
	1.0	$12.6^{de} \pm 0.3$	$5.89^{e} \pm 0.00$	$0.92^{fgh} \pm 0.01$	$8.5^{bcdefgh} \pm 0.8$	$8.8^{g} \pm 1.3$	$1.2^{bcd} \pm 0.1$	$1.4^{de} \pm 0.2$
	1.5	$12.6^{de} \pm 0.0$	$6.31^{p} \pm 0.00$	$0.88^{cde} \pm 0.04$	$9.7^{fghi} \pm 1.4$	$8.8^{g} \pm 0.7$	$1.2^{bcd} \pm 0.1$	$1.3^{cd} \pm 0.1$
JAS	0	$11.1^{abc} \pm 0.1$	$5.59^{b} \pm 0.00$	$0.86^{bcd} \pm 0.00$	$6.1^{abc} \pm 1.4$	$7.8^{def} \pm 0.8$	$1.6^{gh} \pm 0.1$	$1.1^{ab} \pm 0.1$
	0.25	$11.0^{ab} \pm 0.1$	$5.61^{c} \pm 0.00$	$0.90^{defg} \pm 0.01$	$13.2^{kl} \pm 2.3$	$8.4^{efg} \pm 0.6$	$1.3^{cde} \pm 0.1$	$1.4^{de} \pm 0.2$
	0.50	$10.0^{a} \pm 0.1$	$5.59^{b} \pm 0.00$	$0.89^{cdef} \pm 0.02$	$17.1^{no} \pm 1.2$	$7.5^{cde} \pm 0.3$	$1.2^{bcd} \pm 0.0$	$1.2^{bc} \pm 0.3$
	0.75	$10.8^{a} \pm 0.2$	$5.58^{ab} \pm 0.00$	$0.90^{defg} \pm 0.02$	$14.4^{klmn} \pm 3.5$	$8.2^{efg} \pm 0.3$	$1.3^{cde} \pm 0.1$	$1.3^{cd} \pm 0.0$
	1.0	$11.1^{abc} \pm 0.3$	$5.58^{ab} \pm 0.00$	$0.90^{defg} \pm 0.01$	$8.1^{abcdefgh} \pm 2.3$	$7.9^{defg} \pm 0.4$	$1.2^{bcd} \pm 0.0$	$1.3^{cd} \pm 0.1$
	1.5	$10.9^{a} \pm 0.1$	$5.58^{ab} \pm 0.00$	$0.93^{ghi} \pm 0.03$	$10.3^{hij} \pm 3.0$	$8.1^{efg} \pm 0.3$	$1.3^{cde} \pm 0.1$	$1.1^{ab} \pm 0.1$

[†] Each value represents the mean of three experiments ± standard deviation. Values with different letters in a column are significantly different at $P < 0.05$.

value of local rice varieties. Gamma irradiation has been used for insect disinfestation and microbial decontamination of foods (Aldryhim and Adam, 1999; Loaharanu et al., 1971). The use of irradiation is however limited by its effect on rice quality. Irradiation has been reported to cause changes in colour, amylose content, water absorption, loss of solids during cooking, paste viscosity, cooked rice hardness and oxidative rancidity in rough and brown rice (Hayashi et al., 1998; Roy et al., 1991; Sabularse et al., 1992, 1991; Wang et al., 1983; Wootton et al., 1988). Similar effects have been reported when milled rice was irradiated (Bao et al., 2001; Loaharanu et al., 1971).

Various gamma irradiation doses have been reported to maintain the sensory quality of irradiated rice. An acceptable limit below 3 kGy was recommended for Taiwanese rice (Wang et al., 1983) and up to 5 kGy for Indian rice (Roy et al., 1991). Bao et al. (2001) also stated that irradiation of milled rice for human consumption should be limited to a maximum dose of 2–4 kGy, due to its negative effect on rice colour and aroma. However, a maximum dose of 1 kGy was suggested for Australian rice and ordinary Thai rice (Loaharanu et al., 1971; Wootton et al., 1988).

There is little information on the effects of gamma irradiation (for insect disinfestation) on the quality characteristics of the resultant flours obtained from local rice varieties. The objective of this study was to determine the effect of gamma irradiation as insect disinfestation technique on some physicochemical, functional and pasting properties of selected locally-produced rice cultivars in Ghana with the aim of preserving and widening the utilization of the rice cultivars.

2. Materials and methods

2.1. Materials

2.1.1. Collection and preparation of rice cultivars

Four local rice cultivars, namely 'Viwotor' (VWR), 'Viwonor' short (VNS), 'Viwonor' tall (VNT) and 'Balemi' 1 (BAL) were bought from rice farmers in Kpong, Ghana. One imported rice type, Jasmine (JAS) was also purchased from a local market in Accra, Ghana. The paddy rice samples were sorted to remove any extraneous materials and defective rice seeds. The local rice cultivars were dehulled and then packaged into low density polyethylene bags (about 50 g each) along with the imported rice sample for gamma irradiation.

2.2. Methods

2.2.1. Gamma irradiation

The five packaged rice samples (50 g each) were irradiated using a gamma irradiation facility, Cobalt 60 source (SLL-515, Hungary) at the Radiation Technology Centre (RTC) of the Ghana Atomic Energy Commission (GAEC). Samples were exposed to gamma irradiation doses of 0.0, 0.25, 0.50, 0.75, 1.0 and 1.5 kGy with a dose rate of 0.63 kGy/h. The absorbed dose was confirmed using Fricke's dosimetry system. The irradiated rice samples were milled into flour to pass through 250 μm mesh using a hammer mill (Brook Crompton Series 2000, England) and then packed into low density polyethylene bags prior to analyses.