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The use of irradiated potato flour as a partial replacement of wheat flour in producing biscuits

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Abstract: The study aimed to demonstrate how irradiation affects the chemical composition and amino acids of *Spunta* potato flour, and the sensory evaluation of biscuit samples partially composed of irradiated potato flour. The potato flour was irradiated with 50 and 150 Gy. Protein, fat, total dietary fibre, ash, carbohydrates, ascorbic acid, and amino acids were analysed. Sensory evaluation of biscuits was conducted after adding potato flour as a partial replacement for wheat flour at ratios of 5, 10, and 15%. The results showed that potato flour contained ascorbic acid, which was absent in wheat flour. Potato flour had less total protein and carbohydrate and more ash and fibres than wheat flour. Total essential amino acids appeared at the highest percentage, particularly lysine at 8.29 ± 0.02, compared with non-essential amino acids in the samples irradiated at a dose of 150 Gy. The biscuits were prepared with different ratios of the irradiated potato flour at dose 150 Gy to white flour. Sensory evaluation for biscuits with 10% of potato flour scored 8.61 ± 0.01, 8.33 ± 0.02, 8.77 ± 0.02, and 8.38 ± 0.00 for overall acceptance, colour, texture and appearance, respectively. This study recommends using 10% of irradiated potato flour at 150 Gy blended with wheat flour to produce biscuits.

Keywords: amino acids; irradiation; chemical composition; sensory evaluation; overall acceptance

The potato is a tuber vegetable of the family *Solanaceae* and an abundant and inexpensive crop, so that it is an important security factor in world food. The potato tuber is characterised by its carbohydrate metabolism and has a high level of water content, which triggers a short shelf life and increases storage expenses, hence affecting and reducing its use. Dehydrating the fresh potato by producing potato flour is one effective solution to overcome these problems (Zhang et al. 2020). Potato flour has a wide range of uses such as gravy thickener and additive in bakery products (Bashir et al. 2017), since it is characterised by its water and oil absorption capacity, foam stability, bulk density, gelation, foaming, and emulsion capacity (Adeleke & Odedeji 2010). Joshi et al. (2016) claimed that it is commercially produced flour that can be safely stored and incorporated into various bakery products, particularly biscuits, breads, and cakes. Thus, it has been exploited to overcome any shortage of wheat flour in bakery production. Making bakery products requires flour that absorbs water well but does not require strong gluten (Khaliduzzaman et al. 2010). Potato flour encourages yeast fermentation and has excellent anti-staling properties as well as a pleasing taste (Adeleke & Odedeji 2010). The process of making potato flour means that owing to a high level of damaged and broken cells, the free starch content is also high in the finished product. Consequently, potato flour absorbs and holds water extremely well, which means pota-

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to flour dough is cohesive and thus readily kneaded and shaped (Joshi et al. 2018). Potato skins are considered as a good source of ascorbic acid and potato flour is both cheap and nutritious and provides a usually safe source of carbohydrate calories. The potato also contains one of the best plant proteins. There are significant differences in the potato flour made from different cultivars in terms of their rheological parameters. The physicochemical and rheological properties are higher in terms of water absorption index, amylose content, and solubility in the flour of some potato cultivars than in maise flour. Furthermore, biscuit functional properties were significantly affected by adding sweet potato flour to wheat flour. Lastly, adding the potato flour improved the biscuit spread factor and reduced the fracture force more than adding maise flour (Adeleke & Odedeji 2010).

Gamma irradiation was proved to be utilised successfully in food preservation; and for the modification of the physicochemical properties of macro-components in foods by a free radical mechanism that hydrolyses the chemical bonds, therefore large molecules of starch are cleaved into smaller fragments of dextrin, sugars and organic acid (Verma et al. 2018). This results in increasing solubility, as well as in reducing the swelling power and viscosity of starch (Bashir et al. 2017). Abboudi et al. (2016) noticed an increase in almost all amino acids such as aspartic acid, serine, alanine, leucine, lysine and arginine although methionine and cysteine decreased, when the potato tuber was irradiated with 50, 90, 100, 120, 150, and 180 Gy. High doses of gamma irradiation made potato starch granules more sensitive to shear, and granular structure appeared to be higher in potato starch than in wheat starch (Chung & Liu 2010). Gamma radiation from a cobalt-60 source has been proved also for its ability to increase the shelf life of potatoes and inhibit sprouting. Alkuraieef (2012) reported that doses between 60 and 150 Gy, regardless of storage temperature or potato variety, were found to effectively reduce sprouting. The sensory evaluation of some potato flour products obtained high scores for overall acceptability. Seevaratnam et al. (2012) findings indicated that sensory parameters dropped to 'relatively acceptable' when replacing wheat flour with potato flour gradually with 0–30%. In the light of the foregoing, literature encompasses studies on the effect of using different doses of radiation on the chemical, microbiological, and biological properties of many types of flour, such as cassava, wheat, potatoes, etc. However, the majority of studies measured the effect on their local potato type such as *Daimont, Kufri Jyoti, Kufri Badshah*, and *Pukhraj* etc.; while there is a lack of studies conducted to investigate the effect of potato flour of the *Spunta* tuber cultivar, which is cultivated in Saudi Arabia. Therefore, the aim of the present study is to demonstrate how irradiation affects the chemical composition and amino acid profile of potato flour, and to analyse the sensory evaluation of biscuit samples partially composed of irradiated potato flour as compared to those made from white wheat flour.

MATERIAL AND METHODS

Raw materials. *Spunta* potato tuber cultivar was bought from a local farm. White wheat flour 72% extraction.

Irradiation process. Cobalt-60 at Gammacell 220 was used to irradiate the potato tubers at two different doses (50 and 150 Gy). It is located at King Abdul-Aziz City for Science and Technology in Saudi Arabia. For the experiment, an irradiation dose rate of 14.2514 kGy h^{-1} was used. To keep the samples dry and to prevent any effects of humidity, they were stored in ventilated conditions.

Potato flour preparation. Both irradiated and non-irradiated tubers were washed and peeled, then sliced into 1 mm pieces using an ordinary slicing machine and subsequently washed again. In a stainless-steel wire strainer the potato slices were put into, they were boiled in water for 3 min, rinsed in cold water and immediately dried in an air oven (TOV-165, Gallen Kamp Company, England) with a motor fan for 10–12 h at 60 ± 2 °C. A laboratory disc mill (HC-2000Y, DAMAI, China) was then used to mill the dehydrated slices which were then ground until able to pass through a No. 70 sieve. The potato flour was kept in plastic receptacles (Adeleke & Odedeji 2010).

Analytical methods. The methods described in the Association of Official Analytical Chemists AOAC (Official Methods of Analysis, 2000) were employed to ascertain the total protein, moisture, fat, ash, and fibre content; this total was subtracted from 100 to obtain the total carbohydrate. Ranganna's method (2004) was used to determine ascorbic acid content. The presence of amino acids was determined using the method outlined by Moore & Stein (1958). A known weight (0.5 g) of each sample was placed in Pyrex test tubes with 5 mL of 6 N HCl at 110 ± 1 °C for 24 h, then the hydrolysate was filtered and filled up to 50 mL with distilled water; then 5 mL of the hydrolysate were evaporated to dryness in a rotary evaporator (Fisher, USA). Amino acids were determined using a Beckman 7300 high-

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Table 1. The ingredients of the biscuit samples per 100 g (g)

Ingredients	Wheat flour biscuits	Irradiated potato flour biscuits		
		5%	10%	15%
Potato flour	0.00	5.00	10.00	15.00
White wheat flour	100.00	95.00	90.00	85.00
Salt	1.00	1.00	1.00	1.00
Sugar	30.00	30.00	30.00	30.00
Butter	15.00	15.00	15.00	15.00
Powdered milk	0.50	0.50	0.50	0.50
Ammonium bicarbonate	0.33	0.33	0.33	0.33
Sodium bicarbonate	0.40	0.40	0.40	0.40
Egg	24.00	24.00	24.00	24.00
Vanilla	0.05	0.05	0.05	0.05

performance amino acid analyser (Retsch GmbH; Beckman Germany), data system 7000, column: Na-A/B/D 2.5 cm column, sample vol. 50 µL.

Biscuit preparation. The biscuits were prepared based on the best positive result of the chemical composition analysis of irradiated potato flour samples. In the biscuit samples, the chosen irradiated potato flour partially replaced wheat flour at 5, 10, and 15% and these were compared with the control (wheat flour biscuits). The ingredients for the biscuits can be found in Table 1. Biscuits were creamed, mixed and cut in line with the usual methods recommended for semi-hard sweet biscuits 'petit beurre' at the Faculty of Home Economics in Riyadh. The biscuits were baked at 180 °C for 12–15 min. The resulting biscuits were 0.5 cm thick and 2 cm in diameter.

Sensory evaluation. The sensory evaluation of the biscuit samples made with 5, 10 and 15% of potato flour was conducted by a panel of 10 participants who are staff members of the Princess Nourah Bint Abdulrahman University. The overall acceptability as well as the appearance, texture and colour of the biscuits were evaluated by the panellists. All biscuits were coded and duplicated three times, then, served randomly. Their preferences were rated on a 9-point hedonic scale (Lim 2011). The results were analysed by means and standard deviations making an analysis of variance (ANOVA) using IBM SPSS Statistics 22.

RESULTS AND DISCUSSION

Table 2 shows the approximate content of the chemical composition of dried potato flour after gamma irradiation compared to wheat flour. Potato flour had a moisture content of 10.5 ± 0.10%, which was somewhat less than wheat flour (12.01 ± 0.01%); which could have been because of their compositional difference and the extent of drying. In line with other studies, the moisture content was significantly reduced in potato slices and thus in potato flour by the drying process (Khaliduzzaman et al. 2010). Furthermore, it was demonstrated that exposing potato flour to irradiation affected its moisture content, as the higher the dose of irradiation (0, 50 and 150 Gy), the lower the moisture content of potato flour (10.5 ± 0.10, 9.59 ± 0.05 and 9.91 ± 0.01%, respectively).

In agreement with Alkuraieef (2012), it was demonstrated that potato flour has an equal value of total carbohydrate in its non-irradiated and irradiated state and that wheat flour has more carbohydrate than potato flour. Like in Khaliduzzaman et al. (2010), the wheat flour in the present study contains more total protein than potato flour (12.88 ± 0.01 and 10.27 ± 0.05%, re-

Table 2. The chemical composition of wheat flour compared to dried potato flour after gamma irradiation

Chemical compositiona	Wheat flour	Potato flour		
		non-irradiated	50 Gy	150 Gy
Moisture (%)	12.01 ± 0.01	10.50 ± 0.10	9.59 ± 0.05	9.91 ± 0.01
Protein[a]	12.88 ± 0.01	10.27 ± 0.05	9.60 ± 0.01	8.98 ± 0.02
Fat[a]	0.81 ± 0.01	0.87 ± 0.01	1.51 ± 0.01	1.76 ± 0.01
Total dietary fibre[a]	0.45 ± 0.03	5.44 ± 0.08	5.56 ± 0.01	5.95 ± 0.01
Total ash[a]	0.63 ± 0.10	2.53 ± 0.02	3.35 ± 0.01	3.02 ± 0.01
Carbohydrates[a]	73.21 ± 0.06	70.38 ± 0.24	70.38 ± 0.03	70.38 ± 0.01
Ascorbic acid (mg $100g^{-1}$)	ND	5.28 ± 0.15	5.14 ± 0.10	5.00 ± 0.50

Values are mean ± standard deviation (SD) of triplicate sample; [a]dry basis (%); ND – not detected

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spectively). In comparison with non-irradiated samples, the protein content of potato flour was gradually reduced when irradiated with 150 Gy, reaching 8.98 ± 0.02%, which tallies with results by Alkuraieef (2012).

In addition, the fibre and total ash content seemed to be considerably higher in potato flour compared to wheat flour. This could be attributed to the wheat peeling and grinding operations that result in the decline in the wheat flour.

Results show that potato flour contains ascorbic acid compared to wheat flour that does not contain any of it, which agrees with Khaliduzzaman et al. (2010) findings. When the ascorbic acid content of non-irradiated potato flour (5.28 ± 0.15 mg 100 g^{-1}) was compared with that of irradiated potato flour, a slight decrease was detected at a dose of 50 Gy (5.14 ± 0.10 mg 100 g^{-1}), with a significant decrease at 150 Gy (5.00 ± 0.50 mg 100 g^{-1}) compared with the non-irradiated sample. This decrease in ascorbic acid is possibly due to the ionising radiation reacting with water; that results in the release of electrons and in the formation of highly reactive free radicals. The way that free radicals interact with vitamins can change and degrade their activity and structure (Bamidele & Akanbi 2015).

Some variation was apparent in the concentration of each essential amino acid between non-irradiated and irradiated potato flour (Table 3). Lysine and arginine are higher in potato flour (8.29 ± 0.01 and 6.35 ± 0.01%, respectively) than in wheat flour (3.44 ± 0.01% and 3.03 ± 0.01%, respectively. There was also a slight increase in the concentration of amino acids in potato flour with increasing irradiation doses; so that samples of potato flour irradiated with 150 Gy were higher in amino acids than samples irradiated with 50 Gy. The presence of lysine and arginine at a dose of 150 Gy increased to 8.29 ± 0.02% and 6.61 ± 0.01%, respectively. This increase is similar to Nassed's findings (1995), who concluded that irradiating the potato flour with doses of 0, 50 and 150 Gy doubled the amount of lysine content compared to wheat flour, while the activity of the enzyme caused a decrease in the protein level. In line with findings by Bamidele & Akanbi (2015), the total essential amino acids in potato flour (56.29 ± 0.27%) exceed those of wheat flour (49.0 ± 0.01%); with total essential amino acids for irradiated potato flour with 150 Gy being the greatest when compared to other samples.

The non-essential amino acids such as aspartic acid, threonine, serine, glycine and alanine were shown to be higher in potato flour than in wheat flour although proline and glutamic acid contents were higher in wheat flour than in potato flour. Aspartic acid (6.39 ± 0.01%), glycine (5.03 ± 0.02%) and alanine (5.40 ± 0.01%) were higher in potato flour irradiated with a low dose than when they were not irradiated at all (Table 4).

Such changes in the concentration of amino acids that occur with irradiation are possibly due to free radicals that could be produced as the peptide bonds split, and to the formation of new radicals from the chemical chain caused by splitting the amino and carboxyl groups of amino acids (Bamidele & Akanbi 2015).

The total non-essential amino acids in wheat flour were higher than in potato flour. However, in potato flour irradiated with 150 Gy, total non-essential amino acids increased slightly (43.54 ± 0.02%) when compared to samples exposed to 50 Gy (42.84 ± 0.01%). Thus, it was relatively stable for all of the doses delivered

Table 3. Comparison of essential amino acid ratios between wheat flour and potato flour (dry basis) (%)

Essential amino acids	Wheat flour	Potato flour		
		Non-irradiated	50 Gy	150 Gy
Valine	5.96 ± 0.01	4.50 ± 0.10	4.42 ± 0.01	4.31 ± 0.01
Isoleucine	6.95 ± 0.03	7.74 ± 0.01	7.73 ± 0.02	7.77 ± 0.01
Leucine	14.97 ± 0.02	12.81 ± 0.01	12.76 ± 0.01	12.83 ± 0.02
Tyrosine	2.03 ± 0.01	3.12 ± 0.01	4.19 ± 0.01	4.19 ± 0.01
Phenylalanine	10.12 ± 0.09	10.0 ± 0.01	10.20 ± 0.01	10.14 ± 0.02
Histidine	2.50 ± 0.02	3.48 ± 0.02	2.20 ± 0.02	3.02 ± 0.02
Lysine	3.44 ± 0.01	8.29 ± 0.01	8.19 ± 0.03	8.29 ± 0.02
Arginine	3.03 ± 0.01	6.35 ± 0.01	6.40 ± 0.09	6.61 ± 0.01
Total essential amino acids	49.0 ± 0.01	56.29 ± 0.27	56.09 ± 0.01	57.16 ± 0.02

Values are mean ± SD of triplicate sample; $P < 0.05$

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Table 4. Comparison of non-essential amino acid ratios between wheat flour and potato flour (dry basis) (%)

Non-essential amino acids	Wheat flour	Potato flour		
		Non-irradiated	50 Gy	150 Gy
Aspartic acid	3.63 ± 0.01	4.55 ± 0.02	6.39 ± 0.01	7.80 ± 0.02
Threonine	4.07 ± 0.01	6.14 ± 0.04	6.15 ± 0.03	6.17 ± 0.03
Serine	3.09 ± 0.01	6.11 ± 0.03	5.65 ± 0.02	5.01 ± 0.02
Glutamic acid	29.39 ± 0.01	15.11 ± 0.02	13.12 ± 0.04	13.14 ± 0.01
Glycine	2.79 ± 0.02	4.58 ± 0.04	5.03 ± 0.02	5.00 ± 0.02
Alanine	2.57 ± 0.01	4.92 ± 0.04	5.40 ± 0.01	5.41 ± 0.03
Proline	4.82 ± 0.01	1.90 ± 0.02	1.10 ± 0.01	1.01 ± 0.01
Total non-essential amino acids	50.96 ± 0.02	43.31 ± 0.01	42.84 ± 0.01	43.54 ± 0.02
Total amino acids	99.36 ± 0.04	99.60 ± 0.02	98.93 ± 0.01	100.7 ± 0.01

Values are mean ± SD of triplicate sample; $P < 0.05$

($P < 0.05$). This is in line with Ahuja et al. (2014) findings which reveal a rise in protein and essential amino acids, by 2–3%, after irradiating the wheat flour with 150 Gy compared with non-irradiated samples. As can be seen, potato flour irradiated with 150 Gy showed the highest amino acid content (100.7 ± 0.016%) when compared to other samples.

Sensory evaluation of biscuits. A sample of potato flour treated with a dose of 150 Gy was chosen to prepare biscuit samples for the sensory evaluation, as it was shown to have better nutritional advantages by enhancing the essential amino acids level, especially lysine.

Results of the sensory evaluation of biscuits are shown in Table 5. Regarding the appearance of the biscuits, no significant differences were reported between wheat flour biscuits and those containing 10% of potato flour as the latter were evaluated as having a 'highly acceptable' appearance. These results are consistent with Khaliduzzaman et al. (2010), who noted that chapatti and biscuits made from potato flour and wheat flour were perceived as more acceptable than other blends.

The texture of biscuits with 10% of potato flour was also evaluated as 'highly acceptable' and reported as being softer than the other samples. The main factor here is attributed to potato flour having a higher water absorption rate than that of wheat flour (Zeng et al. 2019).

The panellists judged the colour as 'slightly acceptable' for biscuit mixtures containing 15% of potato flour, the biscuit colour was deemed satisfactory, but slightly darker than the other samples and scored 6.52 ± 0.01. However, biscuits containing 10% of potato flour were classed as 'highly acceptable', and the score was 8.33 ± 0.02. Clearly, the evaluation of the colour quality of the biscuits declined as the amount of potato flour added increased.

The results might be attributed to the effect of radiation on monosaccharides that are split from starch polysaccharides by the Maillard reaction. This echoes those results on irradiated maise, sago and bean starches noted by Sofi et al. (2013).

These results are in accordance with Ijah et al. (2014), who noted that moisture is retained in bread

Table 5. Mean sensory scores of biscuits given by the taste panel

Quality attribute	Biscuits with non-irradiated wheat flour	Biscuits with irradiated potato flour (150 Gy)		
	100%	5%	10%	15%
Appearance	8.37 ± 0.01	8.11 ± 0.01	8.38 ± 0.01	7.12 ± 0.01
Texture	8.62 ± 0.01	8.55 ± 0.15	8.77 ± 0.02	6.80 ± 0.01
Colour	8.65 ± 0.01	8.26 ± 0.01	8.33 ± 0.02	6.52 ± 0.01
Overall acceptability	8.41 ± 0.01	7.89 ± 0.01	8.61 ± 0.01	7.08 ± 0.07

Values are mean ± SD ($n = 10$) of triplicate sample; $P < 0.05$

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containing potato flour for longer periods than in normal bread. However, according to Bamidele & Akanbi (2015), the final product is affected by adding a higher percentage of potato flour because wheat gluten is diluted; and this affects its functional properties, especially if the product has pieces of small volume.

It is clear that the effect on the overall acceptability scores was negligible when 5% of potato flour was added (7.89 ± 0.01); whereas adding 15% considerably reduced the overall acceptability scores (7.08 ± 0.07), as was found by Gunes & Tekin (2006). There was a slight difference in overall acceptability scores between biscuits with 10% of potato flour (8.61 ± 0.015) and wheat flour biscuits (8.42 ± 0.01). These results demonstrate that using 10% of potato flour in biscuits is perfectly acceptable. Trejo-González et al. (2014) noted a similar result when physical and sensory analyses demonstrated that replacing 5 and 10% of sweet potato flour with wheat flour resulted in a moderately accepted bakery.

CONCLUSION

The study has found that adding potato flour as a replacement of the wheat flour enhanced the nutritional value of biscuits. Irradiated potato flour with a dose of 150 Gy was found to be a better dose for improving the essential amino acid level. The sensory evaluation revealed that adding 10% of irradiated potato flour was highly acceptable in overall acceptance. Therefore, the study recommends using 10% of irradiated potato flour (150 Gy) blended with wheat flour to produce the biscuits. Thus, it is suggested to study their chemical composition, textural properties, and to conduct their economic feasibility study.

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