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GAMMA IRRADIATION DOSES INFLUENCES ON INSTRUMENTAL COLOUR ANALYSIS AND SENSORY CHARACTERISTICS OF IRISH POTATOES IS VARIETAL DEPENDENT

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ABSTRACT: Gamma irradiation has been used over time to alter tuber's colour, which affects the sensory properties of potato products, but few studies have focused on explaining these effects. This study therefore investigated the effects of gamma irradiation on colour and sensory characteristics of French fries made from improved tubers (IP1, IP2, and IP3) irradiated at 15, 30, and 20 Gy, respectively, at a dose rate of 2Gy/minute relative to their parent tubers. From the results, gamma irradiation had varied effects on the colour parameters of tubers, with a significant ($p<0.05$) reduction recorded for the skin and flesh lightness of IP1 relative to the parent tuber post-irradiation. Similarly, an increase in flesh yellowness of the tubers was noted for IP2 and IP3, after irradiation. A significant ($p<0.05$) increase in all sensory parameters of French fries made from IP1, IP2 and IP3 relative to their parents was also noted, indicating that irradiation had a net positive effect on the sensory characteristics. A strong positive correlation was also noted between the texture, flavour, oiliness, and taste of the French fries, which all contributed to their overall liking. Gamma irradiation can be adopted to produce tubers with better colour and sensory attributes.

KEYWORDS: Gamma irradiation, sensory characteristics, Irish potatoes, colour

INTRODUCTION

Majority of the populace in developing world especially in Sub-Saharan Africa and Asia live at an increased risk of food and nutrition insecurity. This has been a major concern, leading to the commitment by world leaders to end hunger and malnutrition as stipulated in the Sustainable Development Goals (SDGs) by 2030 (von Braun *et al*., 2021). To achieve this SDG goal of zero hunger, concerted efforts including policy actions (Development Research of the University of Bonn **[**ZEF], 2020), which can involve diversified production, food fortifications, novel crop breeding strategies, and a shift from the overdependence of common staples such as maize, rice and wheat have been recommended. The Food and Agriculture Organisation [FAO] (2022) records that Irish potato (*Solanum tuberosum L.*) is a potential food crop that can help address this challenge. Irish potato is ranked third in production and it is the fourth most consumed food crop in the world after maize, rice and wheat worldwide (Mlaviwa & Missanjo, 2019; Lal *et al*., 2021; FAO, 2022). It is considered an excellent source of carbohydrates (starch) compared to cereals and other tubers and also supplies other nutrients, including fibre and vitamins such as vitamin C, some B-complex vitamins, carotenoids and other phenolic compounds (Bonierbale *et al*., 2010; Ndungutse *et al*., 2019; Gikundi, 2021).

Globally, Irish potato utilization has been shifting from the conventional use of fresh potatoes to the contemporary value addition and industrial application. More than 50% of the total harvest is used by food processors,

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animal feed production, and industrial purposes (International Potato Centre [CIP], 2022). Despite the demonstrated importance of Irish potatoes, production and utilization is often hampered by numerous challenges including diseases such as bacterial wilt. Nevertheless, it has been proposed that novel breeding technology using gamma irradiation can help address some of these challenges through improvement of potato traits, thus improving yield, growth habits, plant stature, disease and pest resistance, physiological characteristics, and its nutritional value (Zia *et al*., 2018; Chepkoech *et al*., 2018).

Typically, gamma irradiation can influence potato attributes including colour and sugar content among others. Colour is an essential attribute of tubers since it influences consumers choice when purchasing. The flesh colour of tubers varies from white to purple depending on the varietal type, and it affects the end product of the tubers (Oliveira *et al*., 2020). For instance, yellow to cream white tubers have been reported to produce golden-coloured products desirable in French fries and crisps (Oliveira *et al*., 2020). Colour is also perceived to have a link to their nutritional and phytochemical content. Yellow, purple and red-fleshed tubers are an excellent source of anthocyanin and carotenoid pigments, which can be used as natural colourants and antioxidants that play a significant role in the human body, such as scavenging for free radicals (Subía, 2013). Besides the flesh colour, the skin colour is also vital for selection. The red and purple coloured (skin and flesh) tubers tend to have high levels of these antioxidants and vitamin C, making them highly preferred by most people for domestic use (Lindqvist-Kreuze *et al*., 2015). Various factors influence the tuber's colour chief of which are the genotypes and the prevailing climatic conditions in the region where they are cultivated (Kumari *et al*., 2018). The location where tubers are planted and maturity stage, also influences the lightness, redness, and yellowness of the tuber's flesh (Githieya *et al*., 2021). According to Bordoloi *et al*. (2012), tuber flesh colour after peeling among different cultivars is influenced by variations in polyphenol oxidase, antioxidants, phenolic compounds and pigments in the tubers.

Despite the positive contributions of gamma irradiation on improving shelf life and aiding in preventing tuber susceptibility to pests and diseases, applying the rays can also confer unfavourable characteristics to the tubers by interfering with some physical or sensory properties. A study by Sarkar & Mahato (2020) on *Kufri Jyoti* potato varieties grown in India which were exposed to irradiation doses of 100 and 200 Gy found that there were noticeable changes in colour and weight of those tubers irradiated with 200 Gy, unlike those with 100 Gy which displayed insignificant changes. A study by Rezaee *et al*. (2013) also documented that gamma radiation treatment of Irish potatoes with doses ranging between 50 to 100 Gy decreased the specific gravity of the tubers and vitamin C, which resulted in an impact on the texture, mouthfeel and nutritional quality of French fries.

Similarly, the International Atomic Energy Agency (IAEA) noted that gamma irradiation of Irish potatoes at higher doses results in a significant reduction of colour parameters and appearance of the tubers and their processed products (World Health Organization, [WHO], 1997). Effects of irradiation on other nutrients like sugars in Irish potatoes are more variable, with reducing sugars increasing

and non-reducing sugars decreasing with irradiation depending on the dosage used (Rezaee *et al*., 2013), which can have an impact on the overall taste and appearance of products made out of the tubers. To qualify gamma-irradiated tubers for consideration as a food and nutrition security alternative, consumer acceptability has to be achieved for products made out of these tubers. However, most of the existing literature focuses on tubers irradiated as a post-harvest handling strategy, and limited studies have been done to establish the effects of irradiation breeding on physical and sensory characteristics. The current study, therefore, is set to investigate the effects of gamma irradiation on the physical and sensory characteristics of improved tuber varieties that were developed from two common tubers in Kenya.

MATERIALS AND METHODS

Materials

Asante and Sherekea parent tubers and three improved tuber varieties (IP1, IP2, and IP3) were used in the study. Asante was used to produce IP1, while Sherekea was used to produce IP2, and IP3 through exposure to gamma radiation at dosage rates of two grays per minute (Gy/min) from a Co^{60} source at 15, 30, and 20 Gy, respectively (Chepkoech *et al*., 2018). The three were selected for their better agronomic characteristics after comparison with several other tubers exposed to different irradiation levels (Chepkoech *et al*., 2022). The tubers were collected from the Mau-Narok Agriculture Development Corporation (ADC) farm and taken to the Kenya Agricultural and Livestock Research Organization (KALRO) horticulture centre in Njoro, Nakuru. The collection and handling of the tubers were guided by the regulations and guidelines of the Kenya Plant Health Inspectorate Service (KEPHIS, 2020). The tubers were sorted, cleaned, and dried under ambient conditions in a naturally ventilated area for one week before subsequent experiments.

Colour of skin and flesh of irish potatoes

The skin and flesh colour of the tubers was determined following methods described by Yang *et al*. (2016) using a hand-held colourimeter (PCE-TCR 200, China). Standard black (*L*:* 55.49, *a**: 527.08, *b**: 54.66) and white (*L*:* 593.41, *a*:* 521.18, *b*:* 50.75) tiles were used to calibrate the colourimeter before use. Five randomly selected tubers from each variety were assessed at six different points to obtain the values for lightness (*L**), redness (*a**) and yellowness (*b**). The hue angle (*H**) and chroma (*C**) were derived using the formulas below:

$$H^* = \tan^{-1}(b^*/a^*) \text{ and } C^* = (a^{*2} + b^{*2})^{1/2}$$

French fries preparation

Tuber samples (3 kgs of each variety) were selected, peeled and sliced into 11 ×11 mm strips using a manual hand-held chipper (Figure 1). The potato strips were rinsed in cold water to remove the surface starch. The strips were then deep fried in an institutional batch-type deep-fryer (model MC-DF 1031, Cool Touch deep fryer, China) using corn oil in a 1:10 (w/v) potato to oil ratio for approximately 6-8 minutes at 170°C following the process outlined by Nairfana et al. (2021) and Ngobese et al. (2017)the effect of low-temperature long-time (LTLT. The fried strips were placed on glass trays lined with paper towels to drain off excess oil, cooled to an ambient temperature and taken for sensory evaluation.

Consumer acceptability

French fries' sensory acceptability for the three improved tuber varieties and the parents was done by 52 randomly selected panellists using a 9-point hedonic rating scale to evaluate the consumer acceptance of the

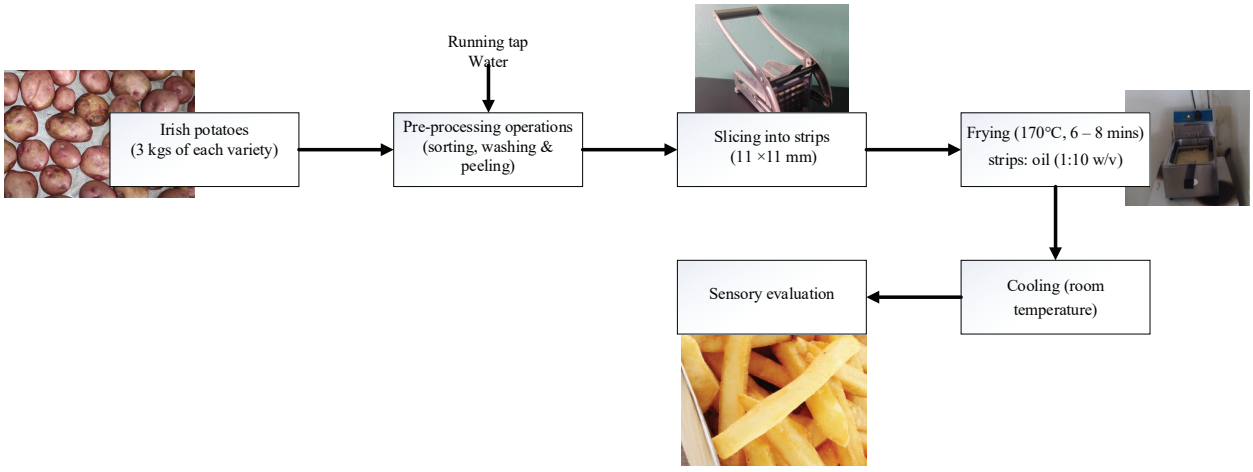

Fig. 1. French fries preparation process flow

products (1 = dislike extremely and 9 = like extremely). The participants were recruited from the University of Eldoret (UOE) through an advert that contained details of the tuber varieties to be evaluated to ensure those applying were consumers of Irish potatoes and were not allergic to the products from the tubers. The panellists consisted of students and staff members of age ranges between 18 to 55 years. Informed consent was sought from the members who signed and agreed to participate in the sensory evaluation exercise. The panellists were informed of the aspects of scoring for colour, flavour, taste, and overall acceptability of potato products. The samples were blinded using three-digit numbers generated from The Table of Random Numbers and served to each panellist following a random order fashion derived from the Table of Random Permutations of Nine. The panellists were provided with a glass of distilled water to cleanse the palate in between evaluation of the samples.

Data analysis

Data obtained from colour measurements and consumer acceptability tests were analysed using R software (Version 4.2.3). Considering tuber varieties as a source of variations, data was subjected to a one-way analysis of variance (ANOVA). The means were considered significantly different at $p<0.05$, and results were expressed as the mean ± standard deviation (SD). Tukey's HSD was used to separate the means for those that showed significant differences. A Principal Component Analysis (PCA) biplot was generated to illustrate the interrelationships between the sensory characteristics of the tubers, where eigenvalues were retained for varimax rotation to generate two dimensions.

RESULTS AND DISCUSSION

Irish potato skin colour

The results for skin colour are shown in Table 1. The skin colour measurements of the tubers showed significant differences in lightness, redness, yellowness, hue angles, and chroma values across the varieties. A significant decrease in L^* was recorded for IP1 (28.79 ± 0.57) relative to the parent Asante (49.91 ± 2.13); however, no significant differences were noted for values of a^*, b^*, H^* and C^* after irradiation. The decrease in lightness of IP1 relative to the parent Asante could have been due to the effects of gamma irradiation. Irradiation using gamma rays at lower doses (<20 Gy) has been noted to result in a reduction of carotenoid levels in

Table 1. Skin colour of tubers.

Variety	(L*) Lightness	(*a**) Redness	(*b**) Yellowness	(*H**) Hue angle	(C*) Chroma
Asante	49.91 ± 2.13^{c}	8.67 ± 2.01^{a}	21.34 ± 1.85^{b}	67.67 ± 6.03^{a}	23.15 ± 1.14^{a}
IP1	28.79 ± 0.57^{b}	8.14 ± 1.00^{a}	24.48 ± 1.04^{b}	71.58 ± 2.60^{a}	25.82 ± 0.87^{a}
Sherekea	25.16 ± 1.87^{a}	60.75 ± 4.18^{b}	-19.95 ± 4.09^{a}	341.97 ± 2.71^{b}	64.00 ± 5.06^{b}
IP2	26.35 ± 1.88^{ab}	65.59 ± 2.40^{b}	-24.06 ± 1.90^{a}	339.85 ± 1.47^{b}	69.88 ± 2.48^{b}
IP3	25.59 ± 2.34^{a}	60.02 ± 7.15^{b}	-22.60 ± 3.38^{a}	339.39 ± 1.73^{b}	64.16 ± 7.66^{b}

Values are means ± standard deviation. Means with different superscript letters along the same column are significantly different at $p<0.05$, as assessed by Tukey's HSD. Hue angle (*H**) and Chroma (*C**) were calculated from *a** and *b** values.

tubers and increases the amount of phenolic content, which affects the lighter appearance of the tuber (Maltsev *et al*., 2022; Mounir *et al*., 2022). The skin colour of IP1 and Asante was relatively yellow, as indicated by the positive *b** values. On the other hand, IP2, IP3, and Sherekea had no significant changes in the values for *L**, *a**, *b**, *or H** and *C** post-irradiation. The high positive values of *a** indicate that the skin colour of Sherekea, IP2, and IP3 was relatively red. The distinct skin colours indicate that IP1 could easily be selected for preparation of brightly coloured potato products such as French fries or crisps.

Asante and IP1 were further classified with low hue angles (*h**) (67.67 ± 6.03 and 71.58 ± 2.60, respectively), which is found in the yellow region on the International Commission on Illumination (CIE) colour scale. On the contrary, Sherekea, IP2, and IP3 had very high hue angles in the fourth quadrant but leaned towards the first quadrant. The hue angles of the varieties indicated that the skin colour for Sherekea, IP1 and IP2 was darker than that of IP1 and Asante. Skin colour is an essential parameter for tuber selection since it is consumers' first impression of judgement (Spence, 2015). The colour of potatoes similarly affects the processing applications and directly influences the nutritional composition of the tubers (Zhu & He, 2020). Irish potato skin colour influences consumer preferences and selection, as noted by Zarzecka et al. (2023), since red and purple-fleshed tubers accumulate more vitamin C and tend to have distinct tastiness and cooking properties compared to the yellow-fleshed ones (Zarzecka *et al*., 2023). On the other hand, tubers with yellowish skin have high carotenoid levels, which are also essential antioxidants in the body; hence, visual selection of intense yellow-fleshed tubers can help consumers choose healthier options (Valcarcel et al., 2015).

Irish potato flesh colour

Results for the flesh colour measurements are presented in Table 2. Across the varieties, the flesh colour of most tubers did not differ significantly ($p<0.05$) in lightness except IP1. Relative to the parents, irradiation significantly reduced the lightness of 1P1 relative to the parent Asante, but no significant differences were noted between Sherekea and its daughters. Generally, the measures for redness, yellowness, hue angle, and chroma showed no significant differences between IP1 and Asante after irradiation. There was a significant increase in yellowness and chroma values for IP2 and IP3 relative to their parent Sherekea. However, a significant reduction in Hue angle was calculated between Sherekea and its daughters IP2 and IP3.

The tubers' *L** and *b** values indicated that most tubers had a light-yellow flesh

Table 2. Flesh colour of tubers.

Variety	(L*) Lightness	(^{a}*) Redness	(^{b}*) Yellowness	(^{H}*) Hue angle	(C*) Chroma
Asante	62.99 ± 2.45^{b}	-4.14 ± 0.12^{b}	14.01 ± 0.66^{a}	106.48 ± 0.95^{a}	14.61 ± 0.63^{a}
IP1	47.15 ± 1.04^{a}	-4.46 ± 0.20^{b}	14.23 ± 0.70^{a}	107.44 ± 1.11^{ab}	14.91 ± 0.68^{a}
Sherekea	62.08 ± 4.09^{b}	-5.22 ± 0.39^{a}	13.45 ± 0.89^{a}	111.28 ± 1.95^{c}	14.43 ± 0.83^{a}
IP2	64.96 ± 2.76^{b}	-5.45 ± 0.30^{a}	18.91 ± 1.41^{c}	106.12 ± 0.96^{a}	19.68 ± 1.40^{c}
IP3	62.67 ± 4.56^{b}	-5.59 ± 0.24^{a}	15.81 ± 0.60^{b}	109.51 ± 1.38^{b}	16.77 ± 0.50^{b}

Values are means ± standard deviation. Means with different superscript letters along the same column are significantly different at $p<0.05$, as assessed by Tukey's HSD. Hue angle (H*) and Chroma (C*) were calculated from a* and b* values.

colour. However, there was a significant difference in the b* values between IP2 and IP3, which had higher values for yellowness than the other three varieties. Furthermore, Asante, IP1, IP2, and IP3 had significantly lower value measures of hue angles relative to Sherekea, which are located in the second quadrant of the CIE $L^*a^*b^*$ colour scale. This is indicative that they are in the yellow region (90°h) as the highest values are in the green region (180°h) (Cabezas-Serrano *et al*., 2009). IP2 and IP3 also had relatively higher values for chroma (C*), signifying their yellow colour measure had higher intensity than other varieties. Tuber flesh colour is of significant importance since it directly impacts the selection criteria for food processing and indicates nutrient content. Potato varieties with yellow to cream-coloured flesh produce brightly golden colours for fried products and bright yellow for boiled potato products, which are desirable for consumers (Oliveira *et al*., 2020; Kisakye S. *et al*., 2020; Ooko, 2008). This implies that all the varieties in this study can be well suited for producing fried products and can also be boiled owing to the bright colours of the flesh.

From a nutrition standpoint, the high amount of yellowness in the tubers also indicates the presence of high amounts of carotenoids (Zhu & He, 2020), which are important antioxidants in the diet. Tubers with reddish or purple skin/ flesh colour contain high amounts of anthocyanin and phenolic compounds, in addition to essential antioxidants in the human diet (Subía, 2013; Yang *et al*., 2016). The current findings agree with a study by Soares *et al*. (2016), who reported that gamma irradiation on tubers done to a rate of about 4 kGy results in a reduction in the values for lightness (L*) of the potatoes. This is because induced mutation by gamma irradiation reduces the amounts of carotenoids in tubers and increases the amount of phenolic content (Blessington Tyann, 2005), reducing brightness in the tubers.

Consumer acceptability tests

The sensory attributes of French fries evaluated by the panel on a 9-point hedonic scale are shown in Figure 2. The sensory characteristics of French fries showed significant variations in colour, flavour, taste, texture, oiliness, and overall acceptability between the three tuber varieties relative to their parents. Asante and IP1 were generally rated as above fair (6.5) and good (7.0) for all attributes on a 9-point hedonic scale. French fries from Sherekea had the lowest scores (below fair 5.0) for all attributes, unlike its daughter tubers. Mostly, a significant difference was recorded between French fries made from the parent tubers and their corresponding daughters, with daughters scoring higher, thereby indicating that the developed tubers had better sensory characteristics than their parents. The sensory characteristics of Irish potato products depend partly on the tubers'

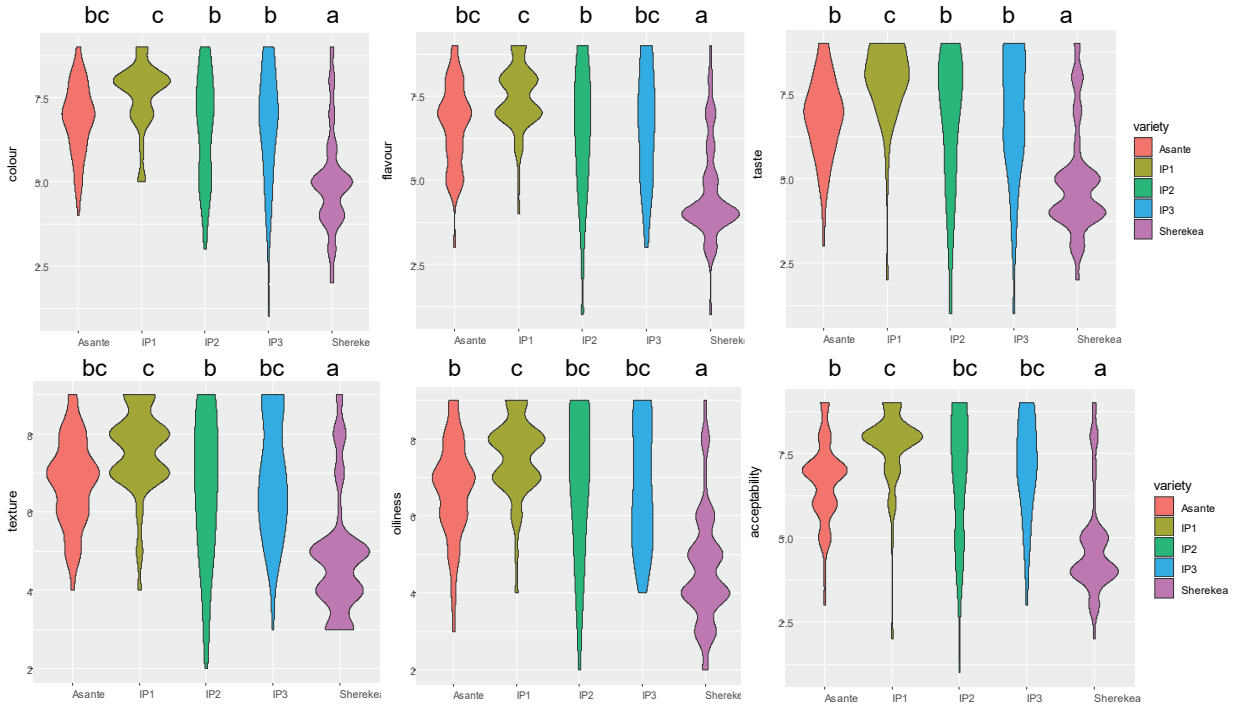

Fig. 2. Violin plots showing the sensory evaluation of products made from the tuber varieties

Plots with different superscript letters are significantly different at $p<0.05$, as assessed by Tukey's HSD.

physicochemical properties, such as colour, starch content, lipids, sugar contents, and amino acids (Ndungutse *et al.*, 2019). High amounts of starch and lipids contribute to the French fries' flavour and result in products with a good texture. Higher scores recorded for the flavour of the daughter tubers could be due to the presence of a relatively higher concentration of amino acids, such as glutamate, which is known to contribute positively to desirable flavours in fried products (McKenzie & Corrigan, 2016).

However, high amounts of proteins and sugar content might produce darkened fried products when tubers are exposed to high temperatures, rendering them undesirable and unappealing to consumers (Ooko, 2008). Reducing sugars in Irish potatoes plays a vital role in determining the taste of fried tuber products, but low amounts of these sugars are preferred to increase consumer acceptability (Johnson *et al.*, 2019). Based on the current findings, the French fries produced had both desirable taste and appealing colours to the panellists; hence, the tubers used had the right amounts of reducing sugars and protein composition suitable for the production of potato fried products. The study findings of superior sensory attributes for the daughter tubers could influence agricultural practices by shifting the focus towards cultivating these improved varieties for consumers' taste, appearance, and overall acceptability. Additionally, food processors and retailers might leverage these findings in tuber selection, potentially increasing and meeting the consumers' demands.

Correlation between sensory evaluation characteristics

A factor reduction method was used to determine the correlations between the sensory evaluation characteristics for the tuber varieties and their parents by reducing the

variables into two components/dimensions, as shown in Figure 3. The first PCA dimension (taste, oiliness, texture and flavour) accounted for 81.3% of the total variations, while the second component (colour) accounted for 6.5%. The degree of representation for the attributes was high for the colour and taste of the French fries based on their square cosine values of above 0.90. Texture, flavour, and oiliness were strongly positively correlated, as represented by the angles between them on the biplot (less than 30°). All attributes (colour, texture, flavour, oiliness, and taste) strongly contributed to the liking of the French fries, as shown by the attribute values above 0.75 on the scale. Several studies have used PCA to explain the correlation between sensory evaluation attributes of food and to help determine the highly appreciated attributes of the sensory evaluation panellists. Principle component loading attributes close to each other are termed positively correlated; loadings separated by 180° are negatively correlated, whereas if separated by 90°, they are independent (Cañeque *et al*., 2004). From the current findings, all attribute loadings have angles less than 90°; hence, they are positively correlated.

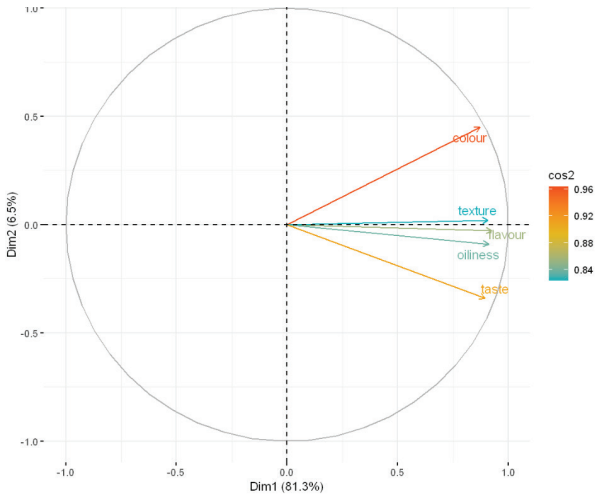

Fig. 3. Principal Component Analysis (PCA) biplot showing the correlation between sensory evaluation parameters.

A study by Ndungutse *et al*. (2019) reported two principle components that accounted for 80.3% of sensory attributes of French fries prepared from five Irish potato varieties. Concurrently, Mohapatra *et al*. (2007) noted 70% total variations in three principle components representing fermented sweet potatoes' sensory characteristics. According to Liu *et al*. (2003), principle component loadings are termed weak in representation when ranging between 0.3 and 0.5, moderate between 0.5 and 0.75, and strong when above 0.75. From the biplot generated, taste, oiliness, flavour, and texture loaded strongly (above 0.75) in the first PCA, as well as colour in the second PCA. Since the attributes (taste, oiliness, flavour, and texture) were loaded strongly in the same component, they are strongly correlated and directly contribute to the liking of the product; hence, priority should be given to these attributes during the processing of French fries to enhance acceptability by the consumers. The findings indicate that the tuber varieties used in the preparation of French fries had superior sensory characteristics (taste, oiliness, flavour, texture and colour) and could easily be adopted by potato processors for the production of fried products.

CONCLUSIONS

Gamma irradiation at a low dose of 15 Gy resulted in reduced values for lightness in skin and flesh colour of IP1 relative to its parent tuber, unlike the other tuber varieties that were done at a relatively high dose. However, the skin colour of IP2 and IP3 were darker than that of IP1; hence, consumers would easily select IP1 due to its bright colour. The flesh colour parameters (lightness and yellowness) of all tubers showed that they were relatively yellowish, making them easily applicable to processing fried potato products such as French fries and crisps.

Gamma irradiation was noted to significantly increase the flesh yellowness for IP2 and IP3 relative to the parent tuber, diversifying their applicability in preparing fried products and improving their selection criteria. The sensory characteristics of the French fries revealed that there was a significant increase in liking of colour, taste, texture, oiliness and overall acceptability of the products made from the daughter tubers relative to their parents, indicating that irradiation conferred better processing application to the daughter tubers. The PCA correlation also showed that the colour, texture, flavour, oiliness and taste of the prepared French fries were positively correlated, and all contributed positively to the overall liking of the French fries. Therefore, gamma irradiation might be proposed as a technique to generate Irish potato cultivars with improved processing characteristics for small-scale farmers, as most of them cannot afford to access the technology at the post-harvest stage.

DECLARATIONS

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DISCLOSURE STATEMENT

The authors declare no financial or non-financial interests directly or indirectly related to the article.

DATA AVAILABILITY

The data used to generate the findings in this study are available upon request from the corresponding author.

LITERATURE CITED

Blessington, T. (2005). The effects of cooking, storage, and ionizing irradiation on Carotenoids, Antioxidant Activity, and Phenolics in Potato (*Solanum tuberosum L.*) (Doctoral dissertation, Texas A&M University).

Bonierbale, M., Zapata, G. B., zum Felde, T., & Sosa, P. (2010). Composition nutritionnelle des pommes de terre. *Cahiers de Nutrition et de Diététique*, *45*(6), S28–S36.

Bordoloi, A., Kaur, L., & Singh, J. (2012). Parenchyma cell microstructure and textural characteristics of raw and cooked potatoes. *Food Chemistry*, *133*(4), 1092–1100. https://doi.org/10.1016/j.foodchem.2011.11.044

Cabezas-Serrano, A. B., Amodio, M. L., Cornacchia, R., Rinaldi, R., & Colelli, G. (2009). Suitability of five different potato cultivars (Solanum tuberosum L.) to be processed as fresh-cut products. *Postharvest Biology and Technology*, *53*(3), 138–144.

Cañeque, V., Pérez, C., Velasco, S., Dıaz, M. T., Lauzurica, S., Álvarez, I., De Huidobro, F. R., Onega, E., & De la Fuente, J. (2004). Carcass and meat quality of light lambs using principal component analysis. *Meat Science*, *67*(4), 595–605.

Chepkoech, E., Kinyua, M. G., Kiplagat, O., Ochuodho, J., & Kimno, S. (2022). Application of gamma induced mutation in breeding for bacterial wilt (Ralstonia olanacearum) disease resistance in potato (Solanum tuberosum L.). Thesis.

Chepkoech, E., Kinyua, M. G., Kiplagat, O., Ochuodho, J., & Kimno, S. (2022). Analysis of Gamma Irradiated Potato Genotypes Based on Selected Agronomic Traits. The International Journal of Biotechnology, 11(1), 1–11. https://doi.org/10.18488/57.v11i1.2911

CIP. (2022). *Potato Processing and Uses*. https://cipotato.org/potato/potato-processing-uses/

de Oliveira, A. C. S., de Araújo, T. H., Spers, E. E., da Silva, H. M. R., & de Lima, L. M. (2020). Consumer Preferences for Potato Cultivars with Different Culinary Aptitudes: a Case Study from São Paulo. *American Journal of Potato Research*, *97*(6), 535–546. https://doi.org/10.1007/s12230-019-09756-1

FAO.(2022). *Doubling global potato production in 10 years is possible*. https://www.fao.org/newsroom/detail/doubling-global-potato-production-in-10-years-is-possible/en

Gikundi, E. N. (2021). Physico-chemical properties and storability of selected Irish potato varieties grown in Kenya. JKUAT-CoANRE.

Githieya, R. N., Kahenya, P. K., & Karanja, P. N. (2021). Effects of variety , maturity stage , storage conditions and period on the physico-chemical properties of potatoes. *85*, 1–4.

Johnson, A. M., Porter, G., & Camire, M. E. (2019). Low-Acrylamide French Fry Acceptance: A Pilot Study. *Journal of Food Science*, *84*(12), 3717–3725.

KEPHIS (2020). Plant Protection (General) Regulations. Retrived from chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://kephis.org/images/plant-protection-bill/draft%20plant%20protection%20(general)%20regulations%202020.pdf

Kisakye S., Tinyiro E, Mayanja S, & Naziri D. (2020). Current status of knowledge about end-user preferences for boiled potato in Uganda – A food science, gender and demand perspective. https://doi.org/10.4160/9789290605546

Kumari, M., Kumar, M., & Solankey, S. S. (2018). Breeding Potato for Quality Improvement. *Potato - From Incas to All Over the World*. https://doi.org/10.5772/intechopen.71482

Lal, M. K., Tiwari, R. K., Kumar, R., Naga, K. C., Kumar, A., Singh, B., Raigond, P., Dutt, S., Chourasia, K. N., Kumar, D., Parmar, V., & Changan, S. S. (2021). Effect of potato apical leaf curl disease on glycemic index and resistant starch of potato (Solanum tuberosum L.) tubers. *Food Chemistry*, *359*, 129939. https://doi.org/10.1016/j.foodchem.2021.129939

Lindqvist-Kreuze, H., Khan, A., Salas, E., Meiyalaghan, S., Thomson, S., Gomez, R., & Bonierbale, M. (2015). Tuber shape and eye depth variation in a diploid family of Andean potatoes. *BMC Genetics*, *16*(1), 1–10. https://doi.org/10.1186/s12863-015-0213-0

Liu, C.-W., Lin, K.-H., & Kuo, Y.-M. (2003). Application of factor analysis in the assessment of groundwater quality in a blackfoot disease area in Taiwan. *Science of the Total Environment*, *313*(1–3), 77–89.

Maltsev, S. V., Andrianov, S. V., Timoshina, N. A., Knyazeva, E. V., Biryukova, V. A., & Tsygvintsev, P. N. (2022). The influence of gamma irradiation on the storability and biochemical parameters of potato tubers. *The Agrarian Scientific Journal*, *10*, 50–54. https://doi.org/10.28983/asj.y2022i10pp50-54

McKenzie, M., & Corrigan, V. (2016). Potato flavour. In *Advances in potato chemistry and technology* (pp. 339–368). Elsevier.

Mlaviwa, J., & Missanjo, E. (2019). Recent trends and future directions on value addition of irish potato (Solanum tuberosum L.) among smallholder farmers. *Emerging Science Journal*, *3*(1), 41–52. https://doi.org/10.28991/esj-2019-01167

Mohapatra, S., Panda, S. H., Sahoo, S. K., Sivakumar, P. S., & Ray, R. C. (2007). β-Carotene-rich sweet potato curd: production, nutritional and proximate composition. *International Journal of Food Science & Technology*, *42*(11), 1305–1314.

Mounir, A. M., El-Hefny, A. M., Mahmoud, S. H., & El-Tanahy, A. M. M. (2022). Effect of low gamma irradiation doses on growth, productivity and chemical constituents of Jerusalem artichoke (Helianthus tuberosus) tubers. *Bulletin of the National Research Centre*, *46*(1), 146.

Nairfana, I., Nikmatullah, A., Sarjan, M., & Kisman. (2021). Tuber and Organoleptic Characteristics of Four Potato Varieties Grown Off-season in Sajang Village, Sembalun. *IOP Conference Series: Earth and Environmental Science*, *913*(1). https://doi.org/10.1088/1755-1315/913/1/012044

Ndungutse, V., Vasanthakaalam, H., Faraj, A. K., & Ngoda, P. (2019). (Solanum Tuberosum L .) Cultivars Grown. *Potato Journal*, *46*(July), 48–55.

Ngobese, N. Z., Workneh, T. S., & Siwela, M. (2017). Effect of low-temperature long-time and high-temperature short-time blanching and frying treatments on the French fry quality of six Irish potato cultivars. *Journal of Food Science and Technology*, *54*(2), 507–517. https://doi.org/10.1007/s13197-017-2495-x

Ooko, G. A. (2008). Evaluation of the physico-chemical properties of selected potato varieties and clones and their potential for processing into frozen french fries (Doctoral dissertation).

Rezaee, M., Almassi, M., Minaei, S., & Paknejad, F. (2013). Impact of post-harvest radiation treatment timing on shelf life and quality characteristics of potatoes. *Journal of Food Science and Technology*, *50*(2), 339–345. https://doi.org/10.1007/s13197-011-0337-9

Sarkar, P., & Mahato, S. K. (2020). Effect of Gamma Irradiation on Sprout Inhibition and Physical Properties of Kufri Jyoti Variety of Potato. *International Journal of Current Microbiology and Applied Sciences*, *9*(7), 1066–1079. https://doi.org/10.20546/ijcmas.2020.907.125

Soares, I. G. M., da Silva, E. B., Amaral, A. J., Machado, E. C. L., & Silva, J. M. (2016). Physico-chemical and sensory evaluation of potato (Solanum tuberosum L.) after irradiation. *Anais Da Academia Brasileira de Ciencias*, *88*(2), 941–950. https://doi.org/10.1590/0001-3765201620140617

Spence, C. (2015). On the psychological impact of food colour. *Flavour*, *4*(1), 1–16.

Subía, X. C. (2013). *Potato quality traits: variation and genetics in Ecuadorian potato landraces*. Wageningen University and Research.

Valcarcel, J., Reilly, K., Gaffney, M., & O'Brien, N. (2015). Total carotenoids and l-ascorbic acid content in 60 varieties of potato (Solanum tuberosum L.) grown in Ireland. *Potato Research*, *58*, 29–41.

von Braun, J., Chichaibelu, B. B., Torero Cullen, M., Laborde, D., & Smaller, C. (2021). *Ending hunger by 2030–policy actions and costs*.

Yang, Y., Achaerandio, I., & Pujolà, M. (2016). Classification of potato cultivars to establish their processing aptitude. *Journal of the Science of Food and Agriculture*, *96*(2), 413–421. https://doi.org/10.1002/jsfa.7104

Zarzecka, K., Ginter, A., Gugała, M., Mystkowska, I., & Rymuza, K. (2023). Potato with Coloured Flesh Valuable and Attractive to the Consumer. *Journal of Ecological Engineering*, *24*(6).

ZEF, F. A. O. (2020). Investment Costs and Policy Action Opportunities for Reaching a World Without Hunger (SDG2). *Center for Development Research of the University of Bonn (ZEF) and Food and Agriculture Organization of the United Nations (FAO)*.

Zhu, F., & He, J. (2020). Physicochemical and functional properties of Maori potato flour. *Food Bioscience*, *33*(November 2019), 100488. https://doi.org/10.1016/j.fbio.2019.100488

Zia, M. A. B., Bakhsh, A., & Çalıskan, M. E. (2018). Mutation breeding in potato; endeavors and challenges. *Journal of Animal and Plant Sciences*, *28*(1), 177–186.

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