



## Modification of Cassava Flour Chemical, Functional Properties, and Sensory Attributes Through Gamma Irradiation

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### Abstract

Gamma irradiation is an emerging food processing technology increasingly applied to improve the safety, shelf life, and quality of staple crops such as cassava (*Manihot esculenta*). It induces significant changes in cassava starch, including reductions in amylose content, moisture, and overall carbohydrates. These changes are accompanied by increased starch solubility and altered swelling and pasting behaviors, which are critical for food texture and processing. Notably, irradiation decreases peak, breakdown, and setback viscosities while modifying gelatinization temperatures, indicating starch depolymerization and changes in crystalline structure. Such alterations enhance starch digestibility and improve its functional performance in various food applications. Protein content and digestibility in cassava also increase due to radiation-induced breakdown of complex proteins into simpler, more bioavailable forms. Conversely, fat content tends to decrease, with concurrent lipid oxidation and shifts in fatty acid profiles. Dietary fiber undergoes structural transformations that enhance solubility, potentially benefiting digestive health. Mineral contents generally remain stable; however, gamma irradiation can improve mineral bioavailability by degrading anti-nutritional factors. Furthermore, gamma irradiation significantly enhances the sensory qualities of cassava products by increasing sweetness through starch breakdown, reducing viscosity for easier processing, and modifying color and texture to improve consumer appeal. These sensory improvements contribute to greater consumer acceptance, making irradiated cassava flour a promising ingredient for both traditional and modern food applications. Overall, gamma irradiation presents a promising technology for enhancing cassava's nutritional and functional qualities. However, optimizing irradiation doses is essential to maximize benefits while minimizing adverse effects on texture and nutrient integrity.

**Keywords:** Gamma irradiation, Cassava, Chemical properties, Functional properties, Pasting properties.

### Introduction

Cassava (*Manihot esculenta*) is a perennial woody shrub that originated in Brazil and Paraguay and was initially disseminated across South and Central America (O'Connor, 2013). In the 16th century, Portuguese explorers introduced cassava to Africa, where it rapidly gained significance as a staple crop. It spread to Asia in the 19th century. Today, cassava is cultivated in over 100 countries, playing a central role in food security, particularly in Africa, Asia, Latin America, and the Caribbean (Ceballos *et al.*, 2016). In Kenya, cassava is grown countrywide, with the eastern, coastal, and western regions serving as primary production zones (Githunguri *et al.*, 2015). Its remarkable resilience to drought, tolerance to a wide pH range (4–8), and ability to yield under poor soil conditions make cassava an ideal crop for marginal environments (Orek *et al.*, 2020; Nassar & Ortiz, 2007). Harvesting time is variable, depending on genotype and environmental conditions, and ranges from six to twelve months after planting (Mtunguja *et al.*, 2016).

Globally, cassava is a staple food for over 800 million people (Uarrotta *et al.*, 2016). It is the second most important root crop after the Irish potato and is the world's second-largest source of starch (Morante *et al.*, 2016). In Africa, over 80% of cassava is used subsistently, with products ranging from flour for porridge and *ugali* to fried chips and fermented foods (Githunguri & Njiru, 2021; Ouma *et al.*, 2021). In Kenya, approximately 90% of cassava is consumed as food, 6% is used in animal feeds, and the remainder is processed into industrial products (Mulu-Mutuku *et al.*, 2013). Despite the numerous benefits associated with cassava, its production and utilization have been hampered by diseases such as cassava mosaic disease (CMV), root rot, and pests such as mites (Kinyua & Okwaro, 2021; Sholihin *et al.*, 2019). Further high amounts of hydrogen cyanide (HCN) in most varieties, above the 10 mg/kg limit set by the World Health Organization (Codex & intergovernmental, 2009), dramatically impact cassava consumption and uptake among the populations (Ouma *et al.*, 2021).



Mutation breeding using gamma rays and efficiency-enhancing mechanisms is effective in addressing some of the challenges in the cassava value chain, besides conferring better nutritional characteristics (Ceballos *et al.*, 2016, 2020; Chaicharoen *et al.*, 2023; Chepkoech *et al.*, 2015; Kinyua & Okwaro, 2021; Sholihin *et al.*, 2019). This technique has been used to produce higher-yielding, taller, higher total starch content, mite resistance, and reduced HCN content cassava varieties (Maharani *et al.*, 2015; Sholihin *et al.*, 2019). However, to ascertain their application in ensuring food security, the physicochemical and functional characteristics of the mutated cassava through gamma irradiation and their derived products need to be assessed.

### **Cassava Proximate and Chemical Composition**

The nutritional composition of cassava (*Manihot esculenta*) roots is highly variable, influenced by factors such as production location, variety, environmental conditions, and harvest age (Hasmadi *et al.*, 2020). Cassava is predominantly composed of carbohydrates, with a 100-gram serving of cooked cassava providing about 40 grams of carbohydrates, which accounts for roughly 80% of its caloric content (USDA, 2023). Its starch is primarily made up of amylose (17–25%) and amylopectin (75–83%), with these proportions varying based on genetic and environmental factors as well as post-harvest processing (Wang *et al.*, 2023). The lower amylose content relative to cereals enhances cassava's rapid digestibility, as amylopectin's branched structure is more accessible to digestive enzymes, while amylose forms resistant crystalline structures that slow hydrolysis (Adeyanju *et al.*, 2024). Cassava's protein content is relatively low, averaging about 1.5 g per 100 grams, and it lacks essential amino acids such as lysine, methionine, and cysteine, making it an incomplete protein source (Khajarearn & Khajarearn, 1992; Zidenga *et al.*, 2017). As a result, diets heavily reliant on cassava may lead to protein-energy malnutrition unless complemented with other protein-rich foods (Stephenson *et al.*, 2010). The fat content in cassava is minimal, with approximately 0.3 g per 100 grams, consisting mainly of monounsaturated (oleic acid) and polyunsaturated (linoleic acid) fatty acids, which can enhance product texture and stability but do not contribute significantly to dietary fat intake (Oyeyinka *et al.*, 2019). Cassava also contains about 2 g of dietary fiber per 100 grams, primarily insoluble fiber such as cellulose, hemicellulose, and lignin (Morgan & Choct, 2016). Additionally, cassava is rich in resistant starch, which acts as a prebiotic, supporting gut health and potentially improving insulin sensitivity (Slavin, 2013). The moisture content of fresh cassava roots is relatively high, typically ranging from 60% to 70% which contributes to its perishability, while that of the flour is relatively lower, ranging from 10-15% (Hasmadi *et al.*, 2020). Ash content, representing the total mineral content, is generally low, usually less than 1% (USDA, 2023). Overall, while cassava is an excellent energy source, its low protein, fat, and fiber content necessitate dietary diversification for balanced nutrition.

Additionally, cassava provides several essential minerals that contribute to its nutritional profile. Calcium is an essential mineral important for bone health, muscle function, and nerve transmission. In cassava, the calcium content is relatively low, providing about 0.18 g/100 g of cooked cassava, which accounts for approximately 2% of the Daily Value (DV) (USDA, 2023). While cassava can contribute to calcium intake, it is not a significant source compared to dairy products or leafy greens. Adequate calcium intake is crucial for maintaining bone density and preventing osteoporosis (Ayetigbo *et al.*, 2018).

Magnesium plays a vital role in numerous biochemical reactions in the body, including energy production, protein synthesis, and muscle function. Cassava contains about 27 g/100 g of magnesium, contributing approximately 5% of the Daily Value DV (USDA, 2023). Magnesium deficiency can lead to various health issues such as muscle cramps, fatigue, and increased risk of chronic diseases like hypertension and type 2 diabetes (Micha *et al.*, 2017). Iron is crucial for the formation of hemoglobin in red blood cells and plays a vital role in oxygen transport throughout the body. Cassava contains approximately 0.5 mg/ 100 g, which provides about 3% of the DV (USDA, 2023). However, cassava's iron content is relatively low compared to other sources such as red meat or legumes (Ayetigbo *et al.*, 2018).

Zinc is an essential trace mineral involved in numerous biological functions, including immune response, protein synthesis, and wound healing. Cassava contains about 0.3 mg of zinc per 100 grams, providing around 2% of the DV (Dada, 2016). While this amount contributes to overall zinc intake, it is lower than that found in meat, shellfish, legumes, and seeds (Bayata, 2022).

### **Effect of Gamma Irradiation on the Chemical Composition of Cassava**

#### **Starch**

Gamma irradiation has been increasingly recognized as a valuable post-harvest processing technique that can modify the nutritional and chemical properties of cassava. At doses ranging from 5 to 20 kGy, gamma irradiation



cleaves glycosidic bonds in starch molecules, causing depolymerization and reducing total carbohydrate and amylose content. Amylose may decrease from around 20.21% to as low as 13.27% at higher doses (Asare & Darfour, 2024). This reduction is accompanied by increased starch solubility and digestibility, resulting from the cleavage of glycosidic bonds and reduction of molecular weight (Kumar *et al.*, 2017; Oyeyinka, 2019). According to Sunder *et al.* (2022), swelling capacity exhibits a complex response as it generally decreases at lower doses (< 2 kGy) due to amylopectin branch breakdown but may increase at doses above 5 kGy owing to structural loosening that facilitates water penetration. These modifications improve the starch's functional properties, including gelatinization and pasting behavior, which are essential for diverse food processing applications (Asare & Darfour, 2024).

### Protein

The impact of gamma irradiation on cassava protein content is variable across studies. Some research indicates that doses (5–10 kGy) can increase apparent protein content and improve digestibility due to the breakdown of complex proteins into smaller peptides and amino acids by radiation-induced free radicals (Khumaida *et al.*, 2015; Sunder *et al.*, 2022). However, higher doses (>10 kGy) may lead to protein denaturation, aggregation, and loss of functional properties as a result of unfolding and degradation of protein molecules (Bahraini *et al.*, 2017; X. B. Wang *et al.*, 2018). Other studies report no significant differences in total protein content following irradiation, suggesting that varietal differences and methodological factors may influence the outcome (Paixão *et al.*, 2021; Verma *et al.*, 2023). This highlights the critical need for dose optimization to maximize benefits while minimizing adverse effects.

### Lipids

Gamma irradiation also affects the lipid fraction of cassava, which is naturally low. At doses of 10 kGy, fat content can decrease substantially, from approximately 0.47% to 0.19% (Momchilova *et al.*, 2023). The reduction is attributed to the cleavage of triglycerides into fatty acids and glycerol, as well as enhanced lipid oxidation triggered by free radical formation. These oxidative reactions not only reduce total lipid content but can also alter the fatty acid profile, potentially compromising nutritional quality (Olotu *et al.*, 2014). Higher irradiation doses and longer storage periods can exacerbate lipid loss, and the formation of harmful oxidation products may offset the benefits of reduced fat content (Saad & Kabbashi, 2014).

### Dietary Fiber

Dietary fiber in cassava, primarily insoluble forms such as cellulose and hemicellulose, undergoes notable structural changes upon gamma irradiation. The process cleaves glycosidic bonds, increasing fiber solubility and fermentability, which can enhance its prebiotic effects by promoting beneficial gut microbiota (Moneim *et al.*, 2022; Choi *et al.*, 2012). The extent of these changes is dose-dependent. Low doses (1–5 kGy) cause minor modifications, while higher doses (10–20 kGy) induce extensive breakdown, potentially altering the balance between soluble and insoluble fiber fractions (Asare & Darfour, 2024). Additionally, gamma irradiation can increase resistant starch content, further supporting gut health and metabolic benefits.

### Mineral Content

Gamma irradiation generally maintains the mineral content of cassava, including calcium, magnesium, zinc, and iron, while potentially enhancing their bioavailability. Calcium levels remain largely unaffected at doses up to 10 kGy, though higher doses (15–20 kGy) may reduce calcium content; importantly, irradiation can improve calcium absorption by breaking down anti-nutrients like phytic acid (Chepkoech *et al.*, 2022; Osae, 2001). Similarly, magnesium content is stable under irradiation, with studies on legumes showing no significant changes; however, bioavailability may increase due to the degradation of mineral-binding compounds (Janthanasakulwong & Yoksan, 2024; Khan *et al.*, 2018). Zinc content often remains unchanged, but its bioavailability improves as phytates are broken down (Ayetigbo *et al.*, 2018). Iron levels in cassava are also stable following irradiation, with enhanced bioavailability resulting from reduced anti-nutritional factors, which is particularly beneficial for populations dependent on cassava as a staple food (Asare & Darfour, 2024; Osae, 2001). Overall, gamma irradiation preserves mineral content while improving nutritional quality through increased mineral accessibility.

### Cassava Functional Properties

Functional properties of food ingredients are critical determinants of their behavior during processing and cooking, directly influencing the texture, appearance, flavor, and overall quality of the final product (Dikkala & Shirisha, 2018). Cassava flour, recognized for its versatility, is extensively used in food, pharmaceutical, and



textile industries (Ndubuisi & Chidiebere, 2018). Its functional properties underpin its suitability across these diverse applications.

### **Water Holding Capacity**

One of the most notable functional properties of cassava flour is its water-holding capacity (WHC). Studies have reported that cassava flour exhibits a high WHC, ranging between 1.12 and 1.30 mL/g, which is superior to many cereal flours (AACC *et al.*, 2009; Agbemafle *et al.*, 2020). This elevated WHC is primarily attributed to cassava's starch composition, particularly the branched structure of amylopectin and the presence of phosphate groups that facilitate the formation of a sponge-like matrix capable of effectively absorbing and retaining water (Agbemafle *et al.*, 2020). Such properties are essential in food formulations where moisture retention is critical, such as in baked goods and meat products.

### **Oil Absorption Capacity**

The oil absorption capacity (OAC) of cassava flour is another important functional attribute influenced by the lipophilic nature of starch granules and protein content. Starch molecules' lipophilic sites physically entrap oils, while proteins with hydrophobic regions bind lipids, collectively enhancing oil retention (Dudu *et al.*, 2020; Gul *et al.*, 2016). This property is vital in food products where flavor retention, mouthfeel, and shelf life depend on effective oil absorption, including baked goods and fried snacks.

### **Swelling Power and Solubility**

Cassava flour also demonstrates a high swelling power, ranging from 10.48 to 12.04, exceeding that of wheat flour (Chisenga, Workneh, Bultosa, & Alimi, 2019). This is largely due to its higher starch content and the relatively loose association between starch polymers (Hasmadi *et al.*, 2020). The increased swelling power enables composite flours containing cassava to retain more water, contributing to the production of firmer, drier food products (Verma *et al.*, 2023). Additionally, cassava flour's solubility varies between 11.0% and 20.8%, depending on the variety, which influences dough cohesion and the texture of baked goods, thereby enhancing product quality (Kayode *et al.*, 2021).

### **Bulk Density**

The bulk density of cassava flour, typically between 0.40 and 0.70 g/cm<sup>3</sup> (Verma *et al.*, 2023) and is lower than that of wheat flour, which averages around 0.80 g/cm<sup>3</sup> (Hasmadi *et al.*, 2020). This lower bulk density is associated with cassava's reduced protein and fat content, making it suitable for formulating nutrient-rich, lightweight food products (Asare & Darfour, 2024). Bulk density is also influenced by factors such as moisture content, particle size, and fiber content, with higher moisture levels generally increasing bulk density (Hasmadi *et al.*, 2020).

### **Pasting Properties**

Pasting properties describe how starches behave when subjected to heat and water, playing a crucial role in determining the texture, consistency, and stability of various food products (Olatunde *et al.*, 2017). For cassava flour, the key pasting properties include peak viscosity, breakdown, and final viscosity. Peak viscosity refers to the highest viscosity reached by cassava starch during heating in the presence of water, reflecting the starch's capacity to absorb water and swell (Braşoveanu & Nemţanu, 2020). Cassava flour typically exhibits high peak viscosity compared to other starches due to its unique structure characterized by its high amylopectin and low amylose content with relatively large and intact granules (Chamorro *et al.*, 2025). This structure enables efficient water absorption and gelatinization compared to other starches, resulting in high peak viscosity. The branching pattern and molecular weight distribution of amylopectin contribute to rapid swelling and significant granule expansion, which enhance viscosity development (Chamorro *et al.*, 2025; Oladunmoye *et al.*, 2014). At the molecular level, the abundant hydrophilic hydroxyl (-OH) groups present on the glucose units of amylopectin and amylose play a crucial role in starch-water interactions. These hydroxyl groups form hydrogen bonds with water molecules, enabling the starch granules to absorb water effectively and swell during gelatinization (Chamorro *et al.*, 2025). This water absorption capacity is fundamental to the development of high peak viscosity. Research has shown that increasing cassava starch content in flour blends increases peak viscosity because a higher concentration of starch granules, especially from cassava, means more particles can absorb water and swell during heating, producing greater thickening (Batey & Curtin, 2000). This is evidenced by observations that as cassava proportion rises in composite flours, peak viscosity increases accordingly, whereas replacing cassava with flours like millet lowers peak viscosity due to reduced water-holding and swelling capacity (Imoisi *et al.*, 2024). High



peak viscosity also signifies that cassava flour is well-suited for products where thickness and viscosity are essential for quality, such as in the preparation of gluten-free foods (Reddy & Viswanath, 2019).

Breakdown viscosity is the measure of how much the viscosity of the starch paste decreases after reaching its peak viscosity, typically as a result of continued heating and mechanical shearing (Castanha *et al.*, 2021). Cassava flour tends to show moderate breakdown viscosity, meaning that while its starch granules swell significantly, they are not highly resistant to disintegration under heat and shear (Hasmadi *et al.*, 2020). The starch granules swell extensively during heating because of their branched amylopectin structure and abundant hydrophilic hydroxyl (-OH) groups, which form hydrogen bonds with water, promoting water absorption and swelling (Balet *et al.*, 2019). However, these swollen granules have only moderate resistance to mechanical shear, leading to some granule fragmentation and viscosity loss under continued stress (Franck., 2020). This balance between granule swelling aided by hydrophilic interactions and partial granule breakdown under heat and shear results in breakdown viscosity levels suited to maintaining paste stability without excessive thinning (Balet *et al.*, 2019). The presence of hydrophilic groups facilitates water retention even as granules rupture, helping the paste sustain a degree of viscosity during processing. A higher breakdown viscosity can lead to less stable pastes, making it a critical consideration for processing methods that require starches with enhanced resistance to breakdown (Lu *et al.*, 2020). In food products like baked goods that need to maintain their structural integrity, cassava flour's moderate breakdown properties offer an advantage, as it balances water retention without excessive breakdown of the starch granules (Oladunmoye *et al.*, 2014).

Final viscosity measures the viscosity of the starch mixture after it cools down following gelatinization. It is a key indicator of the starch's ability to form a stable gel and retain structure after cooling, which is important in products like puddings, porridges, and other foods that may be consumed cold or reheated (Lu *et al.*, 2020). Cassava starch's high amylopectin content with many hydrophilic hydroxyl (-OH) groups enables strong hydrogen bonding with water molecules, which supports the formation of a tight, water-trapping gel matrix during cooling (Castanha *et al.*, 2021). This molecular arrangement restricts the retrogradation process that would otherwise harden and weaken the gel structure. The branching pattern and hydrophilic nature of amylopectin chains create a stable network that maintains paste thickness and texture upon cooling, making cassava flour ideal for products requiring firm, stable gels such as puddings, porridges, and gluten-free baked goods (Abiodun & Abimbola, 2014; Li *et al.*, 2023). High final viscosity also enhances the quality of gluten-free baked goods, as it contributes to the formation of consistent textures without the need for gluten (Wanjala *et al.*, 2016).

### **Effect of Gamma Irradiation on the Functional Properties of Cassava Flour.**

Gamma irradiation is documented to affect the functional and rheological properties of various flours, including cassava flour. Gamma irradiation can significantly alter water absorption capacity (WAC), oil absorption capacity (OAC), swelling power, solubility, and pasting properties of cassava flour.

#### **Water and Oil Absorption Capacity**

Several studies have reported that gamma irradiation increases the WAC of cassava flour, primarily due to the breakdown of starch granules into smaller fragments that provide greater surface area for water binding (Agyei-Amponsah *et al.*, 2015; Verma *et al.*, 2023). This enhancement in WAC is typically observed at moderate doses ranging from 10 to 50 kGy. However, at higher doses (75kGy), excessive degradation of starch structure may reduce water absorption capacity (Sunder *et al.*, 2022). Similarly, the oil absorption capacity of cassava flour tends to increase at low to moderate irradiation doses (5-20kGy). This increase is attributed to the exposure of hydrophobic groups within the starch granules, which are otherwise embedded in the starch matrix, thereby improving flavor retention and mouthfeel in food products such as baked goods and fried snacks (Verma *et al.*, 2023).

#### **Swelling Power and Solubility**

Swelling power, an important parameter reflecting the ability of starch granules to absorb water and swell upon heating, generally decreases with increasing gamma irradiation doses from 5kGy to 20kGy (AACC *et al.*, 2009). This reduction is linked to the disruption of the crystalline structure of starch granules and partial depolymerization of amylopectin, which weakens the hydrogen bonds responsible for granule stability (Chisenga, Workneh, Bultosa, & Alimi, 2019). The decreased swelling power influences the texture of cassava-based products like sauces and batters.

Conversely, the solubility of cassava starch increases with irradiation dose (0-10kGy), especially at higher levels > 10kGy, due to the breakdown of amylose and amylopectin molecules into smaller, more water-soluble fragments



(Agyei-Amponsah *et al.*, 2015; Raffi *et al.*, 2000). This enhanced solubility benefits applications requiring rapid dispersion and uniform consistency, such as instant foods and beverages.

### **Bulk Density**

Bulk density, a critical property for packaging and handling, is reduced following gamma irradiation (Verma *et al.*, 2023). This reduction results from the formation of finer particles due to starch granule breakdown, making irradiated cassava flour suitable for lightweight and low-calorie food formulations (Agyei-Amponsah *et al.*, 2015).

### **Pasting Properties**

Gamma irradiation also affects the pasting properties of cassava flour, including peak viscosity, breakdown viscosity, and final viscosity. Studies have shown that gamma irradiation breaks glycosidic bonds in starch molecules, leading to the depolymerization of amylose and, more notably, amylopectin. This degradation reduces the molecular weight and disrupts the granule's ability to absorb water and swell during heating. As a result, the peak viscosity, which reflects the maximum thickening power and water-holding capacity of starch, generally decreases with increased gamma irradiation dose from 0-20kGy ( Verma *et al.*, 2023; Chisenga, Workneh, Bultosa, & Laing, 2019). High doses (20-50kGy) cause substantial cleavage of amylopectin branches, lowering swelling and water binding, and making granules more fragile and prone to breakdown under heat and shear (Dikkala & Shirisha, 2018).

Breakdown viscosity also decreases with gamma irradiation. Irradiated starch granules become more fragmented and structurally weakened (Chung *et al.*, 2015). While they may rupture more readily, the diminished swelling capacity and lower peak viscosity result in a reduced magnitude of viscosity loss during breakdown, yielding lower breakdown viscosity and signaling less stable pastes with diminished resistance to mechanical and thermal stress (Chung *et al.*, 2015). A study investigating gamma-irradiated cassava starch found that breakdown viscosity significantly decreased at high irradiation doses of 20 kGy; breakdown viscosity dropped from ~1268 BU to ~398 BU (Asare & Darfour, 2024).

Final viscosity is reduced by gamma irradiation as well (Verma *et al.*, 2023). The fragmentation of amylopectin reduces the ability to form strong hydrogen-bonded networks during cooling (Suriya *et al.*, 2017). Additionally, irradiated starches exhibit increased solubility but decreased retrogradation stability, resulting in weaker gels and lower final viscosity (Chung *et al.*, 2015). This compromises texture stability important for products that require firm gels or thickness retention over time (Chisenga, Workneh, Bultosa, & Laing, 2019)

Conclusively, the relationship between irradiation dose and the functional properties of cassava flour is complex and dose-dependent. Moderate doses improve water and oil absorption capacities and solubility, while reducing swelling power and bulk density, thereby modifying texture and processing characteristics beneficially. However, excessively high doses may cause over-degradation of starch components, leading to diminished functional quality. Therefore, optimizing gamma irradiation parameters is essential to enhance cassava flour's functional properties without compromising its structural integrity and usability in food applications.

### **Sensory Evaluation and Consumer Acceptability of Cassava Products**

Sensory evaluation is a scientific discipline focused on measuring, analyzing, and interpreting food characteristics perceived through the five human senses: taste, touch, smell, sight, and sound (Lawless & Heymann, 2010). Acceptance of cassava and its products is often region-specific; communities that cultivate cassava tend to have a higher acceptance due to product familiarity. Studies on various cassava products, including roots, thin porridge, and composite flours, have revealed factors influencing consumer acceptability. For instance, research by Koch *et al.* (2014) indicated that the flavor, texture, and appearance of cassava-based dishes significantly impact consumer preferences. Similarly, a study by Obi *et al.* (2019) highlighted that the blending of cassava flour with other flours, such as wheat or maize, improved the sensory attributes and acceptability of the resulting baked goods. These findings suggest that the formulation of cassava products, considering local taste preferences, plays a crucial role in their marketability.

### **Influence of Gamma Irradiation on the Acceptability of Cassava Products**

Gamma irradiation is increasingly recognized as an effective method for improving the safety and quality of food products, including cassava (Arapcheska *et al.*, 2020). This technique utilizes high-energy gamma rays to reduce microbial load and extend the shelf life of food items, thereby addressing common concerns related to spoilage and foodborne illnesses (Arapcheska *et al.*, 2020). By minimizing microbial contamination, gamma irradiation



enhances the overall safety of cassava products, making them more appealing to consumers who prioritize food safety (Indiarto *et al.*, 2023).

Gamma irradiation can significantly enhance the sensory qualities of cassava products by modifying their chemical and physical properties. One notable effect is the breakdown of starch molecules into simpler sugars, such as glucose, maltose, and various oligosaccharides. This cleavage occurs through the breaking of glycosidic bonds in amylose and amylopectin molecules, which can increase the sweetness and improve the taste profile of cassava-based dishes (Maherani *et al.*, 2016). Additionally, gamma irradiation can reduce the viscosity of cassava flour suspensions by breaking down starch granules into smaller fragments, making them easier to mix and process due to increased surface area (Asare & Darfour, 2024). This reduced viscosity enhances the versatility of cassava flour in various culinary applications.

Furthermore, gamma irradiation can alter the color and appearance of cassava products. The formation of new chromophores or the degradation of existing pigments can result in changes in color, such as increased yellowness, which can affect consumer perception and preference (Katunzi & Fortunatus, 2022). Texture modifications are also significant, as the structural changes in starch granules can lead to a softer or more pliable texture, making cassava flour more suitable for different uses (Kilewela & Fortunatus, 2022). These sensory enhancements are crucial for market success, as consumers often prioritize products with appealing taste, texture, and appearance.

Consumer studies have indicated that products with improved sensory qualities are more likely to be accepted and purchased because enhanced attributes such as taste, texture, and aroma make food products more appealing and enjoyable to consume (Katunzi-Kilewela & Fortunatus, 2022; Maherani *et al.*, 2016). For example, irradiated cassava flour can serve as a substitute in traditional recipes, potentially leading to greater consumer acceptance in regions where cassava is a staple. The enhanced quality can help bridge the gap between traditional food preferences and the growing demand for safer, longer-lasting food options.

### Conclusion

Gamma irradiation causes dose-dependent changes in cassava flour and starch that affect its chemical composition, functional properties, and sensory qualities. It breaks down starch polymers into simpler sugars like glucose, enhancing sweetness and digestibility, while slightly reducing moisture and pH and increasing protein, fiber, and ash content. Also, gamma irradiation affects the functional properties. It generally improves water absorption, solubility, and swelling at low to moderate doses due to exposed hydrophilic sites from starch fragmentation, but higher doses weaken granule integrity, reducing peak, breakdown, and final viscosities and thus thickening and gel-forming ability. Gamma irradiation may cause mild granule shrinkage, affecting flow and processing characteristics without major structural damage. Throughout the product life cycle, sensory evaluation is essential to monitor alterations in texture, flavor, and overall acceptability driven by irradiation-induced changes in sugar content and viscosity, which impact mouthfeel and palatability.

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