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Development of Gluten-Free Bread Using Cassava and Sorghum Flour Blends

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Abstract

Cassava–sorghum flour blends have garnered growing interest in gluten-free bread production due to their complementary functional and nutritional attributes. This review synthesizes findings from peer-reviewed literature on the synergistic effects of these blends in enhancing bread texture, flavor, and nutritional quality, with a focus on optimal blending ratios, loaf volume, crumb softness, and shelf life. Evidence indicates that incorporating approximately 25% sorghum flour into cassava-based formulations preserves favorable sensory properties while improving dietary fiber content, antioxidant capacity, and glycemic control relative to traditional wheat-based breads. While cassava contributes advantageous starch characteristics, its inherently low protein and micronutrient content necessitates targeted fortification strategies, including the addition of proteins, vitamins, and minerals. Notable research gaps include limited studies on long-term shelf life, the efficacy of nutrient fortification, and challenges in scaling up production. Emerging food technologies, such as enzyme application, extrusion, and hydrocolloid incorporation present promising opportunities for optimizing product quality and functional performance. Overall, cassava–sorghum breads offer substantial potential in expanding the gluten-free product market, particularly when formulation and processing methods are strategically refined to meet both nutritional and sensory expectations.

Keywords: Cassava Flour; Sorghum Flour; Gluten-Free Bread; Nutritional Fortification; Food Processing Technologies

Introduction

Gluten, a composite of storage proteins primarily gliadin and glutenin in wheat, barley, and rye, imparts unique viscoelastic properties essential to traditional leavened bread, enabling dough to trap carbon dioxide and maintain structure during baking (Wikipedia, 2025). However, for individuals with celiac disease, non celiac gluten sensitivity, or wheat allergy, gluten triggers adverse autoimmune or inflammatory responses, making its avoidance crucial (Wikipedia, 2025). Globally, celiac disease affects about 1 2% of the population, with additional prevalence of non celiac gluten sensitivity (Wikipedia, 2025). Consequently, demand for high quality gluten free bread alternatives continues to rise.

Beyond medical necessity, the gluten free diet has gained popularity as a lifestyle choice, although the trend risks nutritional imbalance. Many gluten free commercial products are lower in fortification, fiber, iron, and B vitamins, while often being higher in lipids and carbohydrates (Wikipedia, 2025). Therefore, identifying nutrient dense, functional gluten free ingredients is both timely and essential.

Cassava Flour, A naturally gluten free flour derived from the whole cassava root (unlike tapioca starch), cassava flour offers a mild flavor, fine texture, and excellent absorptive capacity making it versatile in gluten free baking (Food & Wine, 2023; RealSimple, 2022). Research indicates that breads using cassava starch exhibit softer crumbs, enhanced cohesiveness, and better moisture retention, particularly after several days of storage (Sigüenza Andrés et al., 2021; Sci Direct). Additionally, cassava supplies local food security benefits and economic savings, especially where wheat is imported (Aristizábal, 2017). Nevertheless, a recent Consumer Reports analysis identified lead contamination risks in certain cassava based gluten free products emphasizing the need for careful sourcing and processing to ensure food safety (Food & Wine, 2025).

As a drought tolerant cereal, sorghum is increasingly cultivated globally. It’s gluten free and rich in fiber, antioxidants (e.g., polyphenols), and micronutrients like B vitamins, magnesium, and phosphorus (Health.com, 2024; Verywell Health, 2023). Its whole grain nature promotes gut health, blood sugar regulation, and cardiovascular benefits. Moreover, sorghum lacks immunogenic gluten proteins, making it suitable for celiac patients (Curti et al., 2023; USDA ARS, 2005). However, sorghum bread's quality is influenced by milling type and may require additional functional ingredients like starches or hydrocolloids to improve bread texture and structure (Curti et al., 2023; Akin et al., 2022).

Combining cassava and sorghum flours may harness complementary benefits: cassava contributes moisture retention, softness, and binding capability, while sorghum enriches nutritional value and imparts whole grain benefits. Empirical studies support the blend synergy: breads formulated with cassava sorghum (and rice sorghum) outperform maize sorghum or potato sorghum breads in crumb properties. A formulation containing 50% cassava starch retained the best texture over storage (Onyango et al., 2010; FoodNavigator, 2010). Likewise, trials exploring ratios from 10:90 up to 50:50 cassava starch to sorghum flour demonstrated improved batter rheology and bread properties (ResearchGate, 2020). More recent research further confirms that adding 30 50% cassava (native or gelatinized) into sorghum flour improves cohesiveness, springiness, resilience, and reduces firmness and chewiness (Akin et al., 2022). Early field studies also noted acceptable texture and flavor in sorghum cassava breads, despite challenges like rapid staling (Hugo, 1994).

This review aims to synthesize current knowledge on the development of gluten free bread using cassava and sorghum flour blends by:

1. Exploring the functional and nutritional attributes of cassava and sorghum flours individually and in combination.
2. Examining formulation studies, highlighting optimal blend ratios, textural outcomes, and sensory attributes.
3. Analyzing gaps and challenges, including safety concerns (e.g., heavy metal contamination), shelf life limitations, and need for additives (e.g., hydrocolloids, starch types).
4. Proposing future directions, such as safe sourcing protocols for cassava, improved processing methods, ingredient fortification, and development of scalable baking solutions tailored for both commercial and home applications.

Literature Review

Research into cassava sorghum flour blends has expanded considerably in recent years as both ingredients offer unique yet complementary attributes in gluten free breadmaking. Cassava flour, rich in starch and free from gluten, is widely recognized for its ability to enhance crumb softness and retain moisture in baked goods (Akin, Demirkesen Mert, Bean, & Boyacı, 2022). However, its low protein and micronutrient content limits its nutritional contribution (Vilanculos, Oliveira, & Pinho, 2023). In contrast, sorghum flour provides a richer nutritional profile, containing higher levels of dietary fiber, phenolic compounds, and minerals such as iron (Galassi, Corsi, & Marti, 2023). When used together, these flours can balance functional baking performance with enhanced nutritional quality.

Blending sorghum and cassava flours creates synergistic effects in dough rheology and bread texture. For example, Onyango (2011) found that cassava starch improved the softness and moisture retention of sorghum based bread, while sorghum contributed a richer flavor and higher nutrient density. Supporting these findings, Akin et al. (2022) noted that cassava sorghum composites produced breads with better crumb structure compared to sorghum alone, especially when functional additives such as hydrocolloids or enzymes were included. Likewise, Adzqia, Thongngam, and Suwonsichon (2023) demonstrated that blends containing up to 25% sorghum maintained desirable loaf volume, crumb cohesiveness, and sensory acceptability. Beyond this threshold, however, bread volume and texture declined, while color darkened and nutty flavors intensified.

While sorghum's nutritional strengths are clear, its gluten free nature means it lacks the elastic network needed for optimal bread volume. Consequently, structural improvements often rely on alternative agents. Schober, Bean, and Boyle (2005) reported that xanthan gum and skim milk powder significantly enhanced loaf volume and crumb softness in sorghum bread. Furthermore, enzymatic treatments—such as cyclodextrin glycosyltransferase and α amylase—were found by Akin et al. (2022) to slow crumb firming and delay staling in cassava sorghum formulations. Complementing this, Rumler, Hager, and Arendt (2024) showed that physical modifications to sorghum flour, including decortication and extrusion, improved hydration and batter viscosity, yielding loaves with superior internal structure. From a sensory standpoint, cassava sorghum blends produce distinctive profiles that can still appeal to consumers when properly balanced. Dankwa, Teye, Essilfie, and Afoakwa (2021) observed that flatbreads made from cassava sorghum cowpea composites had a chewier mouthfeel and stronger sorghum aroma compared to wheat based controls, yet overall acceptance remained high. Similarly, Akin et al. (2022) found that cassava starch improved crumb softness during storage, contributing to extended freshness—a critical factor for gluten free products, which tend to stale more quickly than wheat breads.

Nutritionally, incorporating sorghum into cassava based bread significantly enhances its health value. Galassi et al. (2023) highlighted that sorghum increases protein content and improves mineral availability, addressing cassava's deficiencies in essential amino acids and micronutrients. Further evidence from Vilanculos et al. (2023) indicated that phytate degradation in composite wheat cassava sorghum breads boosted iron and zinc bioavailability, offering potential public health benefits in regions where mineral deficiencies are prevalent. These findings align with dos Reis Gallo, da Silva, and de Souza (2021), who reported that sorghum breads exhibit higher fiber content, stronger antioxidant activity, and lower glycemic responses compared to many other gluten free options.

Despite these promising outcomes, several limitations remain. Monteiro (2021) noted that most studies prioritize specific volume as the main quality metric, while overlooking other consumer relevant attributes such as flavor complexity, mouthfeel, and long term shelf life. Additionally, Adzqia et al. (2023) emphasized the need for more comprehensive fortification trials specific to cassava sorghum systems, as current research is limited and often laboratory based. Moreover, sensory testing is frequently conducted with small, trained panels, leaving gaps in understanding broader consumer preferences. To address these challenges, researchers have explored emerging technologies. Enzyme assisted processing, hydrocolloid optimization, and pregelatinization treatments have all shown potential in improving the structure and softness of cassava sorghum breads (Akin et al., 2022). Physical processing techniques such as heat moisture treatment and extrusion, as reported by Rumler et al. (2024), may also enhance the functional properties of these flours. Building on these developments, future work should integrate technological improvements with fortification strategies to produce breads that are both nutritionally superior and widely acceptable to consumers.

The literature reveals that cassava sorghum blends offer a viable foundation for gluten free bread with balanced technological and nutritional attributes. Optimal formulations—often around 25% sorghum inclusion—can maintain bread quality while delivering improved fiber, antioxidant activity, and micronutrient content. However, achieving widespread commercial success will require targeted research into shelf life extension, effective fortification, and large scale production feasibility, ensuring that these breads meet both health and sensory expectations in the gluten free market.

Discussion

The growing demand for gluten free baked goods has driven extensive research into suitable flour alternatives that can replicate the functional properties of wheat flour. Common gluten free flours include rice, maize, sorghum, pseudo cereals (e.g., quinoa, buckwheat, amaranth), root flours (cassava, potato), and legume flours (chickpea, bean), each offering distinct nutritional profiles and sensory characteristics (El Khoury, 2018; Cappelli et al., 2020). Commercial "cup for cup" gluten free blends often combine rice or sorghum flour with tapioca or potato starch, supplemented with hydrocolloids like xanthan gum to provide structure and mimic the "chewiness" of gluten containing flours (Cappelli et al., 2020).

Despite these substitutes, formulating high quality gluten free bread remains challenging due to the absence of gluten's viscoelastic network. This deficiency leads to poor gas retention, resulting in low loaf volume, dense crumb, and irregular texture often accompanied by dryness, crumbliness, coarse crumb structure, and rapid staling (Conte, 2018; Naqash, 2017; Cappelli et al., 2020). Doughs without gluten tend to be batter like rather than dough like, which complicates handling and reduces machinability during processing (Cappelli et al., 2020). Moreover, gluten free products frequently suffer from nutritional inadequacies, lacking fiber, vitamins (e.g., B vitamins), and minerals, while sometimes containing higher levels of saturated fats and carbohydrates than their wheat based counterparts (El Khoury, 2018).

To counteract these issues, formulators incorporate starches, proteins, and hydrocolloids to reconstruct a pseudo gluten network and improve bread quality. Starches, particularly native or modified forms such as tapioca, potato, or pre gelatinized starch, contribute to crumb softness, moisture retention, and structural support, aiding batter viscosity and cohesiveness (Salehi, 2019; El Khoury, 2018). Hydrocolloids, including xanthan gum, guar gum, hydroxypropyl methylcellulose (HPMC), and natural seed gums like basil or cress seed gum, bind water, increase viscosity, stabilize air bubbles, and form gel networks that mimic gluten's viscoelastic properties. Notably, HPMC is often cited as one of the most effective hydrocolloids for gluten free bread manufacturing, forming a robust gel matrix upon heating (Culetu et al., 2021; Salehi, 2019). Proteins from sources such as egg whites, soy, pea, and whey can improve cell structure, elasticity, and gas retention, while emulsifiers and enzymes further bolster texture and extend shelf life (Conte, 2018).

Recent reviews also highlight that combinations of hydrocolloids and starches often yield synergistic improvements. For instance, mixtures of hydrocolloids were reported in most gluten free bread formulations and significantly contributed to enhanced bread quality (Djeukeu, 2024). Moreover, adjusting the ratios of starches and binder systems can yield optimized dough characteristics for example, adjustments in batter hydration, mixing, proofing, and baking times tailored for gluten free systems enhance loaf volume and crumb texture (Cappelli et al., 2020). gluten free bread development hinges on carefully orchestrated formulations that blend starch rich flours with moisture retaining gels, proteins, and texturizing agents. While progress has been made in addressing textural, structural, and sensory shortcomings, continued innovation particularly in ingredient synergy and fortification is needed to fully equal the functional and nutritional quality of traditional gluten containing breads (Conte, 2018; El Khoury, 2018).

Cassava Flour in Bread Making

Cassava (Manihot esculenta Crantz) flour is an appealing gluten free ingredient because it is naturally free of prolamins and largely composed of starch, with a neutral flavor profile that adapts well to baked systems. Nutritionally, cassava root is high in carbohydrate (primarily starch) and comparatively low in protein, fat, and micronutrients when measured against cereal flours; nutrient density varies with cultivar and processing method (Montagnac, Davis, & Tanumihardjo, 2009; Morgan & Choct, 2016). Yellow and orange biofortified cassava can contain significant provitamin A carotenoids, providing opportunities for nutritional enhancement, though their retention depends on processing and storage (Montagnac et al., 2009). From a safety standpoint, cassava contains cyanogenic glucosides (linamarin and lotaustralin); however, standard food processing operations (e.g., peeling, grating/pounding, soaking/fermentation, pressing, roasting, sun drying, and boiling) substantially reduce cyanogens and mitigate risk. Classical and recent reviews report reductions on the order of ~45 50% by boiling alone and ~96 99% with thorough disintegration and sun drying or fermentation plus drying into traditional products (e.g., gari, fufu, lafun), underscoring the importance of validated processing for flour production (Montagnac et al., 2009; Urugo, Chacha, & Abdalla, 2023).

Functionally, cassava starch drives cassava flour behavior in doughs/batters. Its granules gelatinize at relatively moderate temperatures and exhibit high swelling power and paste clarity, which help build viscosity in gluten free batters. Thermal and retrogradation behavior are formulation sensitive: salts (NaCl) and sugars can shift gelatinization temperatures and modulate retrogradation kinetics, with NaCl generally raising gelatinization temperature and inhibiting retrogradation (staling) in gels, while sucrose tends to slightly promote retrogradation under otherwise similar conditions (Thai Science report of DSC based work on cassava gels) (Gelatinization and Retrogradation of Cassava Starch, 2015). Sour (fermented) cassava starch, produced by lactic fermentation and sun drying, is technologically distinctive: compared with native starch, sour starch can yield greater expansion/baking performance in certain applications owing to altered granule surface chemistry and gas holding behavior properties that bakers exploit in "pão de queijo" type products and gluten free breads (Fermentation and Drying Effects on Bread Making Potential of Sour Cassava Starch, 2018; Sigüenza Andrés, Gallego, & Gómez, 2021). Beyond starch chemistry, cassava flour's water absorption and pasting responses shift with gums (e.g., xanthan) or inulin: gums typically raise peak viscosity and stabilize pastes, influencing dough/batter rheology and thermal transitions (Lu et al., 2019).

In bread systems, cassava flour's advantages arise from hydration, viscosity build up, and crumb softening effects especially when part of a composite or gluten free blend while its limitations stem from low protein (no gluten network) and weak gas retention, which can depress specific volume and promote crumb fragility if not counterbalanced by structure building agents. Controlled studies show that increasing cassava flour proportion in composite breads tends to reduce loaf volume and increase density and hardness when no other structural correctives are provided; springiness and ease of chewing can also decline at higher substitution levels (SLU, 2010). Conversely, tailored hydrocolloids and pectins can markedly improve structure: in a factorial study of cassava wheat maize breads, high methoxyl pectin (1 3%) enabled acceptable bread quality at cassava levels up to 40%, improving volume and crumb firmness to near wheat benchmarks in selected treatments

(Eduardo, Svanberg, Oliveira, & Ahrné, 2013). In strictly gluten free matrices, replacing 10 20% of a rice maize base with cassava flour or cassava starches (native/sour) improved hydration/pasting, dough rheology, and crumb softness after storage, with cassava starch breads remaining softer after seven days than controls an important shelf life benefit (Sigüenza Andrés et al., 2021).

Processing form matters. Roasted cassava flour (versus sun dried or fermented) has been reported to increase bread volume at higher cassava levels, likely due to pre gelatinization/partial dextrinization effects that modify water uptake, viscosity development, and gas cell stabilization during baking (Eduardo et al., 2013). That same work highlights that cassava flour type exerts a larger effect on bread quality than cassava level alone, emphasizing the need to specify cultivar and processing when interpreting results. Pectin additions had the strongest influence at the higher cassava inclusion level, reinforcing the strategy of pairing cassava with tailored hydrocolloids (e.g., pectin, HPMC, xanthan) as structure surrogates (Eduardo et al., 2013). Mechanistically, hydrocolloids bind water, increase batter viscosity, and stabilize gas cells, while oven set gelation (notably for HPMC) helps lock in volume and reduce crumb collapse during cooling a general principle supported across cereal systems and transferable to cassava rich formulations (Rosell, Rojas, & de Barber, 2007; Lu et al., 2019).

Cassava can also function synergistically with sorghum and other gluten free bases. In sorghum based breads, adding native vs. pre gelatinized cassava starch at 10 50% of total flour has been used to tune batter rheology and crumb attributes: native starch generally produced springier, less firm crumbs, while enzyme mediated structuring (e.g., transglutaminase) altered firmness/chewiness without improving resilience (Onyango, Mutungi, Unbehend, & Lindhauer, 2010; see also rheology/texture comparisons reported in related work). These reports, together with the cassava in rice/maize blends discussed above, suggest cassava's primary roles in gluten free bread are hydration management, paste viscosity build up, and staling control, rather than protein network substitution hence the common pairing with proteins (egg, dairy, pulses) and emulsifiers/enzymes to support gas retention and crumb setting.

Taking stock of key findings across prior studies, several practical conclusions emerge. First, cassava flour can enhance crumb softness and storage time tenderness in gluten free breads, especially when used as cassava starch (native or sour) at 10 20%

replacement of a rice/maize base (Sigüenza Andrés et al., 2021). Second, bread volume is highly sensitive to both cassava type and hydrocolloid selection/dose; pectin (1 3%) is particularly effective at higher cassava levels (~40%) in composite breads (Eduardo et al., 2013). Third, when used without adequate structuring aids, higher cassava proportions tend to depress volume and increase hardness, underscoring the need for binder systems (SLU, 2010). Fourth, process variables (e.g., roasting/precooking, fermentation to sour starch) substantially shift gelatinization and rheology, and can be leveraged to improve oven spring and crumb architecture. Finally, safety and nutrition must be managed: validated detoxification steps are essential for cyanogen removal, and fortification (e.g., with proteins, fiber, or vitamins) may be advisable to counter cassava's low intrinsic protein/micronutrient content unless biofortified varieties are used (Montagnac et al., 2009; Urugo et al., 2023).

Sorghum Flour in Bread Making

Sorghum (Sorghum bicolor (L.) Moench) is a gluten free, climate resilient cereal increasingly used in bakery applications because of its favorable nutritional profile and functional versatility. Nutritionally, whole grain sorghum flour contains appreciable protein (largely the storage protein kafirin) and dietary fiber, along with a distinctive spectrum of polyphenolic antioxidants notably phenolic acids, flavonoids, tannins, and the rare 3 deoxyanthocyanidins concentrated in the bran (Awika & Rooney, 2004; Khoddami et al., 2023; Xu et al., 2021). Kafirin typically constitutes ~65 75% of sorghum's total grain protein and is characteristically hydrophobic, influencing digestibility and techno functional behavior; its amino acid profile is comparatively low in lysine, which is nutritionally relevant when sorghum is a major protein source (Shah et al., 2021; Shah et al., 2024). From a health perspective, the polyphenol rich sorghums (including high tannin and pigmented types) exhibit high antioxidant capacity in vitro and have been investigated for potential benefits linked to oxidative stress modulation, though bioavailability and processing effects are critical considerations (Awika & Rooney, 2004; Girard & Awika, 2018; Xu et al., 2021).

The functional properties of sorghum flour in doughs and batters are shaped by its starch pasting behavior and kafirin starch interactions. In the absence of gluten, sorghum batters for bread are typically batter like with lower elasticity and weaker gas holding, challenging machinability and loaf expansion relative to wheat systems (Rumler et al., 2021; Akin et al., 2022). Kafirin's hydrophobicity limits hydration and plasticization, hindering the development of a continuous viscoelastic network; classic and recent techno functional surveys attribute sorghum's modest breadmaking performance partly to this protein chemistry (de Mesa Stonestreet et al., 2010; Dube et al., 2020). Process and formulation strategies can, however, modulate viscosity and handling: heat treatment (dry heat or hydrothermal) of sorghum flour tends to increase water absorption and improve batter viscosity and gas cell stability, leading to higher loaf volume and softer crumbs in gluten free breads and cakes (Marston et al., 2016). Likewise, particle size/extraction rate affects water uptake and crumb structure, with mid range extraction flours in some studies showing the best balance of specific volume and texture (Akin et al., 2022).

When positioning sorghum for gluten free baking, its advantages include a whole grain nutrient package (fiber, minerals) and a rich phytochemical profile that can translate to higher antioxidant activity of finished breads relative to rice based controls (Banu et al., 2020; Xu et al., 2021). Sensory wise, well formulated sorghum breads especially those using whole grain red sorghum flour can achieve favorable technological properties and consumer acceptance (Hryhorenko et al., 2023). On the limitations side, 100% sorghum formulations frequently show low loaf volume, denser crumb, and firmer texture without adequate structure building aids; bitterness/astringency from tannins in some pigmented varieties can also affect flavor unless balanced by sweeteners, enzymes, or blending (Adzqia et al., 2023; Awika & Rooney, 2004; Girard & Awika, 2018). Importantly, water level and binder choice are decisive: seminal optimization work on gluten free sorghum bread demonstrated that higher hydration improved specific volume and reduced crumb hardness, whereas xanthan gum at higher levels could negatively affect those attributes, underscoring that hydrocolloid effects are dose and system dependent (Schober et al., 2005).

A central formulation principle for sorghum breads is reconstructing a gas holding and setting matrix via hydrocolloids, proteins, emulsifiers, and enzymes. Hydrocolloids such as HPMC, xanthan gum, guar gum, and pectin increase batter viscosity, stabilize air cells, and delay starch retrogradation mechanisms repeatedly shown to enhance volume and softness in gluten free systems (Culetu et al., 2021; Anton & Artfield, 2008). However, the specific hydrocolloid and level must be matched to sorghum flour type and particle size; interactions with sorghum starch and kafirin can lead to non linear responses in crumb hardness and springiness (Schober et al., 2005; Akin et al., 2022). Protein enrichment (e.g., egg white, dairy, or pulse proteins) often improves elasticity and gas retention, while enzymes (e.g., transglutaminase) can crosslink proteins to strengthen the matrix although outcomes vary with kafirin accessibility (Rumler et al., 2021; de Mesa Stonestreet et al., 2010). Thermo mechanical treatments (pre gelatinization, extrusion, fluidized bed heat) and bioprocessing (sourdough fermentation) can further tune viscosity and flavor, mitigating astringency from polyphenols and improving dough handling (Marston et al., 2016; Rumler et al., 2021).

Key findings from previous studies provide practical guidance. In a systematic comparison of gluten free grains, breads made with sorghum frequently exhibited higher total phenolics and antioxidant capacity than rice breads, highlighting a possible functional food advantage when sensory constraints are controlled (Banu et al., 2020). A design of experiments study on gluten free sorghum bread indicated that maximizing water while minimizing xanthan and skim milk powder produced the best volume texture trade off, and verified predictions experimentally (Schober et al., 2005). In whole grain forward applications, red sorghum addition improved technological quality and consumer liking of gluten free breads, supporting the use of pigmented sorghums when flavor is balanced (Hryhorenko et al., 2023). Conversely, multiple investigations report that 100% sorghum breads tend to underperform in specific volume and crumb metrics, reinforcing the need for blending (with rice, maize, or cassava starches) and tailored hydrocolloid protein systems (Adzqia et al., 2023; Akin et al., 2022). Processing interventions are also influential: heat treated sorghum flours have yielded higher loaf volumes and softer crumbs, likely via increased water absorption and altered starch protein interactions (Marston et al., 2016). Finally, while most conventional sorghum kafirin is poorly suited to viscoelastic network formation, genetic and processing innovations (e.g., high digestible, high lysine sorghum; selective kafirin modification) suggest routes to improved protein networking and baking performance in composite systems (Goodall et al., 2012; de Mesa Stonestreet et al., 2010).

Cassava Sorghum Flour Blends

Cassava sorghum flour blends have demonstrated notable synergistic impacts on bread qualities, particularly in gluten free applications. Studies have evaluated formulations blending cassava (or cassava starch) with sorghum and other grains, finding improvements in texture, flavor, and nutritional aspects in comparison to singular flours (Onyango, 2011; Onyango et al., 2013). For example, Onyango (2011) examined gluten free sorghum bread using cassava, maize, potato or rice starch in various ratios (10:90 up to 50:50), observing that cassava inclusion modifies rheological and structural properties, influencing final product quality. In terms of optimal ratios, blends with approximately 25 % sorghum flour have been shown to preserve loaf volume and texture without compromising baking quality, especially when sorghum is combined with rice, tapioca, and corn starches (Adzqia et al., 2023). Specifically, increasing sorghum beyond 25 % led to decreases in specific volume, cohesiveness, springiness, chewiness, and moistness, while enhancing color intensity and nutty flavor (Adzqia et al., 2023).

Effects on loaf volume, crumb softness, and shelf life are modulated by flour blend composition and use of functional additives. Cassava flour alone has limitations due to low gluten and poor diastatic activity, leading to denser, firmer loaves, yet inclusion of hydrophilic colloids and enzymatic treatments can mitigate these issues (Lu et al., 2019). In sorghum cassava blends, use of hydrocolloids and starch modifiers improved bread quality, including crumb structure and softness (Akin et al., 2022; Onyango et al., 2013). Sensory evaluation and consumer acceptance have been evaluated: flatbreads containing cassava and sorghum composites (with cowpea) elicited intensified sorghum aroma and an altered mouthfeel, but were among the most similar to wheat versions in sensory profiles, suggesting promising acceptance (Najjingo et al., 2025).

Nutritional and Health Implications

Gluten free diets offer relief for individuals with celiac disease or gluten intolerance, but may pose risks such as nutritional deficiencies and higher exposure to refined starches (Renzetti et al., 2023; general literature). Sorghum is a valuable gluten free grain, rich in fiber, antioxidants, and micronutrients, and has been linked to cardiovascular and gut health benefits (Akin, 2022; Verywell Health, 2023). Compared to cassava, which is high in carbohydrates but low in protein and micronutrients (Healthline, 2022), sorghum brings significantly greater nutritional value. Brown sorghum bread demonstrated higher fiber and antioxidant activity, with low glycemic index and glucose response, highlighting its superior nutritional profile among gluten free breads (dos Reis Gallo et al., 2021). Cassava's nutritional insufficiency in protein and essential amino acids underscores the need for fortification when used either through blending with protein sources or adding vitamins and minerals (Healthline, 2022; Lu et al., 2019).

Current Gaps and Future Directions

Research gaps include insufficient data on long term shelf life, large scale production feasibility, and the effectiveness of fortification strategies in cassava sorghum blends. Adzqia et al. (2023) flagged the need for studies assessing hydrocolloid effects to support higher sorghum inclusion, while Najjingo et al. (2025) emphasized the necessity of consumer acceptance research beyond trained panels. Emerging technologies show promise: enzyme treatments (e.g., amylase, glucose oxidase) improve crumb softness and volume in sorghum breads (Renzetti & Arendt, 2013), while physical treatments such as heat moisture, germination, and extrusion enhance functional properties (Akin et al., 2023; Onyango et al., 2013). Future research should focus on optimized formulations combining cassava, sorghum, hydrocolloids, enzymes, and fortificants, with attention to scaling production and ensuring sensory acceptability and nutritional adequacy.

Conclusion

Cassava sorghum flour blends offer compelling opportunities for gluten free bread development, improving texture, flavor, and nutrition when optimized particularly around 25 % sorghum inclusion and the use of functional additives. Nutritionally, blending sorghum addresses cassava's shortcomings in protein, fiber, and micronutrients, with brown sorghum offering low glycemic response and strong antioxidant benefits. Nevertheless, more research is needed on shelf stability, fortification strategies, and production scalability. Taking advantage of advanced processing technologies such as enzyme treatments, extrusion, and hydrocolloids could unlock the full potential of these blends. Ultimately, cassava sorghum breads have the potential to diversify gluten free options with enhanced health and sensory profiles.

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