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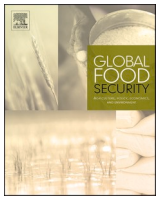

Flour blending can mitigate food insecurity and economic stress

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ABSTRACT

Cereal flour blending can reduce food insecurity risks, as well as contribute to economic and nutrition goals. Yet, the potential for blending has not been realized, and new products have not become scalable commercial propositions. Numerous experiments have shown the potential to produce acceptable foods derived from blended flours of diverse crops including wheat. An important question is whether the incentives, capacities and needs of farmers, processors and consumers have been considered. We argue that technical solutions must be developed within a specific agroecological, commercial, economic, and political environment. Innovations must address the clearly defined objectives of a wheat flour blending policy, if the potential benefits of blending for addressing food insecurity and economic stress are to be achieved.

1. Introduction

The risks of global food insecurity are acute in the short-, medium- and long-term. Resource-stresses, accelerating agro-climatic changes and demographic shifts are raising the stakes for vulnerable populations. Political instability exacerbates these tensions. Global agricultural input and product markets have been hit by the ongoing Ukraine-Russia crisis and reductions in food production and trade. Commodity markets continue to be volatile and food price inflation remains high in most low-, middle-, and high-income countries, with trade restrictions imposed by some countries affecting global grain markets (World Bank 2024). The international community is faltering in the face of these global challenges. However, there are grounds for optimism that the incentives, knowledge, and innovative capacities within the global agri-food sector can have positive local and regional impacts. Innovation and coordinated initiatives among sectoral organizations can serve to deconstruct the global challenges and help to identify technical solutions and policies at national and regional scale to mitigate the food insecurity of vulnerable populations and the economic stresses faced by affected countries.

The focus of this *Perspective* article is staple foods and associated policies in Africa. We review the knowledge of flour blending technologies and processes that have potential to boost agriculture and rural economies, ameliorate food price pressures and attenuate the wider political, social and economic instability.

Food security is one element driving the Kenyan Government's efforts to realise its 'Vision 2030' (Vision 2030 Delivery Board, 2022). Melesse et al. (2023) recently published an analysis of Kenya's maize flour blending policy linked to food security. Since 2018 the Ministry of Agriculture and Livestock Development have coordinated a Flour Blending Secretariat. Reflecting the desire for greater food sovereignty, the proposal is to incorporate sorghum and millet into maize flour at a substitution level of at least 10%, in order to take advantage of the agronomically robust 'minor' grains and to produce a flour that is more nutritionally dense than the 100% maize flour used for the staple food *ugali*.

Many of the issues regarding Kenya's maize policy are relevant to the opportunities for wheat flour blending. We note that addressing food insecurity by boosting domestic agricultural production in order to reduce reliance on sourcing food supplies from global markets—that is, a shift towards 'food sovereignty' (Stella et al. 2019)—is not the preferred policy approach according to conventional economics. But Kenya, like other countries, is facing significant increases in the cost of imports of wheat flour, driven by elevated global prices and increasing consumer demand for wheat-based foods such as white bread and chapati. Low levels of wheat self-sufficiency have alerted industry,

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NGOs and policy makers to the risks of dependence on imported foods (Farm Concern International 2018; Food Crops Directorate, 2019). Political instability in Kenya during 2023 resulting from the high cost of living was traced to food prices, drought and currency depreciation (Singh 2023), emphasising the intersectionality of food security challenges. Other wheat import-dependent developing countries and regions such as the North Africa, the Middle East, and West and Central Asia are facing similar challenges (Behnassi and El Haiba 2022).

Here we explore wheat flour blending as one measure to attenuate supply, demand, and price pressures in African staple foods markets. For decades, blending flours has interested policy makers and researchers looking to reduce imports and promote agricultural development for locally produced crops in different parts of Africa (Dendy 1993). Notwithstanding, flour blending remains uncommon in practice in most developing countries (Melesse et al. 2023). Here we argue that blending wheat flour with locally adapted, nutrient-rich and/or climate resilient crops such as legumes, cassava, sorghum, and millet can enhance food security in Kenya and other vulnerable countries. We take stock of experience and suggest commercially practicable opportunities for blending wheat with other flours to boost agricultural development, enhance food security and improve the macroeconomic conditions of import-dependent countries.

2. Cereals and food security

2.1. Import substitution for food security?

Agricultural and food prices have always been a focus of political attention. Conventional economics explains how, in a world of free and smoothly operating markets, economies of scale, and low-cost logistics, it makes sense for individual countries to import products: 'free trade' is optimal. However, current global agricultural production and trade, particularly for cereals, are governed by conflict, sanctions, and regulations. A food security study funded by the United States Agency for International Development (USAID) and the CGIAR Research Program on Policies, Institutions, and Markets (Ragasa et al. 2020) recognized a desire among African countries to improve domestic agricultural competitiveness for enhancing food security, rather than pursuing uncritical dependence on markets. Other studies have highlighted the dangers of market-dependence for meeting food security needs in developing regions (African Development Bank Group 2019; Christoforidou et al. 2023; Silva et al. 2023). Even countries of the global North are reassessing the policy conflicts between alternative approaches to food sovereignty, food security and environmental sustainability (Morales et al. 2022).

2.2. Supply and demand in Africa

Rising consumption of bread and wheat-derived food products has been reported around the globe for decades and has been linked to increasing urbanization of the population, changing lifestyles, and population growth *per se* (Kennedy and Reardon 1994; Sibanda et al. 2015; Tadesse et al. 2019). Recent grain price rises pose major challenges to businesses, governments, and consumers in Africa, with increasing reliance on uncertain imports. In East Africa, the 'Grain and Feed Annual Report' for Kenya has highlighted these trends for successive years (USDA 2022; USDA 2023)—at the same time indicating that farmers have registered a measurable domestic supply response owing to higher prices. Climate-induced changes in production conditions in Africa will reduce domestic cereal supplies further unless constraints are addressed by adequate support policies, including innovations in resilient seed technologies. The East African highlands and rain-fed production in southern Africa are particularly vulnerable. The climate-related hunger crisis in the Horn of Africa illustrates the current concerns (WFP 2023b). In the Nile region, climate shocks and conflict are causing acute hunger in Sudan and South Sudan, with consequences spreading around the region (International Rescue Committee 2023; WFP 2023a; WFP 2024). Fig. 1 summarizes the food security challenges.

3. Composite flours

3.1. Why blend flours?

Composite flours are derived from blending cereal products, often wheat flour, with flours from other agricultural crops. Blending is not a new solution to food insecurity, but laboratory and scoping experiments have led to little action. Finding innovative processes and acceptable functional formulations that can be scaled up to industrial levels needs more work (Jiménez-Munoz et al. 2021). But science, business and policy must merge: we do not yet know how technical innovations and public initiatives, incentives, and interventions in agrifood markets can be made logistically feasible, commercially operational and economically viable, and—not forgetting the important 'bottom line'—acceptable to consumers at affordable prices.

Flours from substitute products may derive from other major or minor cereals such as maize or sorghum; from pseudocereals like quinoa and buckwheat; from root vegetables such as cassava, potato, and sweet potato; and from diverse legumes. Laboratory-based experiments have been conducted with flours from minor crops that have an attraction for their nutritional qualities, resilience and local availability: e.g. Bambara groundnut (Tan et al. 2020; Kobue-Lekalake et al. 2022); *Prosopis* spp. (González-Montemayor et al. 2019); carob bean (Brassesco et al. 2021); various fruit and vegetable by-products (Santos et al. 2022). Of these, many are likely to be of local interest for niche product innovations but will not be scalable commercial propositions. Among the obstacles to making effective and economic use of minor crops are supply limitations, lack of knowledge of the crop and its agrifood potential, social stigma, and a lack of policy incentives (Tan et al. 2020).

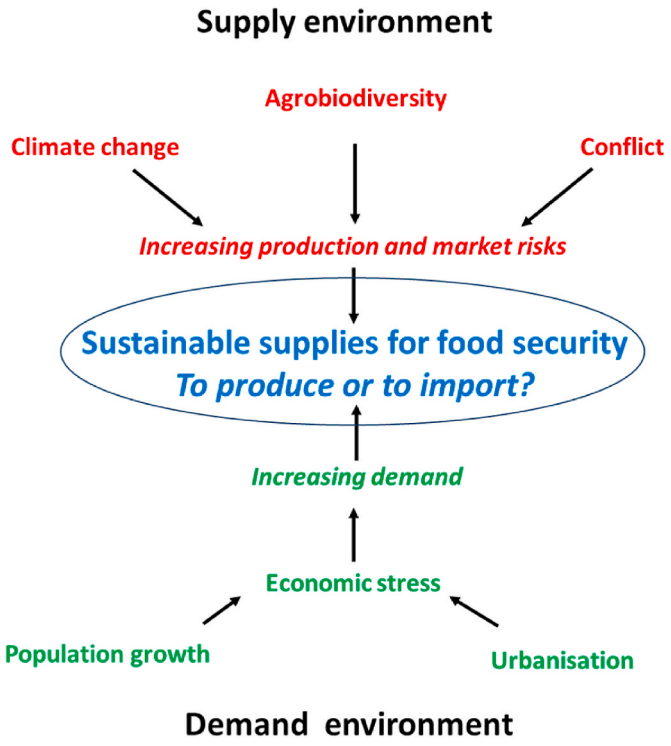

Fig. 1. Critical drivers of decision making to ensure sustainable food security.

3.2. Benefits from blending flours

Flours from maize, barley, cassava and chickpea are among the most studied crops for making composite flour breads (Noorfarahzilah et al. 2014). The ranges of blends have different properties and implications for different food products and processes. Here we summarize knowledge on likely candidate crops.

3.2.1. Millets and sorghums

The potential of millets and sorghums has long been recognized. Millets are receiving increasing attention for their hardiness under conditions of climate change and global warming. They are prized in dry, semi-arid and subtropical zones for their ecological adaptability and short growing season. In Kenya they are a minor crop. Blends of up to 30% millet flour have been shown to produce acceptable bread loaves and chapatis (Aprodu and Banu 2014; Sharma et al. 2017).

Globally, sorghum is another minor cereal and predominantly a subsistence crop, which is little grown in Kenya. However, for many tens of millions of people in other developing countries, sorghum is a major source of micro- and macronutrients with significant drought-resistance properties (Rizk et al. 2015). The health attributes of sorghum make it an attractive substitute flour for both gluten-free and functional food markets (Ari Akin et al. 2022). Products baked from sorghum-wheat flour at substitution rates up to 20% have been found to be of 'acceptable quality', comparable to products using 100% wheat flour (Adebowale et al. 2012; Sibanda et al. 2015).

3.2.2. Legumes

Food scientists have experimented with legumes in breadmaking and there is renewed interest in increasing the proportion of plant-based protein foods in global diets (Hoehnel et al. 2019; Willett et al. 2019; Semba et al. 2021). Sharma et al. (2022) also endorsed the adoption of wheat composites using legume flours, not least for public health and nutrition. Nevertheless, analysis of global food industry data suggests that introducing legumes in innovative products is a challenge, partly due to path-dependency in product formulation (Magrini et al. 2023). Broadly, the manufacture of high-protein quality bread is considered technically feasible and further work should focus on legume formulations of 10%–15%.

3.2.3. Irish potato

The use of potato flour in baking has been studied for decades. Incorporating potato flour in baked bread at a level of 15% has been found to produce loaves acceptable to consumers, with promising impacts on reducing staling (Liu et al. 2016; Lingling et al. 2018; Whitney and Simsek 2020). Liu et al. also found nutritional enhancements by incorporating potato flour in steamed bread through increasing the levels of dietary fibre, ash content and antioxidant activity, and reducing the estimated glycemic index compared with 100% wheat steamed bread (Liu et al. 2016).

3.2.4. Sweet potato

Sweet potato blending is relatively under-researched but is an option due to its appreciable production in Kenya. Processing methods and plant variety are important but can give a bread product with acceptable technological and functional properties (Dereje et al. 2020). Even the flour of the aerial parts of the plant has been incorporated successfully in bread at rates of 5% and 10% (Mau et al. 2020). Recipes are easily discoverable on the internet, and evidently, sweet potato bread is increasing in popularity in different African regions as wheat prices have escalated (see, for example (Africanews 2022),).

3.2.5. Cassava

Finally, cassava has been a promising substitute for wheat in breadmaking for decades (Defloor et al. 1993; Eddy et al. 2007). Research in developing acceptable composite products has accelerated recently (Parmar et al. 2018; Chisenga et al. 2019) and its use could boost local growers and agrifood industries. The processing to which cassava is subjected, and varietal characteristics, determine the textural properties of the doughs (Chisenga et al. 2019; Cazzaniga et al. 2021). Sensory evaluation has demonstrated that wheat breads with 10% and 20% cassava flour were equally acceptable to consumers compared with a control bread with 100% wheat flour (Eddy et al. 2007). At lower levels of inclusion, Eddy et al. even identified 'a tendency for bread baked with 10 and 20% composite flour to be rated higher than the control especially in aroma, colour, flavour, general acceptability and preference to buy' (p.2418). For cassava, as for most other crops, there are value chain issues associated with the quality, variability, and perishability of the purchased crop, which is often sourced from many small-scale producers, and requires timely handling and careful assembly.

4. Discussion

4.1. Challenges for blending

When reviewing the maize flour blending policy in Kenya, Melesse et al. (2023) cited supply constraints and consumer acceptance as major challenges to be overcome. They also detailed the issues of food science, market development and coordination, and communication challenges throughout the supply chain from farmers through processors to consumers. In the end, they argued, it is the interaction of political will with the complex economy of Kenya that will determine the success of the policy. As noted above, many of the issues regarding the maize policy are relevant to wheat flour blending.

Wheat flour blending presents technical challenges for cereal and food scientists. But there are other important considerations: technical solutions must be developed within given agroecological, commercial, consumer, economic and political environments; and they must address clearly defined objectives of blending policies. These may be agroecological sustainability, regional agricultural development, public health, private profitability, national food security and macroeconomic stability. There are important challenges in relation to consumer awareness and confidence: industrial enterprises and public authorities concerned with food regulation, standards, labelling and advertising must ensure dissemination of transparent information and procedures in respect of product specifications, notably nutritional composition and food preparation. Effective blending policies require effective public-private partnerships built on intersectoral political skills. In addition, transmitting the blending policy incentives and product specifications through the industrial sector to agricultural suppliers needs considerable market coordination skills. The value chain challenges and potential impacts are summarized in Fig. 2.

No single policy approach will address all objectives, which must be clarified and prioritized. The likely trade-offs must be calculated with care. Impacts on the private sector must be identified, and benefits to consumers must be marketed with integrity. Lack of clear public policy and failures in the volume and quality of alternative crops have previously frustrated blending initiatives (Aristizábal Galvis et al. 2017:29; Manano et al. 2021). Among the issues to consider are a) negative experiences of blending initiatives; b) debate about the strength of the political will and policy framework; and c) the technical supply chain challenges.

4.2. Negative experiences of blending initiatives

For example, in Nigeria, where both bread and cassava are important foods, there has been considerable research interest in composite flours. In 2003, a presidential initiative was launched advocating the incorporation of cassava flour at a level of 10% in breadmaking. This was unsuccessful due to the risk perceived by industry of apparently poor storage characteristics of composite breads caused by moistness and

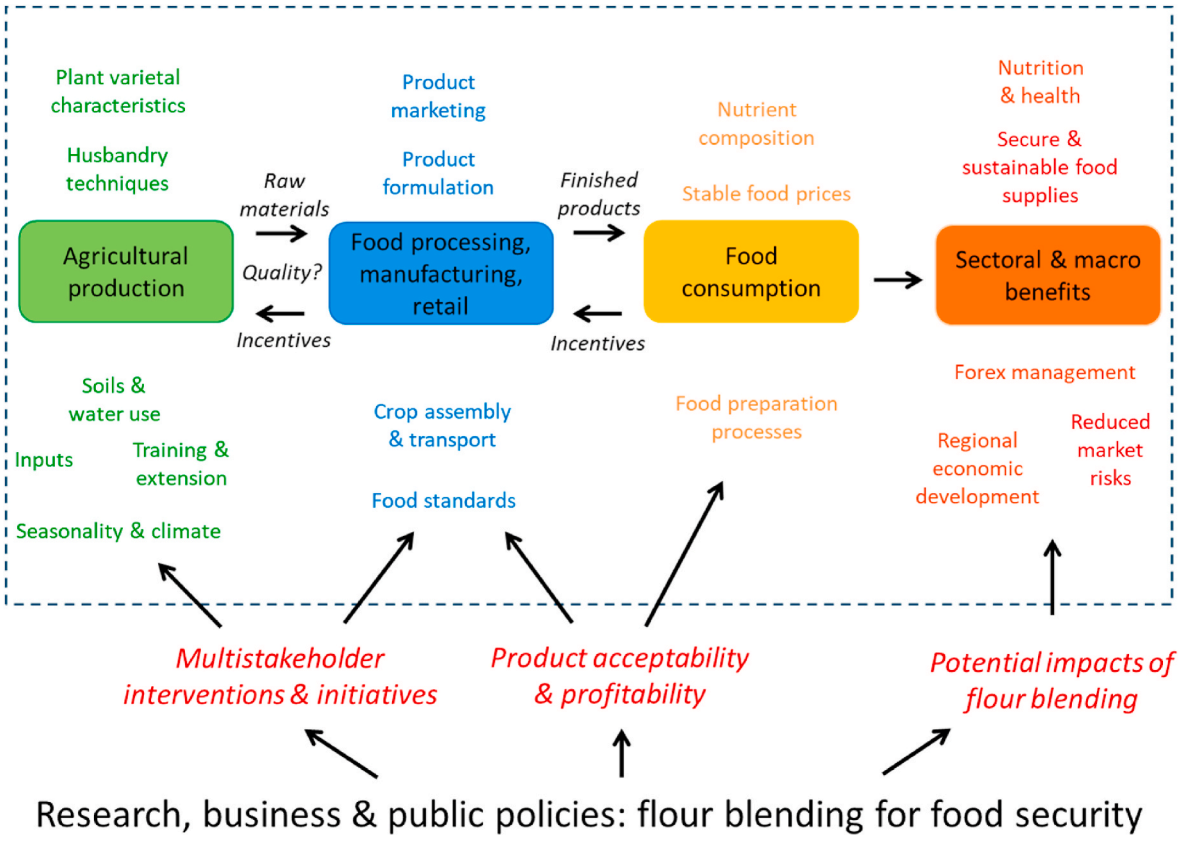

Fig. 2. Value chain challenges and potential impacts of wheat flour blending.

high microbial loads, and by crop supply shortages. Increased taxation by the Nigerian government of wheat imports in 2012 led to a new mandate to use a composite flour blend incorporating 20% cassava flour. However, again the uptake of cassava as an ingredient of composite flours was not successful (Nwanekezi 2013). Several value chain constraints limiting the obvious technical possibilities in Nigerian agro-industry have been cited: 'insufficient policy incentives; lack of favorable policies; low wheat flour prices relative to those of cassava flour; unreliable supply of and low demand for cassava flour; lack of market access; poor logistics; high cost of transportation and poor condition of roads; dependence on weather for drying; lack of working capital' (Aristizábal Galvis et al. 2017:29).

4.3. *The strength of political will: voluntary or mandatory approaches?*

Food governance in the interest of public health is inherently multisectoral, involving markets, governments and consumers (Kaldor 2018). However, voluntary industry-regulated initiatives have often been marked by a lack of substantive achievement (Scrinis 2016), and industry involvement in formulation of voluntary measures is said to be undesirable. It is argued that mandatory measures should be favored (Erzse et al. 2022). Mandating requirements is more likely to create a commercial 'level playing field'. At the same time, there are reservations about the capacity and willingness of commercial firms to contribute to voluntary industry-government partnerships for public health (Poole et al. 2020). More overt criticisms of the conflicts of interest of transnational corporations in relation to public health have been made, because firms' primary responsibility is not to the public but to shareholders. Hence, multisectoral collaboration is essential, but within a strong regulatory framework (Monteiro and Cannon 2019).

4.4. *Technical supply challenges*

Sourcing from diverse local markets for the baking industry, variability in the multiple and complex qualities of raw materials, and incomplete knowledge of the optimal genetic characteristics of crops for composite flours are major issues for processing and ultimate consumer acceptance (Atlin et al. 2017; Chivasa et al. 2022). Last but not least, among these variables, soil types, optimal agronomic practices, and water availability need to be considered in the delivery of the necessary consistent quality and functionality of the crops to be blended.

It is evident from the range of laboratory experiments, the diversity of candidate crops for producing substitute flours, and the heterogeneous conditions impacting value chains, that there is no single ideal crop for blending with wheat flour, either in Kenya or more widely.

Yet, there are grounds for optimism. The new market opportunities for cereal-based products are exemplified by the recent dramatic expansion of gluten-free foods, demonstrating how food science and technological innovation can respond to market incentives for novel products (Xu et al. 2020; Mir et al. 2022). Public policies take time to be formulated and implemented, especially if stakeholder consultations are to be undertaken in the interests of both policy refinement and amelioration of political and business suspicion. Multistakeholder platforms and agricultural public-private partnerships (APPPs) can bring together interested parties such as farmers, food industry firms, advocacy organizations and public sector bodies such ministries of agriculture, food and nutrition, and finance with carefully targeted and bundled interventions that benefit farmers and increase output—even if there are limitations to the effectiveness of APPPs (Aseete et al. 2023).

4.5. *Future directions*

Here we propose four areas for further work by the public and private sectors, and researchers.

1. A sound understanding is needed of three major stages in the value chain: a) costs of supply of optimal crop varieties; b) additional demands on private food processors and manufacturers of quality specifications; and c) the public and business implications of the provision of information, marketing, consumer acceptance and willingness to pay for newly formulated products in multiple market segments. A fourth issue is d) to assess the balance of public costs and benefits for the macroeconomy of reducing imports, of any extra expenditure on incentives such as production subsidies, and alterations in taxation regimes to promote flour blending.
2. Economics is fundamental and yet, to our knowledge, there are no business feasibility analyses to accompany many of the technical studies of blended products. Industry informants in Kenya have cited the need for better data on production and costs of potential crops, and the impacts of a blending policy on the costs of sourcing and processing. Ultimately, the expected level of consumer product prices is a critical factor to identify impacts on poverty and wellbeing.
3. Standardization of experimental methods will help to ensure comparability in feasibility studies. However, this may be challenging in a commercial environment in which knowledge of input, product formulations and standards, optimal techniques and technologies, and the use of additives, can confer an exclusive business advantage. We advocate for the availability of a systematic and open system for testing and refining experimental methods for blending to create common protocols and interoperable results.
4. Finally, regulatory approaches and technical innovations are not scale-neutral. It is not only large-scale enterprises whose performance matters. The interests of smallholder farmer producers and the informal economy of small-scale street retail enterprises and their customers must be considered. Likewise, most people in Kenya and other developing nations depend on home cooking. Households need access to clearly labelled blended flours at a reasonable price. There will be concerns ranging from ease of preparation of doughs, cooking time and energy use, to the preferences of market segments of consumers who eat cereal products of a different kind and who in other ways are different from those who buy commercial products such as white bread and biscuits. These market characteristics and consumer preferences need to be assessed, giving due attention to the gendered impacts of blending policies.

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CRediT authorship contribution statement

Nigel Poole: Conceptualization, Methodology, Writing – original draft, Writing – review & editing. **Jason Donovan:** Conceptualization, Investigation, Writing – review & editing. **Sarah Kariuki:** Conceptualization, Investigation, Writing – review & editing. **Pieter Rutsaert:** Conceptualization, Investigation, Writing – review & editing. **Maria Itria Ibba:** Writing – review & editing. **Alison Bentley:** Conceptualization, Writing – review & editing.

Declaration of competing interest

The authors have no competing or conflicting interests to declare that are relevant to this article.

Data availability

No data was used for the research described in the article.

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