

## Fortified whole grains and whole blends: A timely food systems shift

Peiman Milani<sup>a,\*</sup>, Lawrence Haddad<sup>b</sup>, Roy Steiner<sup>a</sup>, Penjani Mkambula<sup>b</sup>, Mehrdad Ehsani<sup>a</sup>, David Kamau<sup>c</sup>, Daniel Ndung'u<sup>1</sup>, Saskia de Pee<sup>d</sup>

<sup>a</sup> The Rockefeller Foundation, United States

<sup>b</sup> Global Alliance for Improved Nutrition, United States

<sup>c</sup> Fortified Whole Grain Alliance, United States

<sup>d</sup> World Food Programme, United States

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### ABSTRACT

Grains are central to food systems in low- and middle-income countries (LMICs). Their predominant consumption in refined form contributes to the double burden of malnutrition and wastes precious food and natural resources in a world challenged by growing food insecurity and accelerating climate change and biodiversity loss. Shifting consumption from refined grain foods to fortified whole grain and whole blend foods can improve food security and make diets healthier. This would also make food systems more efficient and resilient, and help mitigate the food crisis. School meal programs and other institutional and safety net markets offer the best entry points to initiate this necessary shift in food systems within LMICs.

Grains have been at the heart of food systems worldwide since antiquity. Grain consumption by humans preceded agriculture and was the key driver of its emergence. Wheat, rice, and maize – the “Big 3” – alone contribute to nearly half of the total caloric intake worldwide (Hunter et al., 2020) and 42 percent of protein intake in low- and middle-income countries (LMICs) (CIMMYT, 2020). Globally, grains account for 36 percent of cropland, 34 percent of freshwater, 45 percent of fertilizer used in crop production, and 36 percent of greenhouse gas emissions from plant crops (Global Nutrition Report, 2021).

Refined grains and the “Big 3” currently dominate the grain consumption landscape. Until the Industrial Revolution, most grains were consumed in whole form. The advent of roller mills vastly increased the quantity and quality of refined grains in the market, making a thus far aspirational product widely available and affordable. It also improved shelf stability of grain-based foods, a barrier to then-expanding supply chains and global trade. The Green Revolution increased the yield, availability, and affordability of the “Big 3” – which by then were almost exclusively consumed in refined form. The combined effect of these two agrotechnological revolutions reduced food insecurity in LMICs, but also led to losses in biodiversity, dietary diversity and quality, and system resilience (Milani et al., 2022). Today, urbanization is boosting the trend towards refined “Big 3” consumption in LMICs (Kennedy and Reardon, 1994; Pingali, 2007), often in highly processed foods (Popkin et al.,

2012). In many LMICs, rising incomes often lead to a dietary shift towards more refined grains, particularly rice and wheat. This shift is driven by several factors, including perceptions of refined grains as being “cleaner,” more prestigious or modern, having better taste and texture and longer shelf life compared to whole grains. Studies have shown that as household incomes increase, the consumption of refined grains typically rises while the intake of whole grains decreases (Regmi and Dyck, 2001; Cockx et al., 2019). Globally, consumption of whole-grain foods remains low, representing between 20 and 30 percent of total grain intake and ranging from 4.8 g/day in the Middle East to 32.3 g/day in Asia and 82 g/day in Denmark, the country with the highest per capita consumption (Global Burden of Disease Collaborative Network, 2017; Milani et al., 2022; Boyle et al., 2024).

The dominance of refined grain foods removes essential nutrients and fiber from diets and so diminishes the otherwise positive role of grains in combating food insecurity. Refining removes the nutrient-dense parts of the grain (bran and germ), leaving the refined carbohydrate-rich, nutrient-poor, and low-fiber part (endosperm) for human consumption (Fig. 1). Beyond the loss of nutrients, fiber, and bioactive compounds, precious natural resources are wasted. Between 20 and 30 percent of the global “Big 3” production is diverted away from the food to the animal feed stream. The same amount of wheat-, rice-, and maize-based foods currently consumed could be produced with

\* Corresponding author.

E-mail address: [pmilani@rockfound.org](mailto:pmilani@rockfound.org) (P. Milani).

<sup>1</sup> Independent Consultant.

20–25 percent less land, water, fertilizer, and greenhouse gas emissions if consumption shifted from refined to whole grains (Mitchell et al., 2024). Refining grains can thus be considered one of the most significant forms of food loss in food systems worldwide.

Increasing whole grain food consumption is potentially one of the highest impact dietary shifts to improve global health. Globally, low consumption of whole grains is the dietary risk factor contributing to the most annual deaths (1.8M) and DALYs (42.6M) after high sodium intake (IHME, 2019). Multiple reviews and meta-analyses (Reynolds et al., 2019; Zhang et al., 2018; Aune et al., 2016; Tieri et al., 2020; Hu et al., 2020; Guo et al., 2022; Wang et al., 2021) show the benefits of whole grains to human health. Increased intake of whole grains has been associated with decreased risk of all-cause death and death specifically from cancer, cardiovascular, diabetes, and infectious disease; as well as decreased risk of type-2 diabetes, colorectal cancer, cardiovascular disease, and metabolic syndrome. A recent analysis of the global burden of diet-attributable type-2 diabetes concluded that over half of the new type-2 diabetes cases associated with suboptimal diets in 184 countries between 1990 and 2018 were attributable to insufficient whole grain intake and excess refined grain intake (O’Hearn et al., 2023). A meta-analysis of 19 studies on the relationship between grain consumption and gastric cancer risk found a protective association with whole grain consumption and an increased risk association with large and moderate intake of refined grains (Wang et al., 2020). It is thus not surprising that the majority of dietary patterns associated with positive health outcomes, including the Mediterranean (Davis et al., 2015), EAT-Lancet (Willett, 2019), and DASH diets (Chiavaroli et al., 2019), all promote high consumption of whole grains and low intake of refined grains.

Shifting from the “Big 3” to other crops will make diets more diverse and food systems more resilient and sustainable. The concentration of agri-food systems in wheat, rice, and maize has made diets less diversified and healthy, and food value chains more vulnerable to stresses and shocks. The shift to whole grains should go beyond the “Big 3” to diversify consumption of grains and encompass sorghum, millet, and traditional/neglected grains, as well as other healthful crops such as pulses, nuts, and seeds as ingredients in what could be called “whole blend” foods – foods combining whole grains and other unrefined healthful foods in a flour or powder form (Fig. 2). Such whole blend

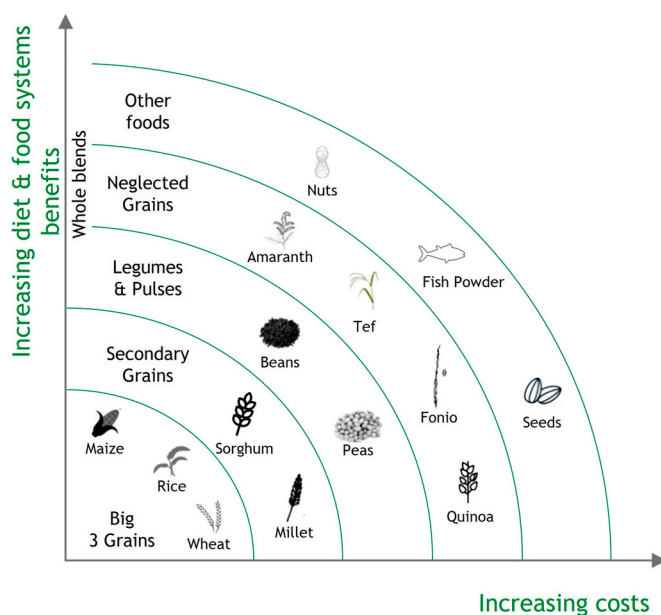


Fig. 2. Whole grain and whole blend foods and their trade-offs within current food systems.

foods in flour form can often be found in LMICs as porridge and baking mixes, with ingredients such as ground pulses and fish powder sometimes being added to the base grain flour. This broader diversification movement will help enable sustainable healthy diets from more resilient food systems for all.

Fortifying whole grain and whole blend foods further improves their nutritional value in a cost-effective way. Fortification of flours, rice, and other grain-based foods is one of the most cost-effective ways to add micronutrients to the diets of undernourished populations (Fig. 3). Fortified whole grain (FWG) and whole blend (FWB) foods bring together two evidence-backed approaches to address multiple forms of malnutrition into a single and compelling value proposition combining the nutrition, diet, and food systems perspectives. Unlike most other

### 2019 Global grain flour available for consumption (million MT)

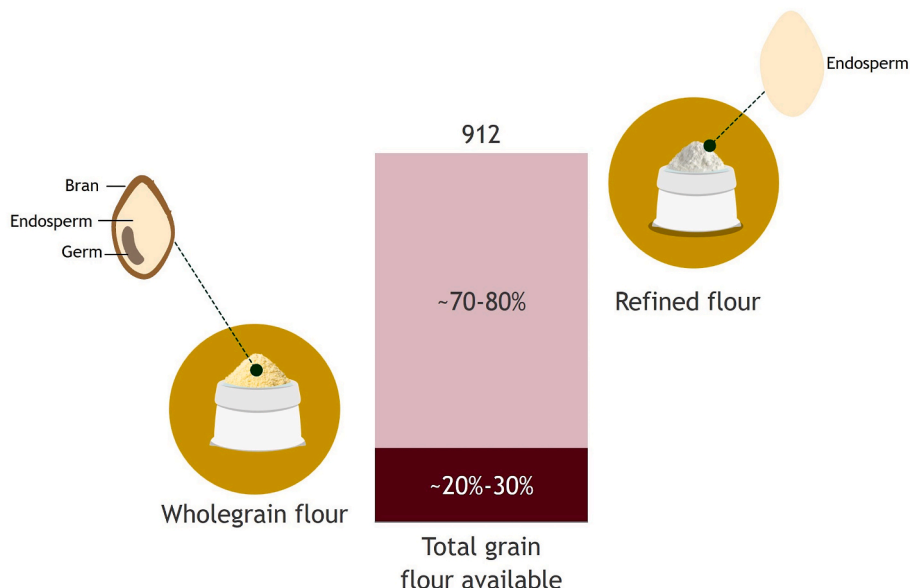


Fig. 1. Whole grain and refined flour global consumption.

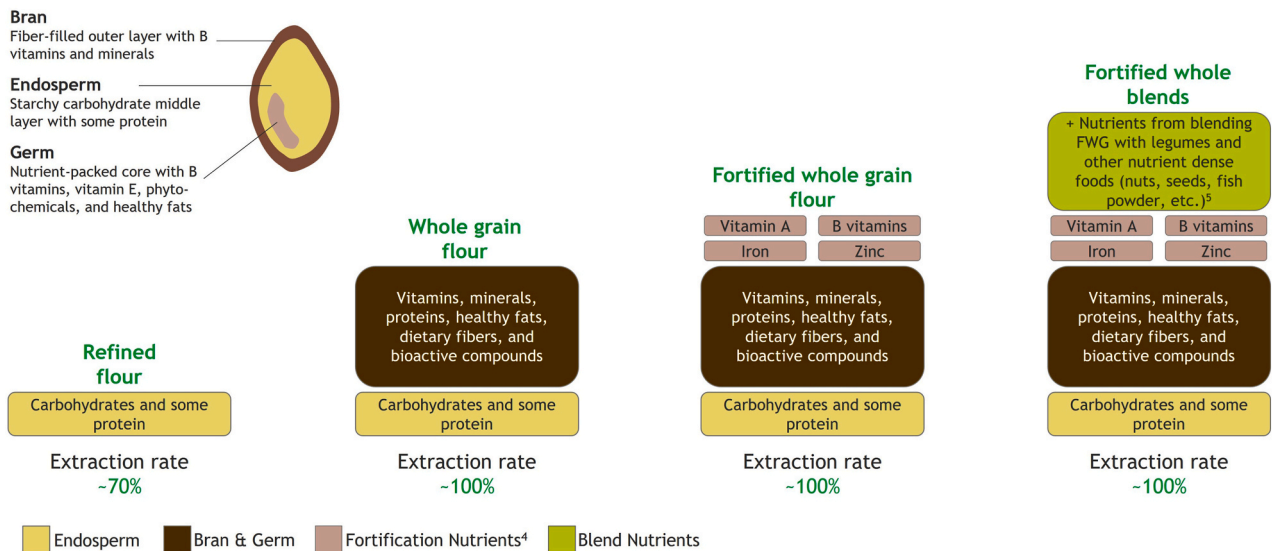


Fig. 3. Fortified whole grain and whole blend foods and their added nutritional value.

currently used fortification vehicles, whole-grain foods are inherently nutrient-dense and health-protective, rich in many micronutrients. However, when the overall diet is not sufficiently diverse, fortification is a proven, cost-effective way to mitigate nutritional dietary deficits. Fortification of refined wheat and maize flours – which is currently mandated in many countries – does improve the micronutrient profile of these products, yet it does not restore the full spectrum of nutrients, fiber, and bioactive compounds that are naturally present in whole grains. Research by Barrett et al. (2020) has demonstrated that the benefits of whole grains are not solely due to their fiber content but also to the synergistic effects of these various compounds. Phytate, a naturally occurring compound in plant foods such as whole grains, can inhibit the absorption of essential minerals such as iron and zinc. However, appropriate processing techniques and the use of formulated fortification premixes can help reduce phytate content and mitigate its binding to minerals, thereby improving mineral bioavailability (Pujol

et al., 2023).

Given the economics of grain processing, FWG foods can be a nutrition-positive, budget-neutral substitute to refined unfortified foods, as well as an alternative to fortified refined foods that has the additional health benefits of whole grains. Producing whole grain foods should not cost more than refined grain foods with modest one-time investments in processing equipment and technical capacity. This is due to the much higher extraction rate from grains to foods achieved with whole grain production (Fig. 4). For instance, from 100 kg of wheat or maize grain, millers can produce about 70 kg of refined flour, or nearly 100 kg of whole grain flour. Such substantially higher yield (in the 15–40 percent range depending on the grain) gives whole-grain foods an intrinsic cost advantage over their refined counterparts. Although bran and germ byproducts are sold in secondary markets, typically as animal feed ingredients, the price they fetch in LMICs is generally lower than that paid for food grade products. In many scenarios, this cost gain in production

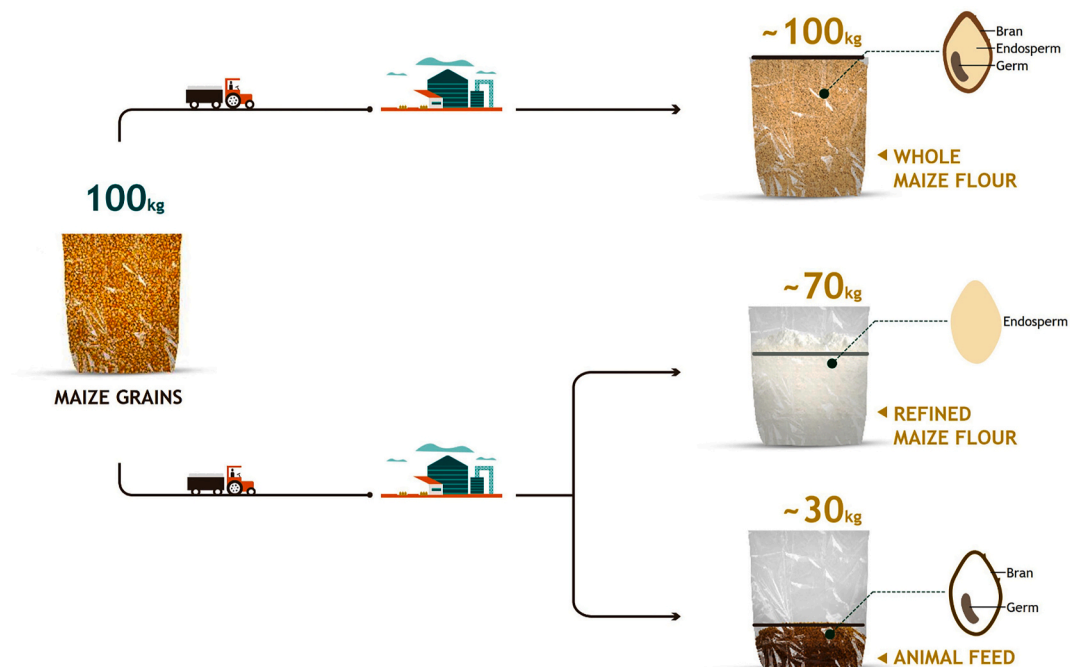


Fig. 4. The economics and extraction rates of whole vs. refined grain foods: the example of maize flour.

can be deployed to absorb the incremental cost of fortification, sometimes a barrier to large scale fortification efforts (Milani et al., 2022). The resulting FWG foods are substantially healthier than refined unfortified ones, offer additional health benefits compared to fortified refined foods, and can be supplied at no incremental cost to buyers (WFP, 2022).

The global polycrisis makes a shift to FWGs/FWBs even more timely and relevant, given the need for pathways to address food security, sustainability, and resilience as budget-neutrally as possible. The confluent challenges of conflict, Covid, and climate change and their devastating combined impact on food and nutrition security have produced one of the worst food crises in the post-war era (FAO, IFAD, UNICEF, WFP and WHO, 2023). Beyond the price rises of the “Big 3” and other food commodities, increased fuel and fertilizer costs seriously threaten current and future agricultural yields, particularly in LMICs – many of which were already struggling with growing fiscal and trade deficits and fragile safety nets. All this is taking place in the context of a world already exceeding several planetary boundaries (Richardson et al., 2023). FWGs present a budget-neutral opportunity to increase the food system’s yield of grain-based foods by 15–40 percent without further burdening the biosphere.

The FWG shift can also turn the grain crisis into an opportunity for sustainable change in many of the worst-affected countries. For example, a vast strip of countries stretching from Morocco to South and Central Asia share characteristics that make for an even stronger case for FWG foods. Wheat is a key staple for them (FAO, 2024), primarily consumed in some form of flat bread made with refined flour (Pasqualone, 2018); most of them rely on imports for a substantial portion of their wheat supply (FAO, 2024) and subsidize wheat and wheat products in some fashion; and virtually all of them suffer from a growing burden of diet-related noncommunicable diseases (Global Nutrition Report, 2022). Given the higher yield from whole-grain food production and the protective benefits of whole grains, a shift to fortified whole wheat breads in these countries has the potential to improve nutrition and health among the most vulnerable, reduce dependence on imports, and relieve overstretched food subsidy budgets and hard-currency reserves.

A system-wide transition to FWGs/FWBs can be jump-started through institutional and social safety net markets. Despite growing demand for whole-grain foods among affluent and health-conscious consumers in LMICs, current consumer preferences favor refined foods. This points to institutional markets as an appealing entry point for whole grain products. Institutional food procurement is a powerful demand tool often underutilized in promoting healthy dietary patterns and other societal goals (FAO, Alliance of Bioversity International and CIAT and Editora da UFRGS, 2021). It comprises food purchases by public and private sector agents and provision of food items and meals through channels such as schools, early childhood development centers, healthcare facilities, military bases, prisons, and cafeterias. The dynamics of access, information, and choice are very distinct between consumer and institutional and safety net markets. Given the need for a gradual shift in consumer preferences towards FWG foods, and the powerful influence public institutions have on institutional markets through direct procurement and incentives, institutional and safety net markets are the best entry points to effect the transition from unfortified or fortified refined flour to FWG and FWB flours. Beyond their direct reach, institutional and safety net markets will be an important catalyst of overall country markets, through predictable, high-volume demand, creating important signaling for consumer markets and nudging them towards scale.

The introduction of whole grains and other healthful products in schools has been shown to improve dietary patterns and health outcomes among children (Cullen et al., 2008; Localio et al., 2024). Studies have demonstrated that school meal programs incorporating whole grains can increase whole grain consumption and improve nutritional intake (Burgess-Champoux et al., 2008; Meynier et al., 2020). Policies

supporting the inclusion of whole grains in school meals have been implemented in various countries, with increased whole grain consumption showing positive impacts on children’s health (Choumenkovitch et al., 2013; Madsen et al., 2024). This has also been demonstrated in pilots in Rwanda (WFP, The Rockefeller Foundation and Vanguard Economics, 2022; WFP, 2022), Kenya (The Borgen Project, 2023) and Burundi (WFP, 2024), with thousands of East African children now regularly consuming fortified whole maize meal and porridge in their school meals, and commercial FWG products beginning to emerge (Milling Middle East and Africa, 2023).

Promoting the shift to FWG and FWB foods requires leadership, capacity development, and investment. Engagement from government and private and development sector stakeholders can catalyze this gradual transition with mutually reinforcing actions on demand, supply, and the enabling environment, as illustrated by Denmark’s successful Danish Whole Grain Partnership (OECD, 2022). Governments need to coordinate across agencies to leverage institutional food procurement (e.g., school feeding) and change policy and fiscal instruments to incentivize consumption and production of FWGs/FWBs. Millers and food processors need blended finance and technical support to efficiently produce FWG/FWB foods. Development partners can de-risk the transition through targeted investments in supply chains, social marketing, and research and development and innovation to further extend shelf life and mitigate phytates. Interdisciplinary collaboration between food scientists, nutritionists, chefs, cooks, bakers, and other experts can generate new formulations, recipes, and culinary processes that will ease and accelerate consumer acceptance. Coordination across these stakeholder groups can facilitate the transition to FWGs/FWBs and enable a budget-neutral pathway to improved food and nutrition security, and healthier diets. Such a shift will make food systems more sustainable and resilient, and help mitigate food crises.

#### CRediT authorship contribution statement

**Peiman Milani:** Conceptualization, Writing – original draft, Writing – review & editing. **Lawrence Haddad:** Writing – review & editing. **Roy Steiner:** Writing – review & editing. **Penjani Mkambula:** Writing – review & editing. **Mehrdad Ehsani:** Writing – review & editing. **David Kamau:** Writing – review & editing. **Daniel Ndung’u:** Writing – review & editing. **Saskia de Pee:** Writing – review & editing.

#### Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

#### Data availability

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

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