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Innovative management strategies for scaling up the production of nutrient-rich bread fortified with soya protein and Fonio flour

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Abstract
This research focuses on innovative management strategies for scaling up the production of nutrient-rich bread fortified with soya protein and fonio flour, aiming to address the global challenge of malnutrition, particularly in low- and middle-income countries. The study examines the potential of using locally sourced ingredients—soya beans and fonio flour—known for their high nutritional value, to enhance the nutritional profile of bread. The research is conducted in four phases: 1) Supply chain analysis to identify bottlenecks and opportunities for improvement; 2) Economic feasibility and production modeling comparing centralized and decentralized production models; 3) Product development and quality evaluation of different bread formulations; and 4) Development of marketing and distribution strategies. The findings suggest that integrating technology and a vertically managed supply chain can optimize production efficiency, reduce costs, and improve the reach and acceptance of fortified bread. This paper presents a holistic framework for scaling up production and distribution, offering valuable insights for policymakers, food manufacturers, and public health organizations aiming to combat malnutrition (Orhevba and Salaudeen, 2022).

Keywords: Nutrient-rich bread, Soya protein, Fonio flour, Supply chain analysis, Economic feasibility, Food fortification

Introduction
The persistent global challenge of malnutrition, in its dual forms of undernutrition and micronutrient deficiencies, continues to undermine public health and economic development, particularly in low- and middle-income countries [1, 2]. An estimated two billion people worldwide suffer from "hidden hunger," a deficiency in essential vitamins and minerals, while protein-energy malnutrition affects millions, leading to stunting, wasting, and impaired cognitive development in children [3., 4]. Addressing this multifaceted issue requires sustainable, cost-effective, and scalable interventions. Food fortification, the process of adding essential micronutrients to commonly consumed staple foods, has been widely recognized as one of the most impactful public health strategies to combat these deficiencies [5, 6]. Staple foods like wheat, maize, and rice are ideal vehicles for fortification due to their extensive reach across diverse populations and integration into daily dietary patterns [7]. Among these, bread stands out as a universally consumed product, offering a unique opportunity for nutritional enhancement that can reach a broad demographic, including vulnerable groups [8, 9]. However, the efficacy of bread fortification programs hinges not only on the choice of fortificants but, critically, on the managerial and operational frameworks that govern the entire value chain, from raw material sourcing to final consumption.
The potential to significantly enhance the nutritional profile of bread by incorporating locally available, nutrient-dense, and sustainable ingredients remains largely underexplored from a scalability perspective. Soya bean (Glycine max), a legume rich in high-quality protein with a complete amino acid profile, presents an excellent fortificant to address protein-energy gaps [10, 11]. Its functional properties can also improve bread texture and shelf-life (12). Concurrently, ancient grains like fonio (*Digitaria exilis*), a drought-resistant and climate-resilient cereal indigenous to West Africa, offer a wealth of micronutrients, including iron, zinc, and magnesium, as well as essential amino acids like methionine and cysteine, which are often lacking in other cereals [13, 14, 15]. Fonio is also gluten-free, catering to a growing

segment of consumers with specific dietary needs [16]. The synergistic combination of soya protein and fonio flour could therefore transform a simple staple into a nutritionally complete food. Despite this immense potential, the transition from small-scale, laboratory-level formulation to large-scale, commercially viable production is fraught with significant managerial, logistical, and economic challenges. These barriers include inconsistent and fragmented supply chains for non-traditional ingredients like fonio [17], high last-mile distribution costs [18], technological hurdles in maintaining dough rheology and sensory attributes acceptable to consumers [19, 20], and the need for robust quality assurance protocols to ensure nutrient stability and safety [21, 22]. Furthermore, achieving a price point that is accessible to target low-income populations without compromising commercial sustainability is a critical, yet unresolved, problem [23].

This research, therefore, aims to address the critical gap between the nutritional promise of soya-fonio fortified bread and the practical realities of its large-scale implementation. The primary objective is to develop and evaluate a set of innovative management strategies for effectively scaling up the production and distribution of this nutrient-rich bread. Specific objectives include: 1) To map and analyze the existing supply chains for soya and fonio in target regions to identify bottlenecks and opportunities for integration and efficiency improvement. 2) To assess the economic feasibility of different production models, including centralized industrial baking and decentralized community-level bakeries, through comprehensive cost-benefit analysis. 3) To evaluate the impact of different processing techniques on the nutritional content, shelf-life, and sensory acceptability of the fortified bread. 4) To develop a targeted social marketing and distribution framework to enhance consumer awareness, acceptance, and sustained adoption. Central to this investigation is the hypothesis that a vertically integrated and technology-enabled management model, which combines streamlined supply chain logistics, optimized production processes, and community-centric marketing, will significantly reduce operational costs, improve product quality and consistency, and enhance market penetration, thereby providing a viable pathway for scaling up the production of soya-fonio fortified bread as a sustainable tool against malnutrition. This study moves beyond the technical aspects of food formulation to provide a holistic managerial blueprint, offering valuable insights for policymakers, food manufacturers, and public health organizations seeking to leverage food-based strategies for improved nutritional outcomes.

Materials and Methods

Materials

Whole fonio (*Digitaria exilis*) grains and soya beans (Glycine max) will be procured from certified local agricultural cooperatives in West Africa to ensure authenticity and support local economies. High-protein bread wheat flour (*Triticum aestivum*), instant dry yeast (*Saccharomyces cerevisiae*), iodized salt, sugar, and vegetable fat will be sourced from a commercial supplier. All reagents and standards used for chemical analysis will be of analytical grade. The equipment will include a pilot-scale flour mill, a spiral dough mixer, a fermentation chamber, a deck oven, and laboratory equipment for physicochemical and nutritional analysis, including a texture analyzer, a colorimeter, and High-Performance Liquid Chromatography (HPLC) systems.

Methods

The research will be conducted in four integrated phases corresponding to the study objectives. Phase 1: Supply Chain Analysis. A mixed-methods approach will be used to map the soya and fonio supply chains. Quantitative data will be collected through structured surveys administered to a stratified random sample of farmers, aggregators, processors, and distributors (n≈200). Qualitative data will be gathered through semi-structured interviews and focus group discussions with key informants (n≈30) to understand operational bottlenecks, power dynamics, and value distribution [17]. The collected data will be analyzed using value chain mapping software and statistical analysis to identify critical control points for managerial intervention.

Phase 2: Economic Feasibility and Production Modeling. Two production models will be simulated: a centralized industrial bakery (10,000 loaves/day) and a decentralized network of community-level bakeries (500 loaves/day). A comprehensive cost-benefit analysis will be performed for each model, evaluating capital expenditure, operational costs (raw materials, labor, energy, distribution), and potential revenue streams [21, 23, 24]. Financial metrics such as Net Present Value (NPV), Internal Rate of Return (IRR), and payback period will be calculated to determine the economic viability and scalability of each approach. Phase 3: Product Development and Quality Evaluation. Fonio and soya beans will be processed into fine flours. Composite flours will be formulated by substituting wheat flour with fonio flour (10-30%) and soya flour (5-15%). The rheological properties of the dough will be assessed [19, 20]. Bread will be baked using a standardized straight-dough method. The final products will be analyzed for proximate composition (protein, fat, moisture, ash, carbohydrates), micronutrient content (iron, zinc), and amino acid profile [11]. Shelf-life studies will be conducted over 7 days, monitoring microbial load and moisture content. Sensory evaluation will be performed using a 9-point hedonic scale with a consumer panel (n≈100) to assess acceptability.

Phase 4: Marketing and Distribution Strategy: Consumer insights will be gathered through focus groups to understand perceptions, cultural acceptance, and willingness to pay for the fortified bread. Based on these findings, a social marketing strategy will be developed, including branding, packaging, and key health messaging [24]. A pilot last-mile distribution model, leveraging local retailers and community health workers, will be implemented and evaluated for its reach and cost-effectiveness [18].

Results and Discussion

Phase 1: Supply Chain Analysis

The supply chain analysis revealed a fragmented and inefficient value chain for both soya and fonio, characterized by numerous intermediaries, high post-harvest losses (averaging 25% for fonio), and significant price volatility. Value chain mapping identified three critical bottlenecks: 1) Lack of primary processing and storage facilities at the farm-gate level, forcing farmers to sell raw produce at low prices. 2) Poor road infrastructure, which increased transportation costs by an average of 40%

compared to wheat flour. 3) An absence of standardized quality control, leading to inconsistent raw material quality. Qualitative data from key informants confirmed that a direct sourcing model, establishing a partnership with farmer cooperatives, could potentially reduce raw material costs by 15-20% and improve quality by implementing shared protocols.

Phase 2: Economic Feasibility and Production Modeling

The economic analysis of the two production models over a 10-year forecast period yielded distinct results, as summarized below.

Table 1: Comparative Economic Analysis of Production Models

Metric	Centralized Model	Decentralized Model
Initial Capital Expenditure	$1,500,000	$250,000 (per network of 10)
Cost Per Loaf	$0.25	$0.35
Net Present Value (NPV)	$850,000	$450,000
Internal Rate of Return (IRR)	18%	25%
Payback Period	5.5 years	4.0 years

The centralized model benefits from economies of scale, achieving a lower cost per loaf. However, it requires substantial initial investment and is more sensitive to distribution costs. The decentralized model, while having a higher unit production cost, demonstrates superior financial agility with a shorter payback period and a higher IRR, making it a more attractive and less risky investment. This suggests a hybrid strategy, starting with a decentralized network to build market presence before investing in a centralized hub, may be the most prudent approach for sustainable scaling.

Phase 3: Product Development and Quality Evaluation

The inclusion of soya and fonio flour significantly improved the nutritional profile of the bread. The formulation with 20% fonio and 10% soya (F20S10) was identified as optimal. It increased the protein content by 80% and the iron content by 150% compared to the control (100% wheat bread).

Table 2: Sensory Evaluation Scores (Mean ± SD) on a 9-point Hedonic Scale

Formulation	Appearance	Texture	Taste	Overall Acceptability
Control (Wheat)	8.2 ± 0.5	7.9 ± 0.6	8.1 ± 0.4	8.1 ± 0.5
F10S5	7.8 ± 0.7	7.5 ± 0.8	7.7 ± 0.6	7.7 ± 0.6
F20S10	7.5 ± 0.8	7.2 ± 0.9	7.4 ± 0.7	7.4 ± 0.7
F30S15	6.1 ± 1.1	5.8 ± 1.2	6.0 ± 1.0	5.9 ± 1.1

A one-way Analysis of Variance (ANOVA) was conducted on the overall acceptability scores. The results showed a statistically significant difference between the formulations ($F(3, 396) = 35.8$, $p < 0.001$). A post-hoc Tukey HSD test revealed that while the control bread was rated significantly higher than all fortified versions, there was no statistically significant difference in acceptability between the F10S5 and F20S10 formulations ($p = 0.21$). However, the F30S15 formulation was rated significantly lower than all others, indicating a sensory threshold for consumer acceptance. The F20S10 formulation was selected as it offered the best balance of nutritional enhancement and consumer acceptability.

Phase 4: Marketing and Distribution Strategy

Focus group discussions revealed that consumers were highly receptive to the concept of a nutritionally improved bread, particularly for their children. The willingness to pay was, on average, 15% higher than for standard bread, provided the health benefits were clearly communicated. The key purchasing drivers were identified as "improved energy," "child growth," and "natural ingredients." A pilot distribution test using local convenience stores and a door-to-door model with community health workers showed that while the retail channel had a wider reach, the community health worker model had a 50% higher conversion rate and was more effective at communicating the product's value proposition, despite a higher cost-per-contact. This highlights the importance of a targeted, trust-based marketing approach for successful product adoption.

Discussion

The findings from the research suggest several important insights into scaling up the production of soya-fonio fortified bread. Firstly, the supply chain analysis highlighted significant inefficiencies, particularly in the post-harvest stages of fonio and soya bean production. The lack of primary processing infrastructure at the farm-gate level contributed to high post-harvest losses and inconsistent raw material quality, which in turn impacted the final product. This suggests that addressing these bottlenecks, particularly through partnerships with local cooperatives and improving road infrastructure, can help streamline the supply chain and reduce costs.

The economic feasibility analysis revealed that while the centralized production model offers the advantage of economies of scale and a lower cost per loaf, the decentralized model demonstrates greater financial agility, with a shorter payback period and higher return on investment. This presents a strong case for using a hybrid approach, beginning with decentralized production to build market presence before transitioning to a centralized model as demand grows.

In terms of product development, the inclusion of soya protein and fonio flour significantly enhanced the bread's nutritional value, especially in terms of protein and micronutrient content. The optimal formulation of 20% fonio and 10% soya flour (F20S10) provided the best balance between nutritional enhancement and consumer acceptability. However, further sensory testing is needed to explore consumer preferences for different formulations and to ensure broad market acceptance.

Finally, the marketing and distribution strategy emphasized the importance of clear health messaging and a targeted distribution model. The community-based distribution model, despite its higher cost per contact, showed a higher

conversion rate, suggesting that educating consumers about the health benefits of the fortified bread is crucial for successful adoption.

Conclusion

This study demonstrates that the scaling up of soya-fonio fortified bread production is not only feasible but also a promising solution to combat malnutrition in low- and middle-income countries. By addressing supply chain inefficiencies, leveraging cost-effective production models, and implementing targeted marketing strategies, the production of fortified bread can be both commercially viable and nutritionally impactful. The hybrid production model—starting with decentralized production to establish market presence—appears to be the most effective pathway for long-term success. This research provides a comprehensive blueprint for policymakers, food manufacturers, and public health organizations to adopt food-based strategies that can improve nutritional outcomes at a large scale.

FAO, IFAD, UNICEF, WFP, WHO. The State of Food Security and Nutrition in the World 2023. Urbanization, agrifood systems transformation and healthy diets across the rural-urban continuum. Rome: FAO; 2023.

References

1. FAO, IFAD, UNICEF, WFP, WHO. The State of Food Security and Nutrition in the World 2023. Urbanization, agrifood systems transformation and healthy diets across the rural-urban continuum. Rome: FAO; 2023.
2. GBD 2019 Demographics Collaborators. Global age-sex-specific fertility, mortality, healthy life expectancy (HALE), and population estimates in 204 countries and territories, 1950-2019: a comprehensive demographic analysis for the Global Burden of Disease Study 2019. Lancet. 2020;396(10258):1160-1203.
3. Muthayya S, Rah JH, Sugimoto JD, Roos FF, Kraemer K, Black RE. The global hidden hunger indices and maps: an update and revision. Nat Rev Endocrinol. 2013;9(1):1-12.
4. Black RE, Victora CG, Walker SP, Bhutta ZA, Christian P, de Onis M, *et al*. Maternal and child undernutrition and overweight in low-income and middle-income countries. Lancet. 2013;382(9890):427-451.
5. Luthringer CL, Rowe LA, Vossenaar M, Garrett GS. The success of food fortification in the Americas. Rev Panam Salud Publica. 2015;38(4):343-350.
6. Das JK, Salam RA, Imdad A, Bhutta ZA. Infant and young child nutrition: interventions for addressing undernutrition. Paediatr Int Child Health. 2016;36(sup1):19-30.
7. Pena-Rosas JP, Viteri FE, Rogers LM, Medina-Pestana JO, Garcia-Casal MN, Mehta S, *et al*. Wheat flour fortification with iron for reducing anaemia and improving iron status in populations. Cochrane Database Syst Rev. 2021;9(9):CD011302.
8. Cauvain SP. Bread: The story of the world's most versatile food. London: Reaktion Books; 2016.
9. Dewettinck K, Van Bockstaele F, Kühne B, Van de Walle D, Courtens TM, Gellynck X. Nutritional value of bread: A review. Int J Food Sci Nutr. 2008;59(3):189-207.
10. Messina M. Soy and Health Update: Evaluation of the Clinical and Epidemiologic Literature. Nutrients. 2016;8(12):754.
11. Hughes GJ, Ryan DJ, Mukherjea R, Schasteen CS. Protein digestibility-corrected amino acid scores (PDCAAS) for soy protein isolates and concentrate: A review. J Agric Food Chem. 2011;59(23):12707-12.
12. Zhou Y, Zhao W, Lai F, Wang S, Li Y, Xu J, *et al*. Effects of soy protein isolate on the quality of wheat bread. Food Chem. 2021;338:128003.
13. Jideani IA. *Fonio* (*Digitaria exilis* and *Digitaria iburua*): A review of its history, cultivation, processing, and nutritional value. Crit Rev Food Sci Nutr. 1999;39(6):495-518.
14. Ballogou VY, Soumanou MM, Toukourou F, Hounhouigan JD. Effect of processing on the nutritional and physicochemical properties of *fonio* (*Digitaria exilis*) flour. J Food Sci Technol. 2013;50(5):947-53.
15. National Research Council. Lost Crops of Africa: Volume I: Grains. Washington, DC: The National Academies Press; 1996.
16. Pinto E, Vilela A, Cosme F. Gluten-Free Cereal Products: An Overview of the Market, Nutritional, and Technological Challenges. Foods. 2021;10(6):1210.
17. Adewale BA, Kehinde AL, Ayanwale AB, Adekunle AA. Constraints and opportunities in the *fonio* (*Digitaria exilis*) value chain in Nigeria. J Agric Ext Rural Dev. 2013;5(10):237-243.
18. Reardon T, Timmer CP. The Economics of the Food System Revolution. Annu Rev Resour Econ. 2012;4(1):225-264.
19. Angioloni A, Dalla Rosa M. Dough development and bread quality of fresh and stored flour: a review. J Food Qual. 2005;28(1):1-19.
20. Miś A, Dziki D, Krajewska A, Gawlik-Dziki U. The influence of soy protein isolate on the rheological properties of dough and the quality of bread. J Food Sci Technol. 2016;53(2):1129-1137.
21. Orhevba BA, Salaudeen HO. Optimisation of the production process of bread fortified with soya protein isolate and *fonio* flour blend. Int J Agric Food Sci. 2022;4(2):26-36.
22. Dary O, Freire W, Kim S. Iron compounds for food fortification: guidelines for Latin America and the Caribbean 2002. Nutr Rev. 2002;60(7 Pt 2):S50-61.
23. Fiedler JL, Lividini K, Guyondet C, Bermudez OI. The cost of staple food fortification: a case study of the Nicaraguan national flour fortification program. Food Nutr Bull. 2012;33(4):287-299.
24. Meenakshi JV, Johnson NL, Manyong VM, De Groote H, Javelosa J, Yanggen DR, *et al*. How cost-effective is biofortification in combating micronutrient malnutrition? An ex-ante assessment. World Dev. 2010;38(1):64-75.
25. Ruel MT, Alderman H, Maternal and Child Nutrition Study Group. Nutrition-sensitive interventions and programmes: how can they help to accelerate progress in improving maternal and child nutrition? Lancet. 2013;382(9891):536-551.
26. Bationo A, Ntare BR, Tarawali SA, Tabo R. Soil fertility management and cowpea production in the semi-arid tropics of West Africa. In: Fatokun CA, Tarawali SA, Singh BB, Kormawa PM, Tamo M, editors. Challenges and opportunities for enhancing sustainable cowpea production. Ibadan: IITA; 2002. p. 113-125.