COMMERCIALISING PUBLIC AGRICULTURAL TECHNOLOGIES AND GOODS

A FRAMEWORK TO IDENTIFY OPPORTUNITIES FOR INTERVENTIONS

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Annette M Nyangaresi, Kate Granger, Valerie M Friesen, Bonnie McClafferty, Dan Haswell, Bho Mudyahoto, Byron Reyes, Mduduzi NN Mbuya, Allison Greenberg

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The Global Alliance for Improved Nutrition (GAIN)
Rue de Varembé 7
1202 Geneva
Switzerland
T: +41 22 749 18 50
E: info@gainhealth.org

SUMMARY

Commercialisation (i.e., the process of introducing a new product or technology into commerce or making it available in the market) is considered a promising strategy to scale up the consumption of biofortified foods. To inform the development of effective commercialisation strategies, a systematic assessment of country- and crop-specific value chains is essential to identify success factors, barriers, and opportunities. Tools, such as commercialisation frameworks, that can be used to systematically synthesise and analyse such information have been developed but vary widely across different value chains and sectors. A commercialisation framework specific for public agricultural technologies and goods was recently developed. In this paper, we summarise the process of developing that commercialisation framework and its finding, and discuss its implications for, and application in, efforts to scale up biofortified foods.

The commercialisation framework for agricultural and publicly developed technologies and goods is made up of both a commercialisation process map and cross-cutting success factors (i.e., supply, demand, policy, finance, and development outcomes), and looks at profitability using a commercialisation framework process wheel. As such, it offers two complementary dimensions (placing profitability at the centre) for identifying bottlenecks and accelerators and can be used to identify where interventions can maximise impact. Case studies on fortified wheat flour in the United States and vitamin A-biofortified cassava in Nigeria were used to illustrate how the framework can be used to synthesise and organise the different information about a food product value chain and subsequently analyse it to inform commercialisation strategy decisions.

KEY MESSAGES

- A commercialisation framework is a tool that stakeholders can use to systematically synthesise and analyse information to inform effective commercialisation strategies.

- A commercialisation framework for agricultural and publicly developed technologies and goods, including biofortified foods, has been developed that enables the identification of bottlenecks and accelerators while considering context specific factors in food product value chains.

- As efforts to commercialise biofortified foods move forward, such tools can be used to identify where interventions can maximise impact and inform strategic decision making related to programming and investment opportunities.

BACKGROUND AND OBJECTIVES

Biofortification (also called nutrient enrichment) is defined as the process of improving the micronutrient content of staple foods through plant breeding methods and/or agronomic practices (1,2). It was developed in the 1990s as a strategy to sustainably tackle micronutrient deficiencies (2–4). As of 2021, approximately 283 biofortified varieties have been released and are grown by 12.8 million smallholder farming households and consumed by 64 million people in those farming households (5). While the consumption of biofortified among poor rural smallholder farming households in low- and middle-income countries is increasing, consumption by people in households that do not grow their own biofortified crops remains limited and poorly documented.

Generally, the adoption of new crop varieties may take years before substantial increases occur if no external efforts are made to scale up their production and consumption. For biofortified crops, these efforts can be derailed due to various factors such as farmers' risk aversion, which may prevent them from adopting new biofortified varieties; the benefits of such biofortified foods not being visible; and consumers not being willing to pay more and/or not understanding the advantages of consuming biofortified foods.

As efforts are being made to make biofortified foods available and accessible to non-farming consumers, the overall impact and sustainability of embedding these crops and foods in food systems will ultimately depend on the development of sustainable commercial markets, through commercialisation (6). Commercialisation is the process of introducing a new product or technology into commerce or making it available in the market. In agriculture, commercialisation can be defined as the use of agricultural technologies and goods for sale rather than for home consumption (7). Commercialisation has been considered as a promising and sustainable strategy to scale up the production and consumption of biofortified crops and foods as opposed to cultivating for subsistence and on-farm consumption (1,6,8,9). It can occur not only on the output side of production, with increased marketing of agricultural surpluses, but also on the input side, with increased and improved use of purchased inputs, such as seeds, aimed at producing enough for home consumption as well as a surplus for sale (7,10).

Commercialisation is a complex process involving different dimensions and degrees, with several factors affecting the process. For example, effective institutions, improved infrastructure, knowledge management, adequate incentives, stakeholders' initiatives, and a conducive and enabling environment (11). It involves the full range of activities that are required to bring a product or service from conception, through intermediary phases of production, to delivery to final consumers (11). When developing commercialisation strategies for public agricultural technologies and goods, including biofortified foods, it is imperative to map out, analyse, and organise information on the value chain processes, such as seed production and distribution, farmer uptake of the new (biofortified) varieties, aggregator and processor uptake and utilisation of the harvested biofortified crops (with effective traceability systems), and consumer uptake of the final food products. To break down these complexities and develop a feasible commercial process map, an in-depth analysis needs to be done to identify potential factors influencing success (i.e., challenges, opportunities, and priorities), which can then inform the development of effective commercialisation strategies. Several approaches and tools to assess and determine the feasibility of agricultural initiatives exist. However, to our knowledge, there is no existing framework that can be used to synthesise and organise complex information across the full agriculture value chain. The existing approaches focus on single aspects of the chain and therefore have limited effectiveness to inform cross-cutting strategies.

The Commercialisation of Biofortified Crop (CBC) programme, jointly led by the Global Alliance for Improved Nutrition (GAIN) and HarvestPlus, aims to use commercialisation as a key strategy to scale up the production and consumption of six biofortified crops: zinc rice and wheat, iron bean and pearl millet, and vitamin A maize and cassava in six targeted countries in Africa (Kenya, Nigeria, and Tanzania) and Asia (Bangladesh, India, and Pakistan) where micronutrient deficiencies are pervasive (12). As part of the CBC programme's inception phase, commercialisation viability assessments for the nine country-crop combinations were carried out to inform the design of commercialisation strategies for specific country-crop combinations (13). In parallel, a review of the broader technology and product commercialisation landscape for agricultural and publicly developed technologies and goods was completed to understand relevant commercialisation strategies that have successfully brought publicly developed technologies and products to market at scale (14). Based on that review, a commercialisation framework specific for public agricultural technologies and goods was developed. In this paper, we summarise the process of developing that commercialisation framework and its findings, and discuss their implications for, and application in, the CBC programme and other efforts to scale up biofortified foods.

METHODOLOGY

First, we conducted a broad landscape analysis of technology commercialisation initiatives, consisting of a comprehensive literature review and key informant interviews (KIIs) to identify relevant examples. We used the resulting data and insights from some of the technology commercialisation models identified to develop a commercialisation process map and identify success factors. The key focus topics of the review were on technology commercialisation, crop biofortification, agricultural policy, agricultural resources, and technology commercialisation within and outside the agriculture sector. Overall, 111 papers were identified, of which 45 were deemed relevant and reviewed in depth; of these, 15 had highly relevant information and were used and cited. From the literature, we identified 24 potential case study examples, of which 13 were used to develop the commercialisation framework.

Second, we synthesised the evidence collected during the landscape analysis and KIIs into a commercialisation process map and a summary of success factors (the key components of the developed commercialisation framework), to understand their interaction (bottlenecks and enablers); these were then transformed into an overarching commercialisation framework. The resulting commercialisation framework relied heavily on specific case studies, prioritising those that focused on public agricultural technologies that were commercialised through the private sector targeting rural poor consumers. It was also influenced by the availability of literature, and key informants for the nine country-crop combinations were consulted to inform case prioritisation.

Finally, we applied the commercialisation framework to three cases to demonstrate how it could be used to help analyse different kinds of commercial technologies and products. Two of these cases—the most relevant to biofortification—are discussed here.

A detailed description of the methods, including the literature review and related citations, key informant details, and the results of all three cases studies is available elsewhere (14–16). In this paper, we distil the main findings and their implications.

FINDINGS AND DISCUSSION

THE COMMERCIALISATION PROCESS MAP

The landscape analysis revealed that many of the identified publications broadly analysed commercialisation processes using illustrative frameworks or process maps. These articles focused on the agricultural value chain but tended to provide generalised processes or focused on research and development steps for various technologies rather than production and sales. For example, a project focusing on early generation seed provided a commercialisation framework that aligned with the agricultural value chain but did not break out specific steps for distribution, marketing, consumption, and the enabling environment (17,18). Additionally, a programme integrating gender and nutrition within agricultural extension services used a technology development pathway in assessing agricultural technologies; however, that pathway stopped at distribution without considering marketing, sales, consumption, and the enabling environment (19). Lastly, a project that focussed on success factors for commercialising agricultural research grouped multiple steps into four broad categories that did not provide enough detail for each step in the process (20,21).

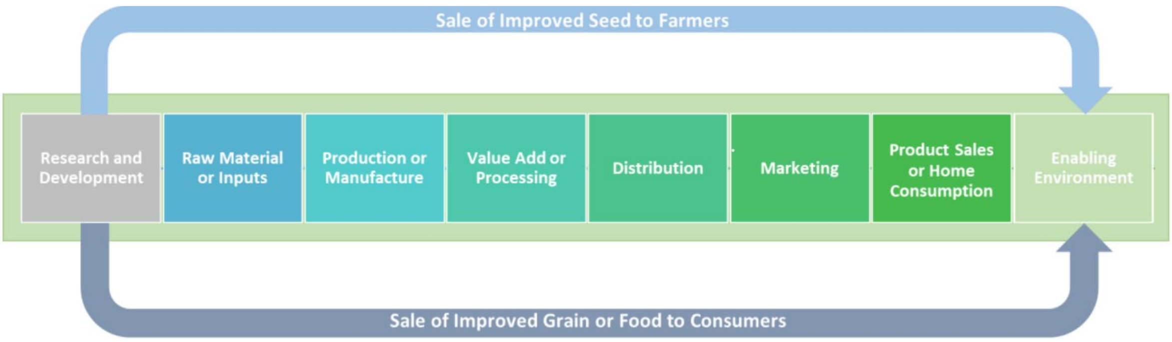

Figure 1. Commercialisation process map for agricultural and publicly developed technologies and goods (source: Development Practice 2019 (15)

Guided by the learnings from the case study examples, we developed a high-level commercialisation process map that mirrors a value chain and provides a more detailed focus on distribution, marketing, and sales and generalises agricultural inputs, production, and post-harvest (Figure 1). With the aim of barrier identification, the process map breaks out the steps that need to be analysed independently and accounts for the unique nature of seed, stem, and vine products, as well as that of foods. While this map generally represents a commercialisation process that is applicable to bringing any agricultural technology to market, for biofortified crops and foods, seed technologies need to be analysed for farmer uptake of new varieties, aggregator and processor uptake of the harvested crops, and consumer uptake and consumption of the final products.

At the centre of any commercialisation initiative is profitability. We thus developed a complementary commercialisation process wheel that places profitability at the centre of the process map (Figure 2). The commercialisation process wheel can similarly be used for the two independent analyses (sale of improved seed varieties to farmers and sale of improved crops or food to processors and consumers), which ensures that key profitability considerations for smallholder seed out-growers and food producers are included in the commercialisation analysis, in addition to those of private-sector seed companies.

Figure 2. Technology and product commercialisation framework process wheel for barrier analysis (source: The Development Practice 2019 (14)

SUCCESS FACTORS FOR COMMERCIALISATION SUCCESS

Success factors apply to multiple steps along the commercialisation process map and fall into five broad categories: supply, demand, policy, finance, and development outcomes (20,21). Signalling these factors is intended to help identify ways to enable commercialisation. We discuss these five categories as broadly applicable to the commercialisation of public agricultural technologies and goods.

SUPPLY

Supply success factors relate to having the production systems and strategic partnerships in place to ensure the product can be supplied at the required quantity, quality, and price. Agricultural supply bottlenecks tend to be more prevalent in earlier phases of the commercialisation process map, such as inputs, production, and manufacture; however, distribution and sales require that strong supply-side systems must also be in place (22). The supply success factors can be further broken down into intellectual property, infrastructure, multiplication capacity, and distribution.

DEMAND

Demand success factors generally relate to creating demand for new products and strengthening markets for commercial sales. Demand must be addressed by clearly understanding the needs of farmers (e.g., agronomic traits of seed varieties) and of food consumers (i.e., their preferred product attributes) and developing the right delivery and sales models to meet those requirements (23). Demand bottlenecks for agricultural goods tend to be more prevalent in the later phases of the process map, such as distribution, marketing, and sales; however, understanding farmer and consumer demand requirements is also key to getting the research, inputs, production, and manufacture phases of the process map correct. The demand success factors can be further broken down into customer demographics, product usage, accessibility and affordability, and information access.

POLICY

Policy success factors generally relate to the establishment of a positive enabling environment, usually in terms of government laws, regulations, and certifications for agricultural and food products (24–27). Services and infrastructure that are publicly provided, such as roads, telecommunications, and health services, are also included. Policy bottlenecks for agricultural goods tend to be most prevalent in the enabling environment phase, which both cuts across the commercialisation process map and captures how individual businesses may be affected by enabling environment factors. The policy success factors can further be broken down into legal and regulatory systems, market regulation, national nutrition strategies, and disaster relief strategies.

FINANCE

Finance success factors relate to ensuring that businesses have access to the working capital needed to establish operations and get new products to market. These factors are generally addressed by accessing financing directly, but they also can be achieved through partnerships that provide capital assets, operational cash flow, and in-kind services. A profitable business model is core to addressing finance bottlenecks. If profitability cannot ultimately be achieved through commercialisation, then different interventions or public financing should be considered for bringing new technologies to consumers. The finance success factors can further be broken down into commercial or impact investments as well as other types of finance (e.g., public finance, blended finance, and public or private microfinance).

DEVELOPMENT OUTCOMES

Development outcome success factors relate to the intended impact or benefits those publicly developed agricultural technologies and goods are meant to create or provide. The degree of impact and the demand for that impact can drive commercialisation if they are high enough. If the technologies or goods being commercialised require longer timeframes to show impact or demonstrate value, or if the impact is not visible to users, then it will be more difficult to create commercial demand, and a publicly financed intervention may be a better approach to raise that demand. The development outcome success factors can further be broken down into intervention scale, target beneficiaries, target indicators, and public sector role.

A detailed description of the success factors, the challenges and opportunities, and related citations is available elsewhere (14). These success factors provide development practitioners with a holistic way to evaluate the potential challenges and opportunities of commercialisation.

COMPLEMENTARITIES OF THE COMMERCIALISATION PROCESS MAP AND SUCCESS FACTORS

When combined, the commercialisation process map shown in Figure 1 and the cross-cutting success factors discussed above offer two complementary dimensions for identifying bottlenecks, best practices, and accelerators. A framework with both components will identify where interventions can maximise impact. Once a commercialisation case has been made, private-sector partners can then be identified based on their unique ability to profitably address the strengths, weaknesses, opportunities, and constraints of the sector when bringing the specific technology/product to market. Partner selection criteria allow development practitioners to clearly recognise how potential private-sector partners will address identified commercialisation bottlenecks and/or provide needed organisational capacity (28,29). Five key criteria for selecting private-sector partners mirror the five success factors: 1) business model (finance), 2) commercial viability (demand), 3) legal requirements (policy), 4) organisational capacity (supply), and 5) beneficiary impact (development outcomes).

These criteria do not focus only on a company's technology. Rather, they allow development practitioners to identify partners that can make a strong business case for profitably bringing a new technology to market. For potential partners that are strong in some key areas but do not meet all five criteria, requirements can be prioritised according to the most pressing capacity needs and potential value added to the partnership.

THE COMMERCIALISATION FRAMEWORK

The developed commercialisation framework serves as an analysis tool that overlays the commercialisation process map and the success factors (as its key components) to break down broad and complex information about public agricultural technologies and/or goods and identify what cross-cutting interventions could be used to address multiple bottlenecks.

The framework allows development practitioners to organise their knowledge in a simple, consistent way. By organising information in this way, complex information for different technologies and goods being commercialised in different markets and across different contexts can be systematically analysed and compared to determine catalytic investments and partnerships. There are key data points that can be collected for each step of the commercialisation process map to explain how a technology or good will be able to profitability reach end consumers or where key constraints might hinder that effort. If the analysis fails to yield a compelling profitable business case, then the framework (with additional profitability analysis using the process wheel, Figure 2) can also be used to map a commercialisation initiative's internal capacity and existing partnerships to identify where new strategic investments or partnerships are needed to achieve market uptake.

APPLICATION OF THE COMMERCIALISATION FRAMEWORK TO TWO RELEVANT CASE STUDIES

CASE STUDY ONE: ENRICHED WHEAT FLOUR IN THE UNITED STATES

Enriched (i.e., industrially fortified) wheat flour in the United States is a historical example of one of the most successful fortification initiatives in the world, allowing the benefit of hindsight to analyse the full trajectory of industry and consumer adoption.

In the 1930s, vitamin-B enriched wheat flour and related products were developed in the US to prevent beriberi and pellagra, diseases caused by vitamin-B deficiency (30,31). Despite their high prevalence, these diseases were not particularly visible, and the public had little awareness of them. Efforts were made to increase demand through public awareness campaigns and public procurement mandates for the military during World War II, but these initially had little effect on consumer demand and willingness to pay. For small mills and bakeries that could not produce enriched products at competitive prices, there was no incentive to enter the market. Large millers, seeing no business sense in fortifying wheat flour, went back to processing non-fortified flour, and ultimately the market for fortified wheat flour and products diminished. Enriched wheat flour and products did not meaningfully take off until after World War II, when the government partnered with national health and science agencies, industry associations, and consumers to create a comprehensive marketing campaign (cutting across multiple points of the process map) that effectively targeted consumers, industry, and legislators. Additionally, state-level legislation for enriched wheat products was eventually passed as public research provided clear evidence on the burden of micronutrient deficiencies and the real impacts of fortified foods and food fortification policy. Federal labelling requirements were also passed, requiring that all unenriched products be labelled as not containing essential vitamins. These initiatives eventually contributed to widescale production and consumption of fortified wheat as well as the elimination of pellagra in the US (30,31).

This example shows the need for strong business cases (profitability) for private-sector uptake. Additionally, it demonstrates the need for public sector/institutional support for effective demand generation. Finally, the case demonstrates how commercialisation is a process that takes time and how synergising the different nodes of the process map by use of cross-cutting strategies, guided by the commercialisation framework (Figure1), may shorten the time.

Annex 1 shows the enriched wheat flour commercialisation process map, and Annex 2 illustrates how the commercialisation framework was used to identify demand bottlenecks at the different nodes of the value chain (14,16).

CASE STUDY 2: VITAMIN A CASSAVA IN NIGERIA

Vitamin A cassava in Nigeria is an example of how biofortified cassava stem technology has started to become commercialised without the benefits of legislation.

The first biofortified vitamin A cassava variety was released in Nigeria in 2011 after being developed through a partnership between global and local agricultural research institutions, including the International Institute of Tropical Agriculture (IITA), the National Root Crops Research Institute (NRCRI), and HarvestPlus (32,33). Uptake has made notable progress, driven by farmer, industry, and consumer demand-creation initiatives including government advocacy, a multi-stakeholder media campaign, marketing through multiple media channels, and promotion of the crop through the agricultural extension system (1,32,34–36). Expansion of production and processing through smallholder farmers and micro-enterprises is steady, but slow and limited in scope mainly due to high costs for land and mechanisation. Additionally, processing at all levels is limited by complex processing requirements that restrict the entry of micro-enterprises and by limited availability of inputs. Limited availability of raw materials reflects the limited production and marketing capacity of smallholder farmers as well as the fact that major production areas are not necessarily located near major processing zones and the product is difficult to move, indicating that market uptake can increase once supply challenges are solved.

This case study essentially shows a supply issue, whereby cassava could not be grown or processed in the quantities needed to fulfil and expand demand, despite the existence of a good demand-creation strategy. The commercialisation framework (Figure 1) provides the insight that direct investment into more farm partnerships or better infrastructure for processing could have improved results.

Annex 3 shows the vitamin A cassava commercialisation process map, and Annex 4 illustrates how the commercialisation framework was applied to identify demand challenges (or bottlenecks) at the different nodes of the value chain (14,16).

POTENTIAL USE OF THE COMMERCIALISATION FRAMEWORK IN BIOFORTIFICATION PROGRAMMES

The resulting commercialisation framework tool has the potential to be used by biofortification programmes, such as the CBC programme, and related commercialisation efforts to assess programming, investment, and partnership decisions across priority countries and biofortified crop value chains. In terms of programming, the framework can help to identify at which point(s) along the commercialisation process map bottlenecks occur and what interventions are required. This in turn helps to define priority activities to overcome those bottlenecks - in the order in which they occur - which then form the basis of a country-crop strategy for commercialising biofortified foods.

In terms of profitability, the framework gives guidance on analysis at two levels (i.e., the production/supply (seed) level and market/demand (crop/food) level) and places the profitability of the initiative at the centre (Figure 2). Profitability analysis can be done at all steps of the process map, looking at the cost of production of seeds, cost of mechanisation, and cost of processing technology, amongst others. Profitability analysis considering economies of scale helps prioritise the biggest barriers to ensure profitability of the commercialisation initiatives.

In terms of investment, understanding success factors across the commercialisation process map can help identify which interventions have the highest potential to result in a commercialised biofortified food product and thus helps support decision-making around resources and funding allocations across priority countries and crops.

In terms of partnership decisions, once a commercialisation case has been made, this framework can help to identify private-sector partners based on their unique ability to profitably address the identified strengths, weaknesses, opportunities, and constraints when bringing the biofortified food product to market. The partnership criteria can be used to assess potential private-sector partners needed to fill gaps in organisational capacity.

CONCLUSIONS

The commercialisation framework is a tool that stakeholders can use to analyse their commercialisation initiatives in an intuitive and consistent way to guide partnerships and investments for successful market uptake of public agricultural technologies and goods, including biofortified crops and foods. While agri-food value chains show similarities in processes involved in getting new technologies and goods to market, each value chain is unique and needs to be analysed separately to determine value chain-, sector-, and/or product-specific bottlenecks and enablers. Many available commercialisation frameworks only partly examine the value chain and set node-specific strategies. While most stakeholders have information about their sectors, products, and/or technologies, analysing this information to inform cross-cutting commercialisation strategies may be complex; hence, partial or illustrative commercialisation models are preferred. A commercialisation framework that holistically overlays success factors may be beneficial in integrating the full value chain information. For agricultural technologies like biofortification, the framework can be adapted to account for the unique nature of the technology (for example, biofortification has two distinct process paths, for seed and food).

The case studies presented in this paper demonstrate how the commercialisation framework can be used to synthesise and organise the different information in a value chain and subsequently analyse it to inform programming, investment, and partnership decisions. As efforts to commercialise biofortified crops and foods move forward under initiatives like the CBC programme, tools such as the commercialisation framework can be used to guide the development of cross-cutting strategies that have high chances of success.

REFERENCES

1. Bouis HE, Saltzman A. Improving nutrition through biofortification: a review of evidence from HarvestPlus, 2003 through 2016. Global food security. 2017;12:49–58.

2. Pfeiffer WH, McClafferty B. HarvestPlus: breeding crops for better nutrition. Crop Science. 2007;47:S-88.

3. Lockyer S, White A, Buttriss J. Biofortified crops for tackling micronutrient deficiencies–what impact are these having in developing countries and could they be of relevance within Europe? Nutrition Bulletin. 2018;43(4):319–57.

4. Bouis HE, Welch RM. Biofortification—a sustainable agricultural strategy for reducing micronutrient malnutrition in the global south. Crop science. 2010;50:S-20.

5. Scaling Sustainability, 2021 Annual Report [Internet]. HarvestPlus; 2021 [cited 2022 Jun 3]. Available from: https://www.harvestplus.org/wp-content/uploads/2022/05/HarvestPlus-2021-Annual-Report.pdf

6. Foley JK, Michaux KD, Mudyahoto B, Kyazike L, Cherian B, Kalejaiye O, et al. Scaling Up Delivery of Biofortified Staple Food Crops Globally: Paths to Nourishing Millions. Food and Nutrition Bulletin. 2021;42(1):116–32.

7. Dewey KG. Nutrition and the commoditization of food systems in Latin America and the Caribbean. Social Science & Medicine. 1989;28(5):415–24.

8. Bouis H, Birol E, Boy E, Gannon BM, Haas JD, Low J, et al. Food biofortification: reaping the benefits of science to overcome hidden hunger. In Council for Agricultural Science and Technology (CAST); 2020.

9. Waized B, Ndyetabula D, Temu A, Robinson E, Henson S. Promoting biofortified crops for nutrition: Lessons from orange-fleshed sweet potato (OFSP) in Tanzania. IDS; 2015.

10. Dewey KG. Nutritional consequences of the transformation from subsistence to commercial agriculture in Tabasco, Mexico. Human ecology. 1981;9(2):151–87.

11. Goletti F, Purcell T, Smith D. Concepts of commercialization and agricultural development. Agrifood Consulting International Discussion Paper Series. 2003;(8).

12. Global Alliance for Improved Nutrition (GAIN). The Commercialisation of Biofortified Crops Programme Flyer [Internet]. 2020 [cited 2021 Oct 28]. Available from: https://www.gainhealth.org/sites/default/files/publications/documents/commercialisation-of-biofortified-crops-programme-flyer.pdf

13. Nyangaresi AM, Friesen VM, McClafferty B, van der Merwe C, Haswell D, Reyes B, Mudyahoto B, et al. Developing strategies to commercialise biofortified crops and foods: Identifying opportunities and barriers to inform country-level interventions [Internet]. Geneva, Switzerland: Global Alliance for Improved Nutrition (GAIN) and HarvestPlus; 2022. Working Paper #28. Available from: https://doi.org/10.36072/wp.28

14. The Development Practice. Commercialisation of Publicly Developed Goods Review: Report [Internet]. 2019 [cited 2022 Jun 3]. Available from: https://nutritionconnect.org/media/83

15. The Development Practice. Commercialisation of Publicly Developed Goods Review: Executive Summary and Framework Quick Reference [Internet]. [cited 2022 Jun 3] p. 2019. Available from: https://nutritionconnect.org/media/84

16. The Development Practice. Commercialisation of Publicly Developed Goods Review: Case Studies [Internet]. 2019 [cited 2022 Jun 3]. Available from: https://nutritionconnect.org/media/85

17. de Boef W, Huisenga M, Atwood D, Mennel J, Dassel K, Prabhala P, et al. Early generation seed study--summary. Gates Open Res. 2019;3(182):182.

18. Prabhala P, de Boef W, Mennel J, Taintor M, Anderson K, Weddle J, et al. Early generation seed study--summary. 2015;

19. United States Agency for International, Development (USAID). Integrating Gender and Nutrition within Extension and Advisory Services" (INGENAES) [Internet]. 2018. Available from: https://ingenaes.illinois.edu/wp-content/uploads/ING-Success-Stories-2018_06-FINAL-all-togetherMosiman-2018_06_12.pdf

20. Fintrac/USAID. Success Factors for Commercializing Agricultural Research Lessons from Feed the Future Partnering for Innovation-A Companion Guide for the Private Sector [Internet]. 2018 Jan. Available from: https://static1.squarespace.com/static/5a7b7b36d55b416e7a7bcd2b/t/5aa977d5ec212d6fb48b2e90/1521055702356/FINAL_Research_to_Commercialization_Companion_Guide_for_Private_Sector.pdf

21. Fintrac/USAID. Success Factors for Commercializing Agricultural Research Lessons from Feed the Future Partnering for Innovation [Internet]. 2017 Nov. Available from: https://static1.squarespace.com/static/5a7b7b36d55b416e7a7bcd2b/t/5ab5143088251b2e6b196cf5/1521816625457/FTF+Partnering+for+Innovation_8+Success+Factors_Research.pdf

22. Sperling L, Boettiger S, Barker I. Integrating seed systems (Planning for Scale Brief No. 3). Retrieved from AgPartnerXChange: https://seedsystem org/wp-content/uploads/2014/03/Integrating-Seed-Systems- pdf. 2014;

23. Birol E, Meenakshi J, Oparinde A, Perez S, Tomlins K. Developing country consumers' acceptance of biofortified foods: a synthesis. Food Security. 2015;7(3):555–68.

24. Pingali PL, Rosegrant MW. Agricultural commercialization and diversification: processes and policies. Food policy. 1995;20(3):171–85.

25. Von Braun J. Agricultural commercialization: impacts on income and nutrition and implications for policy. Food policy. 1995;20(3):187–202.

26. Covic N, Low J, MacKenzie A, Ball A. Advocacy for biofortification: building stakeholder support, integration into regional and national policies, and sustaining momentum. African Journal of Food, Agriculture, Nutrition and Development. 2017;17(2):12116–29.

27. Lamprinopoulou C, Renwick A, Klerkx L, Hermans F, Roep D. Application of an integrated systemic framework for analysing agricultural innovation systems and informing innovation policies: Comparing the Dutch and Scottish agrifood sectors. Agricultural Systems. 2014;129:40–54.

28. Margaret S, Bob R, Mike G, Sara B. Scaling Agricultural Technologies through Public-Private Partnerships [Internet]. 2013. Available from: https://agrilinks.org/sites/default/files/resource/files/ASC%20Oct%2030%20Scaling%20Ag%20Tech.pdf

29. Winter S, Bijker M, Carson M. Multi-stakeholder Initiatives: Lessons in Agriculture. Boston MA: Harvard Kennedy School Consultado en: http://www technoserve org/files/downloads/multistakeholder-initiatives-lessons-from-agriculture-report pdf. 2017;

30. Bishai D, Nalubola R. The history of food fortification in the United States: its relevance for current fortification efforts in developing countries. Economic Development and Cultural Change. 2002;51(1):37–53.

31. Krinsky NI, Beecher G, Burk R, Chan A, Erdman j J, Jacob R, et al. Dietary reference intakes for vitamin C, vitamin E, selenium, and carotenoids. Institute of Medicine. 2000;

32. Ilona P, Bouis H, Palenberg M, Moursi M, Oparinde A. Vitamin A cassava in Nigeria: crop development and delivery. African Journal of Food, Agriculture, Nutrition and Development. 2017;17(2):12000–25.

33. Oparinde A, Abdoulaye T, Manyong VM, Birol E, Asare-Marfo D, Kulakow P, et al. A technical review of modern cassava technology adoption in Nigeria (1985-2013): Trends, challenges, and opportunities. 2016;

34. Onyeneke RU, Amadi MU, Anosike FC. Biofortification in Nigeria: A systematic review. AIMS Agriculture and Food. 2019;4(4):892–906.

35. Bechoff A, Chijioke U, Westby A, Tomlins KI. 'Yellow is good for you': Consumer perception and acceptability of fortified and biofortified cassava products. PLoS One. 2018;13(9):e0203421.

36. Pfeiffer WH. HarvestPlus: State--of--Art and Program Strategic Priorities in Biofortified Crop Development and Commercialization. In 2015. p. 28.

ANNEX 1. COMMERCIALISATION PROCESS MAP FOR ENRICHED WHEAT FLOUR IN THE UNITED STATES (16)

Research and Development	Raw Material or Inputs	Production or Value Add	Processing or Manufacture	Distribution	Marketing	Product Sales or Home Consumption	Enabling Environment
• **Low priority health outcome:** vitamin-B enriched flour prevented beriberi and pellagra which were not considered common public health problems • **No existing target market:** case for enrichment was not existing disease burden, but as insurance against future deficiencies	• procurement processes were already in place and not impacted by the intervention	• production processes were already in place and not impacted by the intervention	• **No economy of scale:** smaller processors could not reach economies of scale without increasing consumer prices, **Lack of consumer demand:** incentivized small processors to make nonenriched products at lower prices than enriched products so that and larger processors reversed production of enriched products • **No profitable business model:** to justify the investment needed for processing enriched flour	• distribution networks were already in place and not impacted by the intervention	• **Failed campaign:** public marketing information used confusing language to describe benefits of enrichment to prevent unknown diseases, resulting in no increase in consumer demand • **Nutritional benefits of the product were not clear** or compelling to most consumers	• **No health outcome demand:** enriched flour prevented beriberi and pellagra which were not considered health problems by consumers and did not have existing disease burden • **Limited health impact:** flour enrichment did not offer an immediate and visible benefit to consumers • **Government procurement:** existed to buy only enriched flour for military consumption during wartime	• **Failed government appeals:** used philanthropic and patriotic language and threats of legislation to try to incentivize industry to enrich, but were not effective in pushing adoption • **Government-issued mandate:** that all flour must be enriched tried to leverage national defense to address nutrition • **No federal labeling requirements:** for enrichment, most efforts at state level and not uniform

ANNEX 2. APPLICATION OF THE COMMERCIALISATION FRAMEWORK TO IDENTIFY BOTTLENECKS FOR ENRICHED WHEAT FLOUR IN THE UNITED STATES (16)

Research and Development	Raw Material or Inputs	Production or Value Add	Processing or Manufacture	Distribution	Marketing	Product Sales or Home Consumption	Enabling Environment
Supply	Supply	Supply	**Supply** • smaller processors could not reach economies of scale needed to enrich without increasing consumer prices	Supply	**Supply**	**Supply**	**Supply** • government-issued wartime mandate that all flour must be enriched to leverage national defense to address nutrition
Demand • prevented beriberi and pellagra which were not considered common public health problems	Demand	Demand	**Demand** • small processors incentivized to make cheaper nonenrich-ed products, larger processors reversed enriched production	Demand	**Demand** • marketing info about benefits of enrich-ment was confusing and focused on pre-venting unknown diseases	**Demand** • health impact was abstract as flour enrichment did not offer an immediate and visible benefit to consumers	**Demand** • philanthropic appeal and legislative threat to incentivize enrich-ment were not effective in industry adoption
Policy	Policy	Policy	**Policy**	Policy	**Policy**	**Policy**	**Policy** • no federal labeling requirements for enrichment, most efforts at state level and not uniform
Finance	Finance	Finance	**Finance** • No business model (profitability) to justify the investment needed for processing enriched flour	Finance	**Finance**	**Finance**	**Finance**
Outcomes • case for enrichment was not disease burden, rather as insurance against future deficiencies	Outcomes	Outcomes	**Outcomes**	Outcomes	**Outcomes** • nutritional benefits of the product were not clearly marketed or compelling to most consumers	**Outcomes** • limited health impact as flour enrichment did not offer an immediate and visible benefit to consumers	**Outcomes**

ANNEX 3. COMMERCIALISATION PROCESS MAP FOR VITAMIN A CASSAVA IN NIGERIA (16)

Research and Development	Raw Material or Inputs	Production or Value Add	Processing or Manufacture	Distribution	Marketing	Product Sales or Home Consumption	Enabling Environment
Sale of Improved Stems to Farmers							
• **Improved varieties: for farmer preferred** traits around pest & disease resistance and high yields • **Significant public resources for studies** around seed traits for farmers and consumers	• **Limited availability and affordability of land** near optimal production areas • **Extension services:** directly promoting in pilot areas for SHF • **Availability of root stock** is growing, but still limited • **Farmer-to- Farmer** seed promotion	• **Inadequate small-scale production** for larger scale volume processing requirements • **High costs for mechanization** to expand production • **Few large-scale producers** are producing • **Limited investment capital** for large scale production	• **High up-front processing costs** are prohibitive for small and medium scale farmers to do on farm processing • **Far distance to processors** limit off-farm processing opportunities	• **Rural production:** is far from purchasers • **Bulky, heavy, product** is difficult to transport to processors and markets • **Farmer-to-farmer** stem distribution	• **GMO concern** due to misperceptions related to color and legal GMO trials of project partners • **Initial free distribution** of stems • **Broad based media campaign** to promote nutrition benefits • **Multiple sales channels**	• **Home consumption and informal markets:** limit commercial availability and sales • **Yellow color is a new trait:** preferences for white varieties varies by state • **Perception that cassava is a staple- not commercial- crop**	• **Federal level promotion** through agriculture and nutrition policies • **Limited state level promotion** particularly in the North and non- pilot states • **Limited investment activity in main** production areas and for cassava
Sale of Biofortified Food Products to Consumers							
• **Extensive and expensive processing systems needed for cassava:** which limits processing capacity for micro-enterprises making final food products	• **Limited, consistent supply** of vitamin A biofortified cassava and/or flour since production is mostly small-scale • **Cost-prohibitive, extensive processing** required to mill raw cassava into flour and other products	• N/A- redundant step to processing/ manufacture	• **High up-front processing costs** are prohibitive for microenterprises to directly process cassava • **Micro-enterprises support programs** and investments are growing, but still relatively limited • **Large-scale processors** still relatively limited	• **Proximity to end markets** • **Large country with varying quality infrastructure** add complexity to any national distribution plans	• **Many market channels and possible customer segments:** including different requirements and standards between urban and rural customers	• **Yellow color is a nutritious trait:** preferences for white gari vary, but nutritious foods are trending in a way that promotes yellow	• **Federal level promotion** through agriculture and nutrition policies • **Limited state level promotion** particularly in the North and non- pilot states

ANNEX 4. APPLICATION OF THE COMMERCIALISATION FRAMEWORK TO IDENTIFY BOTTLENECKS FOR VITAMIN A CASSAVA IN NIGERIA (16)

Research and Development	Raw Material or Inputs	Production or Value Add	Processing or Manufacture	Distribution	Marketing	Product Sales or Home Consumption	Enabling Environment
SUPPLY • **Extensive and expensive processing systems needed for cassava**	**SUPPLY** • **Limited availability & affordability of land** • **Availability of root stock** is growing, but still limited	**SUPPLY** • **Inadequate small-scale production** for larger scale volume processing requirements	**SUPPLY** • **High up-front processing costs** are prohibitive for small scale farmers and limited number of large-scale processors	**SUPPLY** • **Proximity to end markets** • **Bulky, heavy, product** is difficult to transport	**SUPPLY** • **Multiple sales channels** and possible customer segment requires differentiated product delivery	**SUPPLY** • **Home consumption and informal markets:** limit commercial availability and sales	**SUPPLY** • **Federal level programs** to promote and improved, nutritious production
DEMAND • **Improved varieties: for farmer preferred** traits around pest & disease resistance and high yields	**DEMAND** • **Farmer-to- Farmer** seed promotion is growing but still limited	**DEMAND**	**DEMAND**	**DEMAND** • **Farmer-to-farmer** stem distribution	**DEMAND** • **GMO concern** due to misperceptions related to color and partner programs • **Initial free stems**	**DEMAND** • **Yellow color is a new trait:** preferences for white varieties varies by state	**DEMAND**
POLICY •	**POLICY**	**POLICY**	**POLICY** •	**POLICY** • **Large country with varying quality infrastructure** add complexity to any national distribution plans	**POLICY**	**POLICY** •	**POLICY** • **Limited state level promotion** particularly in the North and non- pilot states
FINANCE	**FINANCE** • **Cost-prohibitive, extensive** processing required to mill raw cassava into flour	**FINANCE** • **High costs for mechanization** • **Limited investment capital** for large scale production	**FINANCE** • **High up-front processing costs** are prohibitive for small and medium scale farmers and microenterprises	**FINANCE**	**FINANCE** •	**FINANCE** •	**FINANCE** • **Limited investment activity in main** production areas and for cassava
OUTCOMES • **Significant public resources for studies** around seed traits for farmers and consumers	**OUTCOMES** • **Extension services:** directly promoting in pilot areas for SHF	**OUTCOMES**	**OUTCOMES** • **Micro-enterprises support programs** and investments are growing, but still relatively limited	**OUTCOMES**	**OUTCOMES** • **Broad based media campaign** to promote nutritional benefits	**OUTCOMES** • **Yellow color is a nutritious trait:** growing in popularity, although preferences for white gari still vary	**OUTCOMES** •