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REVIEW ARTICLE

Industry compliance in national micronutrient food fortification programmes: A systematic review with lessons for Uganda

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ABSTRACT

Large-scale food fortification remains a critical strategy for reducing micronutrient deficiencies, but its effectiveness depends on whether industries consistently fortify foods to standard. This review synthesizes global evidence on industry compliance across major food vehicles, including salt, wheat flour, maize flour, edible oil, sugar, and condiments, and applies the findings to Uganda's programme improvement agenda. A systematic review was conducted using peer-reviewed articles, programme evaluations, policy analyses, survey reports, and Uganda-specific regulatory documents retrieved from academic databases and institutional sources. The synthesis incorporated evidence from Africa, Asia, and Latin America, including Uganda and comparator settings such as Senegal, Tanzania, Kenya, Nigeria, Malawi, Mozambique, Bangladesh, India, Indonesia, Chile, and Costa Rica. The evidence shows that compliance is shaped by regulatory clarity, market structure, premix and equipment costs, quality assurance, external monitoring, political commitment, and credible enforcement. Compliance tends to be stronger in centralized industries such as wheat flour and edible oil, but weaker in fragmented maize markets and among smaller millers. Across countries, a persistent fortification quality gap remains between foods that are legally covered or reportedly fortified and foods that are adequately fortified at production, market, and household levels. Uganda reflects this broader pattern: although the legal and policy framework is established, compliance remains uneven across food vehicles, with stronger adherence among salt, wheat flour, and edible oil producers than among maize millers. Therefore, Uganda should strengthen production-based verification, improve inter-agency coordination, adopt differentiated compliance strategies by processor scale and vehicle, and invest in practical monitoring and enforcement systems that make sustained compliance feasible.

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INTRODUCTION

Micronutrient deficiencies continue to undermine human capital development through reduced productivity, and disease burden in many low- and middle-income countries. Deficiencies of vitamin A, iron, iodine, folate, and zinc affect child survival, maternal health, school performance, immunity, and labour productivity, and they impose both direct health costs and wider economic losses (Venkatesh Mannar & Sankar, 2004; Osendarp *et al*., 2018). Large scale food fortification is therefore a consistent central nutrition strategy because it increases micronutrient intake through widely consumed foods without requiring major behavior change at household level (Olson *et al*., 2021). However, fortification only works when the food industry complies with nationally set technical standards. A country may have legislation, premix specifications, and official commitments, yet still deliver weak nutrition outcomes if processors do not fortify consistently, if fortification levels are inaccurate, or if regulatory systems fail to detect and correct under fortification. This implementation problem is increasingly described as the fortification quality gap which is the difference between foods that are meant to be fortified and foods that are adequately fortified when they reach consumers (Mkambula *et al*., 2020; Rowe, 2020). The quality gap majorly reflects broader issues of governance gaps, poor market structure, low technology, lack of incentives, and non-accountability. The global literature now makes three points very clearly. First, legal mandates alone do not guarantee compliance. Second, compliance performance differs markedly by food vehicle and processor structure. Third, regulatory systems are most effective when they combine appropriate standards, internal quality control by firms, simple external verification tools, and credible enforcement backed by political and institutional commitment (Luthringer *et al*., 2015; Marks *et al*., 2018; Rohner *et al*., 2023). These insights are especially important for Uganda, where wheat flour and edible oil are more industrially concentrated and easier to monitor, but maize flour is produced through a far more fragmented market structure. This review therefore examines global evidence on industry compliance in national micronutrient fortification programmes and distills strategic lessons for Uganda's programme improvement. It focuses on the main food vehicles relevant to both the international literature and Uganda's regulatory framework which are salt, wheat flour, maize flour, edible oil, sugar, and selected condiments. The review emphasizes compliance patterns, determinants of compliance, monitoring and enforcement systems, and implications for programme strengthening.

METHODOLOGY

This study used a narrative systematic review to synthesize evidence on industry compliance in national micronutrient fortification programmes. Relevant literature was retrieved from a broad range of reputable academic and institutional sources, including Web of Science, SpringerLink, Google Scholar, PubMed, Taylor & Francis, ScienceDirect, Wiley Online Library, and Access-Science, and complemented by targeted grey literature searches. Additional sources included technical and policy documents from the WHO, Food and Agriculture Organization (FAO), Global Alliance for Improved Nutrition (GAIN), Food Fortification Initiative (FFI), Global Fortification Data Exchange (GFDx), and Uganda-specific programme, policy, and regulatory documents from relevant institutions such as the Ministry of Health and Uganda National Bureau of Standards (UNBS). Search terms combined fortification concepts with compliance and regulatory language, including: food fortification, micronutrient fortification, mandatory fortification, industry compliance, adequately fortified, fortification standards, premix reconciliation, external monitoring, quality assurance, quality control, regulatory monitoring, market surveillance, and selected food vehicles and micronutrients such as wheat flour, maize flour, edible oil, salt, sugar, vitamin A, iron, folic acid, zinc, and iodine. Country-specific search terms were also applied to settings represented in the synthesis, including Uganda, Ethiopia, Senegal, Tanzania, Kenya, Nigeria, South Africa, Cameroon, Côte d'Ivoire, Malawi, Mozambique, Jordan, Bangladesh, India, Indonesia, Chile, Brazil, Peru, Colombia, and Costa Rica. The review included peer-reviewed journal articles, systematic reviews, programme evaluations, implementation studies, regulatory analyses, technical guidance, and national survey and policy documents that addressed fortification adequacy, compliance, monitoring, enforcement, governance, or programme performance.

The review prioritized literature published between January 2000 and March 2026. Recent evidence from 2024 to 2026 was purposively included to capture emerging findings on fortification adequacy, market compliance, and governance across Africa, Asia, Latin America, and comparator settings, including Uganda, Ethiopia, Senegal, Tanzania, Kenya, Nigeria, South Africa, Cameroon, Côte d'Ivoire, Malawi, Mozambique, Jordan, Bangladesh, India, Indonesia, Chile, Brazil, Peru, Colombia, and Costa Rica. Studies focused exclusively on industry compliance to micronutrient food fortification regulatory frameworks. The synthesis was organized around five analytical domains: the scale of the fortification quality gap and global compliance patterns; determinants of compliance; monitoring and enforcement approaches; Uganda's legal, institutional, and implementation context; and strategic lessons for programme improvement. Evidence was narratively synthesized by harmonizing overlapping findings, removing duplication, and consolidating citations into a unified analytical framework suitable for interpreting both global experience and Uganda's programme context.

GLOBAL INDUSTRY COMPLIANCE PATTERNS IN FOOD FORTIFICATION

The literature consistently shows that the existence of mandatory fortification programmes does not automatically translate into adequate fortification at household level. The most important recent synthesis is the global systematic review and meta-analysis by Rohner *et al*., 2023 which estimated that in countries with mandatory large-scale fortification, only about 49% of households consumed adequately fortified salt, 35% consumed adequately fortified wheat flour, and 34% consumed adequately fortified edible oil. These figures are especially important because they shift attention away from whether programmes exist on paper and toward whether foods are adequately fortified in practice. Table 1 shows a systematic analysis of global evidence on industry compliance in food fortification and key implications for Uganda. Recent country studies sharpen this conclusion. In Senegal, Faye *et al.* (2025) found that 26.8% of sampled wheat flour, 44.6% of oil, and 23.6% of salt were not fortified at all, while 51.4% of wheat flour, 17.3% of oil, and 16.3% of salt were fortified below the standard minimum. In Tanzania, Kiwango *et al*. (2020) reported that although 83.3% of wheat flour and 80% of maize flour samples met iron standards, only 25% of wheat flour and 40% of maize flour samples were within acceptable zinc ranges, about 17% and 20% respectively met folic acid ranges, and only 10.5% of edible oil samples were adequately fortified with vitamin A. Together, these studies highlight a critical gap between programme adoption and programme performance, with widespread under-fortification persisting across nutrients and food vehicles. Related work has reinforced this point by distinguishing different implementation gaps. Mkambula *et al*. (2020) argued that fortification programmes commonly face feasibility gaps, fortification gaps, and quality gaps. A feasibility gap occurs where the chosen vehicle is not widely industrially processed or consumed by the target population. A fortification gap exists when foods reach markets but are not fortified. A quality gap exists when foods are fortified, but not to standard. Rowe (2020) advanced this reasoning further by emphasizing that fortification assessments should not stop at legal coverage or market availability but must assess adequacy.

Compliance also varies significantly by food vehicle. Salt iodization tends to achieve comparatively stronger performance because the technology is relatively mature, standards are well established, and markets are often more centralized. Wheat flour and edible oil also tend to perform better than maize flour because these vehicles are frequently processed by fewer, larger firms with greater technical capacity and more visible supply chains (Fiedler *et al*., 2015; Rohner *et al*., 2023). By contrast, maize flour programmes often struggle in settings where processing is highly decentralized, feeder equipment is inconsistently used, premix costs are burdensome relative to output volumes, and end product testing is infrequent or poorly enforced. In Jordan, wheat flour fortification benefited from strong routine monitoring and the use of mill level records that allowed programme managers to verify whether premix use corresponded reasonably with flour production (Wirth *et al*., 2012). In Tanzania, Kiwango *et al*. (2020) documented uneven adequacy of fortification across mandatory vehicles, while Issa-Zacharia & Mareni (2024) found that compliance in fortified maize flour remained inconsistent. In Kenya, Khamila *et al*. (2020) similarly showed that maize flour fortification was characterized by variable micronutrient levels and challenges in maintaining compliance to standard.

Additional country evidence further underscores that compliance with mandatory fortification standards varies widely across settings and is often weaker than programme legislation suggests. In Nigeria, Ogunmoyela *et al*. (2013) reported very low compliance across major mandatory vehicles: only 14.9-20.2% of vegetable oil samples, 11.9-16.7% of sugar samples, 12.2-33.3% of flour samples for vitamin A, and 1.0-21.0% of flour samples for iron fell within the acceptable compliance range. These findings point to serious system-wide weaknesses in micronutrient dosing, programme monitoring, and enforcement despite long-standing mandatory standards. Evidence from South Africa also shows that statutory fortification does not guarantee uniform product quality. Yusufali *et al*. (2012) found low compliance with statutory fortification requirements for both bread flour and maize meal at retail level and concluded that insufficient premix addition at mills was a more likely explanation than nutrient instability. A later household-level study by Van Jaarsveld *et al*. (2015) similarly found substantial variability in micronutrient content: maize meal provided only 0.56-0.98 of the minimum vitamin A requirement and 0.76-1.08 of the iron requirement, while bread samples often exceeded iron and zinc minima, suggesting inconsistent dosing and uneven process control.

In Cameroon, Mark *et al*. (2019) found partial compliance to the vitamin A standard. Mean vitamin A levels in oil samples collected from markets and households were about 75% of the national standard, while wheat flour micronutrient levels were substantially below target. Pooled market and household wheat flour samples provided only about 42% of target iron and 45% of target zinc, with folic acid and vitamin B12 also far below standard. The authors concluded that oil fortification had improved, but wheat flour fortification remained below target because of weak external quality control, limited quantitative testing, and premix-related constraints. Cote d'Ivoire presents a mixed picture that is useful for comparison. Rohner *et al*. (2016a) found that just over half of oil samples were adequately fortified, while flour compliance differed sharply by geography: 69.1% of flour samples met the legal iron level overall, but adequacy was much higher in urban Abidjan than in rural Bouafle. This suggests that even where a national programme is functioning, household-level compliance may remain uneven across locations and supply chains.

A useful contrast comes from Costa Rica, where stronger programme management appears to have produced better compliance and impact. Martorell *et al*. (2015) reported that foods were fortified as mandated and that routine monitoring was in place; fortification was associated with marked reductions in anaemia and iron deficiency, including a decline in child anaemia from 19.3% to 4.0% and in women from 18.4% to 10.2%. Costa Rica therefore illustrates that effective compliance is achievable when fortification standards are matched by appropriate fortificant choice, routine monitoring, and sustained programme oversight. Issa-Zacharia & Mareni (2024) provide a further caution from Tanzania's maize sector. Only 31.6% of samples taken at production sites and 12.9% at retail complied with the national standard, even though iron and zinc retention over six months remained high relative to folic acid. Their findings suggest that the core bottleneck is not only nutrient instability, but also inconsistent dosing, weak feeder performance, and limited operator training. This distinction matters for regulators because it shifts attention toward process control rather than relying only on end product testing. The broader lesson is that compliance is not a two-fold state. Products can be labelled as fortified while still delivering insufficient micronutrient levels. Nutrients can also vary in their compliance performance within the same food vehicle because of premix composition, feeder calibration, nutrient stability, and storage conditions. Such findings underscore that compliance must be assessed at the nutrient level, not only at the product level.

In Asia, recent literature on food fortification compliance suggests that implementation performance remains uneven across countries and food vehicles. The strongest direct compliance evidence comes from Bangladesh, where Saha *et al.* (2021) showed that compliance among edible oil and salt producers varied substantially and was shaped by both institutional oversight and firm-level factors. At the market level, Jungjohann *et al.* (2021) found that vitamin A fortification quality was high for packaged and branded edible oil but poor for unbranded loose oil; among bulk oil composites, 59% were not fortified, while a large share of total oil volume available to consumers was either unfortified or fortified below the standard. More recently, Begum *et al.* (2024) reinforced this concern by reporting that 73% of tested edible oil brands did not comply with Bangladesh standards for vitamin A fortification. In India, the recent evidence is somewhat mixed but still relevant to compliance. Jha *et al.* (2023) reported that nationally 76.3% of households consumed adequately iodized salt, indicating substantial progress but also a persistent adequacy gap. Nandeep *et al.* (2024) further reported efficient rollout and good compliance to intake of fortified rice supplied through the Public Distribution System across six pilot districts, suggesting that programme utilization can be strong where supply systems are functioning, although the study focused more on delivery and use than on laboratory verification of nutrient levels.

In Indonesia, recent implementation literature presents a comparatively stronger compliance picture. UNICEF (2023) reported that in Indonesia more than 80% of wheat flour market samples met fortification requirements in recent years, while UNICEF & BAPPENAS (2024) described a regulatory system based on internal monitoring, pre-market surveillance, and post-market surveillance. Taken together, these studies suggest that recent Asian experience mirrors broader global patterns: fortification programmes may be well established in law and policy, yet actual compliance depends heavily on market structure, product form, firm capacity, regulatory oversight, and the strength of routine monitoring systems. In South America, there is compliance-specific literature on food fortification evidence from Chile, Brazil, Peru, and Colombia. In Chile, monitoring data from the national flour fortification programme showed that compliance with mandated micronutrient levels was far from uniform; among 243 flour samples analyzed in 2008, only 47% met the iron requirement and 10.2% met the folic acid requirement, highlighting the gap between programme design and actual product quality (UNICEF & FFI, 2014).

In Brazil, laboratory evaluation of enriched corn and wheat flours similarly found wide variation in folic acid and iron content, indicating inconsistent fortification across products and reinforcing concerns about the adequacy of implementation under mandatory standards (Boen *et al.*, 2008). In Peru, compliance evidence is strongest for iodized salt. Hernández-Vásquez *et al.* (2021) reported that 21.8% of households had table salt with inadequate iodine concentrations, suggesting that even long-established fortification programmes can leave substantial household-level gaps in nutrient adequacy. Colombia provides a further advisory example, as Fothergill *et al.* (2019) noted that the country's mandatory wheat flour fortification programme had not yet been directly evaluated, even though consumption of wheat-flour-containing foods was associated with lower odds of anemia among preschool children. Taken together, these studies suggest that the South American experience mirrors broader global pattern indicating that fortification mandates may be well established in law, yet compliance in practice remains uneven unless programmes are backed by strong monitoring, laboratory verification, and routine enforcement. In table 1 is a summary of the identified themes, the global evidence provided, the main compliance lesson and the implications for Uganda.

DETERMINANTS OF INDUSTRY COMPLIANCE IN FOOD FORTIFICATION

Industry compliance to food fortification regulatory framework is shaped by a set of interlocking technical, economic, regulatory, and political factors. The literature does not support a single cause explanation. Instead, compliance improves where obligations are clear, standards are technically realistic, premix and feeder systems are accessible, monitoring is practical, and compliant firms are not commercially disadvantaged relative to non-compliant competitors. Figure 1 highlights a systematic analysis of determinants of industry compliance in Food Fortification. The first determinant is regulatory clarity. Firms are more likely to comply when standards specify the food vehicle, nutrient compounds, fortification ranges, labelling requirements, and institutional responsibilities in a way that is understandable and enforceable (Marks *et al.*, 2018). Regulatory ambiguity can lead to under dosing, inconsistent premix selection, confusion about

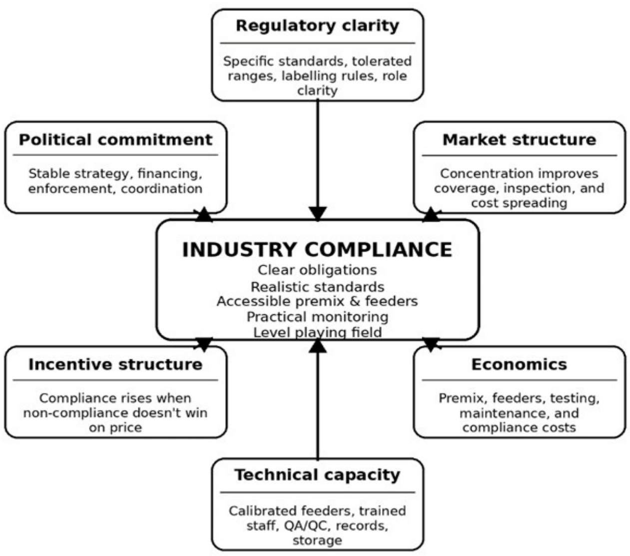

Figure 1. *Determinants of industry compliance in food fortification key literature sources: Marks et al. (2018); Mejia & Bower (2015); Fiedler et al. (2015); Luthringer et al. (2015); Vosti et al. (2024); Lema et al. (2024); Kiwango et al. (2020); Durotoye et al. (2023); Makonda et al. (2026); Karapanou et al. (2024); Osendarp et al. (2018).*

Table 1. Global evidence on industry compliance in food fortification and key implications for Uganda.

Theme	Global evidence	Main compliance lesson	Implication for Uganda
Adequately fortified foods remain limited	The global systematic review by Rohner *et al.* (2023) showed that in countries with mandatory large-scale fortification, only about 49% of households consumed adequately fortified salt, 35% consumed adequately fortified wheat flour, and 34% consumed adequately fortified edible oil. Country evidence from	Legal mandates and programme coverage do not guarantee that households consume adequately fortified foods.	Uganda should track fortification adequacy at household, retail, and production levels, not merely whether a vehicle is mandated or labelled as fortified.
The main challenge is often under-fortification, not programme absence	Studies from Senegal (Faye *et al.*, 2025), Tanzania (Kiwango *et al.*, 2020), Nigeria (Ogunmoyela *et al.*, (2013), and South Africa (Yusufali *et al.*, 2012); Van Jaarsveld *et al.*, 2015) show that products often reach markets but fail to meet micronutrient standards.	The central implementation problem in many settings is under-fortification and inconsistent compliance, rather than absence of legislation.	Uganda should shift performance assessment from 'programme exists' to 'programme delivers adequately fortified foods consistently'.
Compliance gaps are multidimensional	Mkambula *et al.* (2020) distinguish feasibility gaps, fortification gaps, and quality gaps, while Rowe (2020) argue that monitoring must assess adequacy rather than stopping at	Compliance failure may occur because the vehicle is inappropriate, because food is not fortified at all, or because food is fortified below	Uganda should diagnose fortification problems by type of gap and avoid one-dimensional compliance assessments.
Performance differs by food vehicle	Salt iodization generally performs better than flour and oil because systems are more mature and markets are more centralized Rohner *et al.*, (2023). Wheat flour and edible oil often perform better than maize flour because they are processed by fewer and larger firms (Fiedler *et al.*, 2015).	Vehicle characteristics matter. Fortification is easier where processing is centralized, technology is standardized, and enforcement is more visible.	Uganda should adopt vehicle-specific compliance strategies, rather than applying identical approaches to salt, oil, wheat flour, and maize flour.
Maize flour is particularly difficult to regulate in fragmented markets	Evidence from Tanzania (Issa-Zacharia & Mareni, 2024) and Kenya (Khamila *et al.*, 2020; shows that maize flour fortification often faces variable micronutrient levels, inconsistent dosing, and difficulty maintaining compliance to standard.	One-size-fits-all regulation is unlikely to work where maize milling is highly decentralized and technically uneven.	Uganda should use differentiated compliance pathways for maize millers by scale, capacity, and risk profile, with special support for smaller operators.
Process control is as important as end-product testing	In Jordan, external monitoring using premix use and production records helped verify whether mill fortification was plausible (Wirth *et al.*, 2012). In Tanzania, low compliance was linked to inconsistent dosing, weak feeder performance, and poor	End-product testing alone is not enough; fortification depends heavily on feeder calibration, premix reconciliation, and operator competence.	Uganda should strengthen process-based monitoring, including feeder checks, premix reconciliation, production log review, and operator training.
Nutrient-level compliance can differ within the same food vehicle	In Tanzania, iron compliance was much stronger than zinc and folic acid compliance in both wheat and maize flour Kiwango *et al.*, 2020). In South Africa, maize meal and bread showed substantial variability across vitamin A, iron, and zinc (Van Jaarsveld *et al.*, 2015).	A food product may appear compliant overall while still failing for specific micronutrients.	Uganda should assess compliance at the individual nutrient level, not only at the product level.

Table 1. *Contd.....*

Governance and monitoring systems shape outcomes	Better performing programmes, such as Costa Rica and Jordan, combined fortification standards with routine monitoring and stronger programme management (Martorell *et al.* (2015); Wirth *et al.*, 2012). By contrast, Cameroon and Nigeria showed weaker performance where quality control, quantitative testing, and enforcement were constrained (Mark *et al.*, 2019; Ogunmoyela *et al.*, 2013).	Compliance improves when institutions have clear mandates, regular monitoring tools, and functioning enforcement systems.	Uganda should strengthen inter-agency coordination, clarify regulatory roles, and establish regular data-sharing between UNBS, MoH, URA, and industry actors.
Market structure and product form affect compliance	In Bangladesh, compliance differed across firms and product forms; branded packaged oil performed better than unpackaged oil, while many bulk oil samples were unfortified or under-fortified (Saha *et al.*, 2021; Jungjohann *et al.*, 2021; Begum *et al.*, 2024).	Compliance is influenced by firm incentives, branding, traceability, and the ease of monitoring different market channels.	Uganda should pay closer attention to informal and bulk distribution channels, which may carry higher compliance risks than formal branded products.
Household access and utilization do not automatically follow supply-side rollout	In India, adequately iodized salt coverage was substantial but incomplete (Jha *et al.*, 2023), while fortified rice rollout through the Public Distribution System showed that effective utilization depends on functioning supply chains and delivery systems (Nandeep *et al.*, 2024).	Programme delivery and household utilization are distinct from statutory compliance and must be monitored separately.	Uganda should integrate compliance monitoring with coverage and utilization indicators, especially for vulnerable households.
Strong regulatory systems can improve compliance	In Indonesia, more than 80% of wheat flour market samples reportedly met fortification requirements, supported by internal monitoring, pre-market surveillance, and post-market surveillance (UNICEF, 2023;	Compliance improves where regulatory systems combine industry responsibility with systematic government oversight.	Uganda should strengthen a tiered monitoring system that combines internal QA/QC, regulatory inspection, and periodic market surveillance.
Geographic inequities can persist within functioning national programmes	In Cote d'Ivoire, flour compliance was higher in urban Abidjan than in rural Bouafle, even under the same national programme (Rohner *et al.*, 2016b). In Peru, household iodine adequacy also remained uneven (Hernández-Vásquez *et al.*, 2021).	National compliance figures can conceal major geographic disparities in access and adequacy.	Uganda should disaggregate compliance results by region, market type, and processor scale to identify underserved areas.
Fortification can succeed when compliance systems are sustained	Costa Rica provides a positive contrast: foods were fortified as mandated, routine monitoring was functioning, and anaemia and iron deficiency fell markedly among women and children (Martorell *et al.*, 2015).	Effective compliance is achievable when standards are matched by appropriate fortificant choice, continuous oversight, and institutional commitment.	Uganda should frame fortification not only as regulation, but as a managed public health system requiring sustained technical and financial investment.

acceptable tolerances, and disputes over enforcement. Mejia & Bower (2015) made a similar point in relation to condiments and seasonings, noting that regulatory frameworks vary considerably across countries and that effective implementation depends on how broad legal provisions are translated into operational requirements and monitoring systems. A second determinant is market structure. Large-scale processors generally outperform small scale processors because they can spread the costs of premix, equipment maintenance, record-keeping, and quality assurance over larger production volumes. They are also easier for regulators to identify and inspect. This pattern recurs across the literature. Fiedler & Afidra (2010) and Fiedler *et al.* (2014) argued that the feasibility and cost effectiveness of maize flour fortification in Africa are closely tied to market concentration and coverage. Where the majority of consumption comes from small mills or home processing, mandatory industrial fortification reaches fewer households and is harder to enforce.

A third determinant is the economics of fortification. Premix costs, feeder equipment, testing expenses, maintenance, and the managerial time required for compliance all matter. Luthringer *et al.* (2015) found that firms frequently cite the cost of fortification and weaknesses in enforcement as major barriers. Vosti *et al.* (2024) sharpened this point in the Ugandan maize sector by showing that firm level and public sector costs make small scale maize flour fortification particularly challenging. Their analysis suggests that the economics of compliance can become prohibitive for micro and small mills unless support mechanisms, simplified systems, or differentiated approaches are introduced. Similar implementation constraints have been reported among small and medium scale corn millers in Tanzania, where Lema *et al.* (2024) found that awareness gaps, weak enforcement, and operational barriers limit effective implementation. A fourth determinant is technical capacity inside firms. Compliance requires more than possession of a premix bag. Firms need calibrated feeders, staff who understand dosing, proper premix storage, batch or production records, and internal quality assurance systems. Kiwango *et al.* (2020) and Issa-Zacharia & Mareni (2024) both illustrate how deviations in nutrient levels may reflect weak feeder performance, poor mixing, inadequate quality control, or nutrient degradation. Khamila *et al.* (2020) similarly demonstrated that stability and adequacy cannot be assumed simply because flour is labelled as fortified.

A fifth determinant is the incentive structure. Durotoye *et al.* (2023) argued, in the Nigerian context, that industry self-regulation and performance measurement can complement public regulation when firms have incentives to demonstrate good practice. However, self-regulation cannot substitute for public oversight when competition rewards low-cost non-compliance. In many countries, compliant firms bear the extra cost of premix and monitoring while non-compliant firms may sell at lower prices. This creates a classic collective action problem where firms may not comply consistently unless regulators create a level playing field through credible monitoring and sanctions. Recent policy analysis reinforces this pattern. Makonda *et al.* (2026), while comparing Malawi and Mozambique, identify high fortification costs, limited technical expertise, equipment constraints, quality control problems, and regulatory compliance burdens as recurring barriers. They further show that stronger compliance is associated with robust monitoring and clearer policy architecture, while more flexible systems can broaden participation among smaller processors but may weaken enforcement. These findings are consistent with Karapanou *et al.* (2024), who frame effective fortification governance around evidence generation, policy design, authorization, supervision and enforcement, capacity building, and incentives. Finally, political commitment and institutional continuity matter. Osendarp *et al.* (2018) emphasized that large scale fortification works best when embedded within stable national nutrition strategies and backed by long term commitment. Short lived donor attention, fragmented institutional mandates, and underfunded enforcement reduce the probability of sustained compliance even where initial programme rollout appears promising. Figure 1 below highlights a summary of the six interacting determinants of industry compliance from the literature.

MONITORING, VERIFICATION, AND ENFORCEMENT MODELS

The literature strongly suggests that monitoring systems are central to compliance performance. Yet not all monitoring approaches are equally useful. Many programmes over rely on periodic end product laboratory testing, which is expensive, slow, and difficult to sustain at scale. More effective programmes combine internal monitoring by firms with practical external verification methods used by regulators. One of the clearest examples is the external mill monitoring model described by Wirth *et al.* (2012) in Jordan's wheat flour fortification programme. In that model, programme managers used routine mill reports, premix stocks, flour production data, and site inspections to assess whether fortification was occurring at expected rates. The strength of this approach lies in its operational simplicity: if mill throughput and premix use do not roughly correspond, the regulator has an early warning sign that warrants investigation. This type of system does not eliminate the need for laboratory testing, but it reduces sole dependence on expensive end point analysis of fortified foods. Luthringer *et al.* (2015) similarly argued for pragmatic regulatory monitoring systems grounded in feasible administrative and production-based tools. Their review identified multiple barriers to effective monitoring, including inadequate budgets, weak inspector capacity, fragmented institutional responsibility, poor laboratory access, and limited understanding of what practical monitoring should look like. They concluded that good practice requires a mix of industry records, inspection routines, product testing, and clear enforcement pathways. Rowe (2020) proposed a way forward by focusing explicitly on the fortification quality gap. This contribution is useful because it reorients monitoring toward adequacy rather than nominal programme existence. In operational terms, this means that regulators and programme managers should ask several linked questions: Is the vehicle reaching households? Is it produced in the formal industrial system? Is it actually fortified? Is it adequately fortified? Are all major firms complying, or only a subset? This cascade helps regulators avoid inflated assumptions based on legal mandates alone.

Regulatory governance also matters. Karapanou & Makhmudov (2024) emphasized that effective fortification systems depend on role clarity, financing, data flows, legal authority, and coordination across health, standards, customs, and industry institutions. Their governance framing is particularly relevant for countries where oversight is split across multiple agencies and where compliance data are not regularly shared. Marks *et al.* (2018) reached similar conclusions in their review of legislation, standards, and monitoring documents, noting that strong written frameworks do not guarantee effective implementation unless institutions are resourced and procedures are executable. The governance literature also stresses that enforcement should be proportionate and risk based. Karapanou & Makhmudov (2024) argue that effective systems require defined inspection points along the fortification chain, information sharing across agencies, and accredited laboratory capacity, rather than fragmented one off inspections. This is especially relevant where ministries of health, standards agencies, food regulators, revenue authorities, and local governments all touch the same value chain.

Additional insights come from van den Wijngaart *et al*. (2013), who described regulatory monitoring systems in selected ASEAN countries, and from Yusufali *et al*. (2012), who reported post implementation survey findings from South Africa. These studies underscore that compliance measurement should occur at multiple points in the chain, but enforcement must still be anchored in legally defensible and operationally feasible processes. Laboratory tests can confirm nutrient levels; however, inspector checklists, production records, and premix reconciliation often provide the fastest and most affordable compliance signals. In practical terms, three monitoring principles emerge from the literature. First, monitoring should be risk based, with greater attention to high volume firms and higher risk vehicles. Second, routine record-based verification should complement product sampling. Third, enforcement should be proportionate but credible, so that repeated non-compliance has visible consequences. Without these features, monitoring systems often generate data without changing behavior.

UGANDA'S FORTIFICATION PROGRAMME IN LIGHT OF THE GLOBAL EVIDENCE

Uganda has an established legal and institutional base for food fortification, but the literature suggests that this foundation has not yet translated into uniformly strong industry compliance. Mandatory fortification is anchored in the Food and Drugs (Food Fortification) (Amendment) Regulations, 2011 (MOH, 2011), while subsequent policy instruments such as the Uganda Industrial Food Fortification Strategy 2017–2022 and the Fouth National Development Plan (2025/26 - 2029/30) positioned fortification within broader national nutrition and development priorities (MOH, 2017; NPA, 2025). Uganda's earlier experience was strengthened by salt iodization and by efforts to use food intake data to identify appropriate fortification vehicles, an approach that provided an important technical rationale for programme design (Kyamuhangire *et al*., 2013). However, the Ugandan evidence also shows that legal adoption and programme architecture do not by themselves ensure consistent performance. The Fortification Assessment Coverage Tool survey found that adequately fortified products were much more common for salt and edible oil than for maize flour, indicating important variation in compliance across food vehicles (GAIN, 2017). This unevenness mirrors the broader international literature, where more centralized industries tend to achieve better compliance than fragmented milling systems. In Uganda, the maize sector appears to be the clearest pressure point. The State of Maize Flour Fortification in Uganda highlighted structural difficulties in extending effective fortification across the maize market, especially where production is dispersed and routine quality assurance is weak (SPRING, 2018).

More recent implementation evidence confirms that these problems have persisted. A rapid assessment conducted during the COVID-19 period found that 11 of 17 certified maize mills were non-compliant with fortification standards, underscoring the limits of certification in the absence of sustained monitoring and corrective action (MOH & FFI, 2021). Regulatory and institutional mapping also indicates that Uganda's monitoring system involves multiple actors, including UNBS, MOH, URA, NDA, and other stakeholders, but that fragmented mandates, weak data flows, and inconsistent follow-through can reduce overall effectiveness (USAID, 2023). These governance constraints are compounded by economics. Vosti *et al*. (2024) showed that for micro- and small-scale maize millers, the costs of premix, equipment, maintenance, staff time, and public oversight can make fortification disproportionately burdensome. In Uganda, therefore, the core lesson from the global evidence is clear: the challenge is no longer whether fortification is legally mandated, but whether regulation, monitoring, incentives, and support systems are strong enough to make sustained compliance technically and commercially feasible.

STRATEGIC IMPLICATIONS AND LESSONS FOR UGANDA

The literature points to several interrelated strategic implications for Uganda's fortification programme, while also offering broader lessons for programme improvement in similar settings. Overall, the evidence suggests that compliance should be understood not as an isolated industry behavior, but as the outcome of a functioning system in which policy commitment, technical standards, market feasibility, industry capacity, monitoring arrangements, financing, enforcement, and consumer access operate in alignment. This systems perspective helps explain why some fortification programmes appear strong in legal or institutional terms, yet continue to perform weakly in practice.

A central implication for Uganda is the need to move from a primarily legalistic understanding of fortification toward a compliance and adequacy model. Programme success should not be judged only by the existence of standards, regulations, or the number of firms formally covered by law. Rather, it should be judged by whether adequately fortified foods are consistently produced, reach markets, and are actually consumed by households, especially vulnerable targeted groups. In this respect, the findings of Neufeld *et al.* (2017), Rohner *et al.* (2023), and (Kyamuhangire *et al*. (2013) underscore that legal mandates do not automatically translate into effective household coverage. This means Uganda should place greater emphasis on adequacy -focused indicators and clearer reporting on the actual performance of each fortified food vehicle and the nutrients within them. The Uganda Bureau of statistics (UBOS) and the Ministry of Health (MOH) can sufficiently capture these indicators in the Uganda national household survey and Uganda demographic Health survey respectively.

The review also suggests that programme design must remain grounded in the practical suitability of food vehicles and market structures. Evidence from Fiedler *et al.* (2014) and Neufeld *et al.* (2017) cautions against assuming that every staple food is equally appropriate for large-scale industrial fortification. A food may be widely consumed but still offer limited fortification potential if much of it is produced outside formal industrial systems. For Uganda, this implies the need for periodic review of whether priority vehicles, processor structures, and consumption pathways remain aligned. It also highlights the importance of differentiating regulatory strategies according to the structure of each value chain. The global evidence does not support applying identical oversight models to highly centralized wheat flour or edible oil industries and to fragmented maize milling systems. Large firms can be subjected to routine and stringent verification, while smaller and more dispersed processors may require phased compliance arrangements, shared services, pooled access to premix, targeted technical assistance, or selective geographic prioritization. Without such differentiation, regulation risks being formally strict but operationally weak.

A further lesson from the literature is that monitoring innovation matters, especially where resources are constrained. Studies consistently favour practical, repeatable, and lower-cost monitoring systems over highly sophisticated approaches that are difficult to sustain. The Jordan experience, for example, demonstrates that premix stocks, production volumes, and routine mill records can provide powerful and timely indicators of compliance (Wirth *et al.*, 2012). Likewise, Luthringer *et al.* (2015) emphasize the value of monitoring models that can be institutionalized and maintained. For Uganda, particularly in wheat flour and edible oil, stronger routine reconciliation of premix use, production volumes, and factory records could significantly improve oversight at relatively low cost. Such production-based monitoring should not replace laboratory analysis, but rather be linked to targeted confirmatory testing and risk-based inspections.

The literature further shows that regulatory coordination is critical to programme performance. Karapanou *et al.* (2024) and Marks *et al.* (2018) make clear that role-ambiguity, duplication, and weak communication among regulatory institutions can undermine compliance even where standards are well established. Uganda would therefore benefit from stronger operational coordination among standards agencies (UNBS), health authorities (MOH and NDA), customs (URA), and industry support institutions (MTIC). This includes greater harmonization of reporting tools, timely sharing of inspection and testing results, and more consistent enforcement decisions. Better coordination would strengthen accountability while also reducing uncertainty for millers.

Another important lesson is that compliance is shaped by incentives as well as regulations. If compliant firms bear the costs of fortification while non-compliant firms face limited risk or consequence, compliance will predictably weaken over time. Uganda should therefore consider stronger visibility and recognition for compliant firms, more predictable sanctions for repeated non-compliance, and communication strategies that build public and market demand for fortified products. Durotoye *et al.* (2023) suggest that performance-based approaches and self-regulatory mechanisms can complement formal regulation, but only where the broader system of public enforcement remains credible and effective.

The review also highlights that small-scale processor compliance cannot be achieved by regulation alone. Evidence from Lema *et al.* (2024) and Vosti *et al.* (2024) suggests that weak compliance among smaller operators often reflects structural barriers such as limited capital, inadequate equipment, irregular access to premix, and weak technical capacity, rather than mere unwillingness to comply. This does not remove the need for enforcement, but it does suggest that governments need hybrid implementation strategies that combine regulation with targeted support and realistic sequencing. In Uganda, such an approach may be particularly relevant for fragmented milling segments where full immediate compliance may be difficult to achieve without complementary investments and technical assistance. A related strategic lesson is that compliance data should be used for learning and improvement, not only as a punitive measure. Monitoring systems become more effective when the information they generate is routinely analyzed to identify operational bottlenecks, guide technical support, refine enforcement priorities, and inform regulatory adjustment where necessary.

Recent African evidence reinforces why compliance must remain central to programme impact. Coomson *et al.* (2025) show that poor coverage, inadequate fortificant levels, and the use of non-recommended fortificants continue to limit nutritional gains among women of reproductive age in Africa. Tang *et al.* (2025) similarly estimate that under full compliance in Ethiopia, fortifiable wheat flour and edible oil could substantially reduce the risk of inadequate micronutrient intake, although important gaps would still remain among poorer and more rural populations. These findings suggest that compliance is necessary for impact, but not sufficient on its own. Vehicle choice, market reach, and complementary nutrition interventions remain important, especially where vulnerable populations rely heavily on non-industrially processed staples. Therefore, the evidence indicates that Uganda's fortification programme does not necessarily require major redesign. Rather, it requires more disciplined implementation, focused on adequacy, differentiated by food vehicle and processor scale, supported by practical monitoring systems, strengthened through inter-institutional coordination, and aligned with the economic realities of the sector. Above all, the literature makes clear that the final measure of programme success should not be the existence of laws, standards, or inspections alone, but whether adequately fortified foods actually reach at risk populations and contribute meaningfully to narrowing micronutrient gaps.

Conclusion and recommendations

This review demonstrates that large scale food fortification remains a critical public health strategy for reducing micronutrient deficiencies, but its effectiveness depends less on the existence of legislation than on the extent to which industries consistently fortify foods to standard. Across countries, the evidence shows a persistent implementation gap between programme adoption and programme performance. Experiences from Senegal, Tanzania, Nigeria, South Africa, Cameroon, Bangladesh, Chile, Peru, Colombia, and Uganda indicate that a substantial proportion of foods reaching households are either unfortified or inadequately fortified despite the presence of mandatory legislation and technical standards. This reinforces the conclusion that legal coverage alone is a weak proxy for nutritional impact. The review further shows that compliance outcomes are strongly shaped by food vehicle characteristics, market structure, and the practicality of regulatory oversight. Wheat flour and edible oil generally perform better in more centralized systems, as reflected in Jordan, Indonesia, and Costa Rica, where routine monitoring, clearer oversight arrangements, and stronger production systems supported better compliance. By contrast, maize flour fortification remains more difficult in fragmented markets such as Tanzania, Kenya, Uganda, Malawi, and Mozambique, where small processor dominance, higher relative compliance costs, weak technical capacity, and limited monitoring constrain programme effectiveness. These cross-country patterns suggest that compliance is not simply a regulatory issue, but also a function of industrial organization, technical feasibility, and the economics of fortification. For Uganda, several practical recommendations emerge. First, the programme should move from a largely legalistic and coverage-oriented approach to a compliance and adequacy model in which success is judged by whether foods are adequately fortified at production, market, and household levels. Second, routine production-based monitoring should be strengthened through premix reconciliation, feeder calibration checks, production record review, and targeted confirmatory laboratory testing. Third, Uganda should adopt a differentiated compliance strategy by vehicle and processor scale. Large wheat flour and edible oil processors can be subjected to stricter routine verification, whereas maize millers, especially smaller operators, may require phased compliance pathways, shared technical services, pooled premix procurement, and targeted capacity support. Fourth, stronger coordination is needed among UNBS, MOH, NDA, URA, MTIC, and local governments to improve role clarity, data sharing, and enforcement consistency. This can be done by strengthening the national working group on food fortification. Fifth, the economics of compliance should be addressed more directly, especially for small and medium scale millers, through measures that reduce the cost burden of fortification and limit the competitive advantage of non-compliant firms. Evidence from Nigeria and Bangladesh suggests that performance measurement, traceability, and recognition of compliant firms can complement formal regulation, while lessons from India, Peru, Cote d'Ivoire, and Colombia show that national programmes should also monitor geographic, market, and household level inequities in access to adequately fortified foods. In conclusion, the international evidence is consistent in showing that fortification programmes perform best when legal mandates are supported by technically realistic standards, credible monitoring, sustained institutional coordination, and market conditions that make compliance feasible for industry. Uganda therefore does not require a fundamentally new fortification agenda; rather, it requires a more disciplined implementation architecture that closes the gap between regulation and practice. The long-term success of Uganda's fortification programme will depend on its ability to shift from formal policy commitment to reliable delivery of adequately fortified foods.

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