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Review Article

Leveraging orange-fleshed sweetpotato to advance childhood nutrition in Sub-Saharan Africa

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Highlights/Key Messages

- Orange-fleshed sweetpotato complementary food is an excellent source of vitamin A
- Sweetpotato-based complementary food has low phytate
- Sweetpotato-based food matrix is less prone to aflatoxin contamination
- Sweetpotato forms low-viscosity porridge, limiting energy and nutrient thinning

Abstract
Childhood undernutrition, a public health challenge in sub-Saharan Africa, contributes to stunted growth, weakened immune systems, and increased child mortality. Among micronutrient deficiencies, vitamin A deficiency is the most prevalent, affecting nearly half of preschool-aged children. The orange-fleshed sweetpotato (OFSP), a biofortified crop rich in β-carotene, a provitamin A, is a potential sustainable food-based approach to curb the prevalence of vitamin A deficiency. This narrative review synthesises evidence on vitamin A, phytic acid, aflatoxin content, and viscosity of OFSP-based complementary foods. A comprehensive literature search was conducted across Web of Science, Scopus, and Google Scholar to identify studies (n = 38) published between 1985 and 2025. All articles used for this review were peer-reviewed and included reports on provitamin A or vitamin A, phytate, viscosity, and aflatoxin levels in complementary foods made with OFSP. Studies reporting only agronomic data or published in languages other than English were excluded. The vitamin A levels of the OFSP-based complementary foods met the WHO-recommended adequate intake of 400 µg RE/100 g for infants. OFSP-based complementary foods had lower phytate levels, making their nutrients more readily available for absorption. In addition, they had a thinner consistency, appropriate for infants. OFSP is also a low-risk crop for aflatoxin contamination. Based on the review findings, OFSP-based complementary foods could be better alternatives for infant feeding. Incorporating OFSP into nutrition plans could be key to addressing malnutrition and vitamin A deficiency, helping infants and young children in the region achieve positive health outcomes.

Introduction

The consequences of poor nutrition are significant public health issues in sub-Saharan Africa (SSA), since children after the period of exclusive breastfeeding often experience nutritional inadequacies such as stunting, wasting, and micronutrient deficiencies. Approximately half (45%) of all child deaths worldwide are due to undernutrition, and the burden is even greater in SSA (UNICEF et al., 2023). In SSA, four out of ten child deaths are related to poor nutrition (Zachary et al., 2024). Among micronutrients, vitamin A deficiency (VAD) is a concern, as almost half of children under 5 years in the sub-region are affected (UNICEF, 2023). VAD leads to a weakened immune system, poor growth and vision, thus increasing the risk of death from other infectious conditions or chronic diseases. Poor dietary diversity is the main reason for these statistics (Twabi et al., 2021). However, increasing vitamin A intake has received little attention in programmes aimed at overcoming VAD (Mason et al., 2015).

Keywords: **aflatoxin, complementary food, infant nutrition, orange-fleshed sweetpotato, phytate, sub-Saharan Africa, vitamin A**

According to the WHO and UNICEF, infants should be exclusively breastfed for the first six months and then introduced to appropriate complementary foods (CFs) to complement breastmilk and meet the nutrient demands of their growing bodies (WHO & UNICEF, 2003). Hence, complementary feeding plays a crucial role in addressing malnutrition and supporting the health of preschoolers. CFs may be formulated as semi-solid or liquid recipes sourced from combinations of grains, nuts, legumes, and animal products, such as milk (WHO, 2023). Typically, CFs are prepared as porridges with minimal or no seasoning, with an appropriate viscosity and texture suitable for infant feeding. In addition, they should be easily digestible and affordable (White et al., 2017).

According to the CODEX standard, CFs in SSA mainly rely on locally available staples, including cereals (maize, millet, sorghum, and rice) and cassava (Codex Alimentarius Commission, 2006). These ingredients are commonly used to prepare gruels, which are culturally significant and widely consumed across the region. Popular examples include maize-only porridge called "Koko" in Ghana (Lartey et al., 1999), "Ogi" in Nigeria (Adebowale, 2024), and "Uji" in Kenya (Onyango et al., 2003). This gruel is the primary source of nutrition for children aged 6–23 months (or possibly earlier in places where exclusive breastfeeding is not practiced properly) in SSA, providing the necessary energy and essential nutrients for growth and development (Houngbédji et al., 2024). However, maize-only porridge is characteristically low in nutrient density and protein quality (Adebowale, 2024; Mensah & Tomkins, 2003). Some traditional practices include combining cereals with legumes, such as soybeans and groundnuts, to improve protein content (Lartey et al., 1999). While animal-source foods, such as eggs, milk, meat, and fish, are encouraged for incorporation into CFs, their utilisation remains low due to cost constraints, cultural beliefs, and limited availability (Child, 2011). Thus, the nutritional quality of CFs is essential for long-term health outcomes (Gong et al., 2016).

Childhood Malnutrition in SSA

Globally, stunting has steadily declined since 2000. While 33% of the world's children under 5 years of age were stunted in 2000, this figure dropped to 22.3% by 2022. The number of countries with "very high" stunting prevalence declined from 46 to 28 between 2012 and 2022 (Figures 1a and 1b). However, this progress has not been equal across all regions; for example, the African subregion has experienced only a slight decline from 34.4% to 30%. According to UNICEF et al. (2023), most malnourished children live in Africa (43%) and Asia (52%). Although stunting prevalence may decline, wasting persists at alarming rates, dropping only slightly from 8.7% to 6.8% within the same period.

A meta-analysis of demographic surveys between 2006 and 2016 concluded that stunting, wasting, and being underweight (malnutrition indicators) were highest in East and West Africa, with Burundi, Chad, Malawi, and Niger having particularly high prevalence rates (Akombi et al., 2017). The factors contributing to child malnutrition have been cited as including, but not limited to, poverty, food insecurity, infectious diseases, lack of education (particularly among women), poor maternal nutrition, inadequate breastfeeding, and poor complementary feeding practices (Bain et al., 2013). Analysis of recent data from 19 SSA countries revealed that inappropriate complementary feeding practices, such as poor nutritional quality of formulated complementary foods, significantly contributed to malnutrition in 6–23-month-old children (Mekonen et al., 2024). Therefore, all approaches to reduce malnutrition must be integrated to reduce child mortality. In addition to anthropometric indices, micronutrient deficiencies, such as VAD, remain a public health concern.

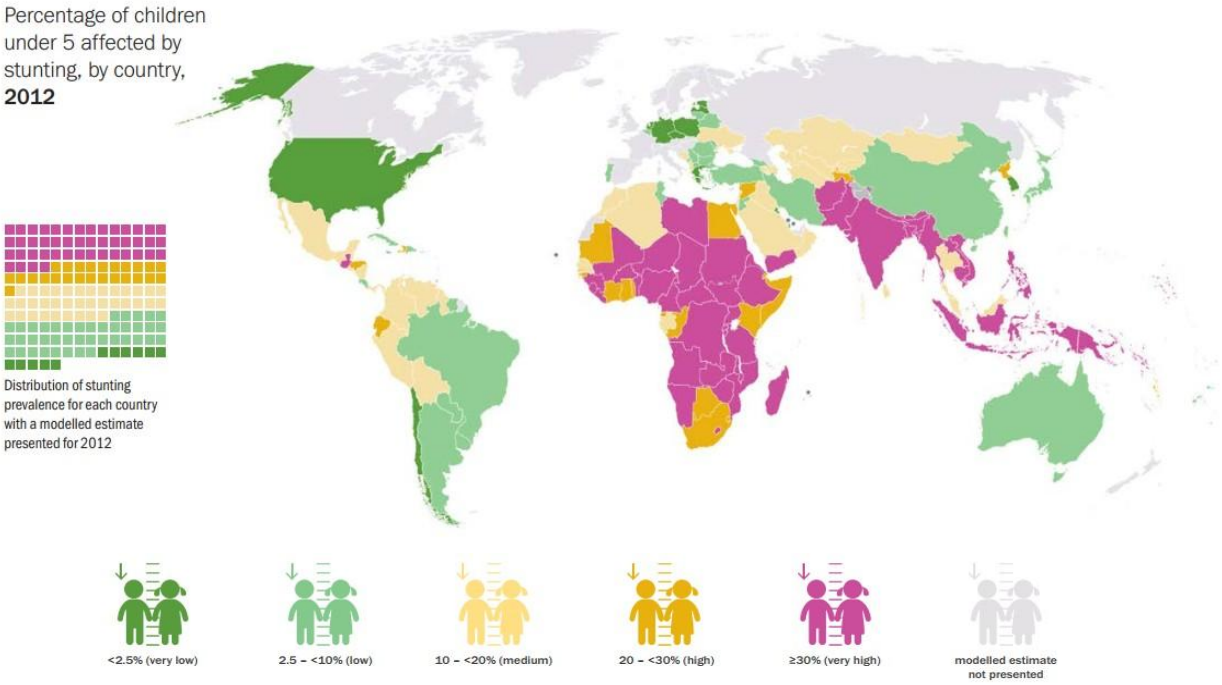

Figure 1a. Percentage of children under five affected by stunting, by country in 2012. Adopted from UNICEF et al. (2023)

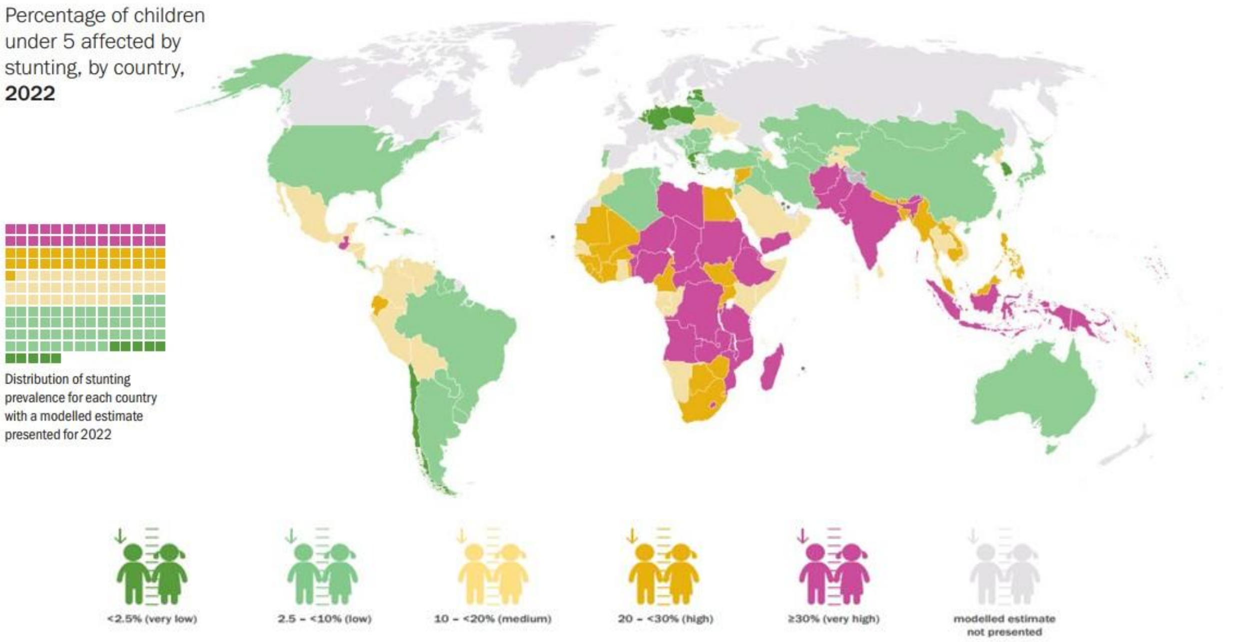

Figure 1b. Percentage of children under five affected by stunting, by country in 2022. Adopted from UNICEF et al. (2023).

Several efforts have been made to identify alternatives to traditional CFs across SSA due to the inadequate vitamin A content of cereals and cereal–legume blends. Orange-fleshed sweetpotato (OFSP) has emerged as a promising food ingredient instead of commonly used cereals in CF formulations. Previous researchers have focused on fortifying traditional CFs with OFSP to enhance their provitamin A carotenoid content (Amagloh & Coad, 2014; Bonsi et al., 2014; Laryea et al., 2018; Mukutu et al., 2019), while maintaining desirable sensory and functional properties (Ashun et al., 2019; Haque et al., 2013; Pillay et al., 2018). All these studies focused on blending OFSP and legumes, such as soybeans, cowpeas, and Bambara beans, alone or in combination with cereals. Unlike the traditional white-fleshed sweetpotato, OFSP is rich in β-carotene, a provitamin A (Bouis et al., 2013). Moreover, it is well-suited to the agroecological conditions of SSA, being drought-tolerant, early-maturing, and high-yielding, even in marginal soils (Nedunchezhiyan & Ray, 2010). Beyond its rich provitamin A, OFSP is a valuable source of dietary fibre and energy-rich carbohydrates, supporting healthy growth and development. Its natural sweetness also enhances palatability, thus making it an ideal base for complementary feeding (Amagloh & Coad, 2014). Therefore, OFSP would promote food and nutrition security and economic sustainability, particularly in regions with a high prevalence of VAD.

This narrative review presents a comprehensive analysis of the existing literature on how OFSP can enhance children's diets in SSA. It examines the vitamin A and phytic acid content, aflatoxin levels, safety, and viscosity properties of CFs prepared with OFSP in many SSA countries. Issues related to OFSP in CFs and their impact on nutrition have also been studied. By collecting and analysing scientific data, this paper proposes how OFSP can effectively address childhood malnutrition in the sub-region. With its high provitamin A content, lower antinutrient levels, and reduced vulnerability to mycotoxin contamination, OFSP-based CFs offer a nutritionally superior and safer alternative to conventional cereal–legume blends, which are primarily used across Africa. In addition to summarising the current state of knowledge on OFSP-based CFs, the review also suggests future directions and how these could influence policies.

Methods

A literature search was conducted using Scopus, Web of Science, and Google Scholar to identify relevant studies on the nutritional benefits of OFSP-based CFs. The search was restricted to articles published within the last 40 years, from 1985 to 2025. This 40-year search window was adopted to ensure that the review comprehensively covered relevant research on OFSP-based CFs. This period captures the early stages of OFSP promotion as a biofortification strategy and its integration into diverse food formulations, while maintaining relevance to current research on CFs and product development. The following keywords and Boolean operators were used: TI= ("sweet potato-based complementary food" OR "sweet potato-based weaning food" OR "sweet potato-based infant food" OR "orange-fleshed sweet potato-based complementary food" OR "orange-fleshed sweet potato-based weaning food" OR "orange-fleshed sweet potato-based infant food" AND "vitamin A" OR "beta-carotene" OR "β-carotene" OR "phytic acid content" OR "aflatoxin concentration" OR "porridge viscosity").

The inclusion criteria were as follows: The review included studies published in peer-reviewed journals that focused on vitamin A, phytic acid content, porridge viscosity, and aflatoxin concentration of OFSP-based complementary foods, specifically those conducted in SSA.

The exclusion criteria were as follows: studies focused on general sweet potato varieties without a specific emphasis on OFSP, addressed only agronomic aspects without considering nutritional impacts, or were published in languages other than English.

Study Selection Process: Two independent reviewers screened the titles and abstracts and assessed the full texts of eligible studies. Discrepancies were resolved through discussion or consultation with a third reviewer. Studies were managed using EndNote reference software. A Preferred Reporting Items for Systematic Reviews (PRISMA) flow diagram illustrates the selection process (Figure 2). The authors acknowledge the limitations of the methodology in this narrative review, including reliance on secondary data and wide variability across the included studies.

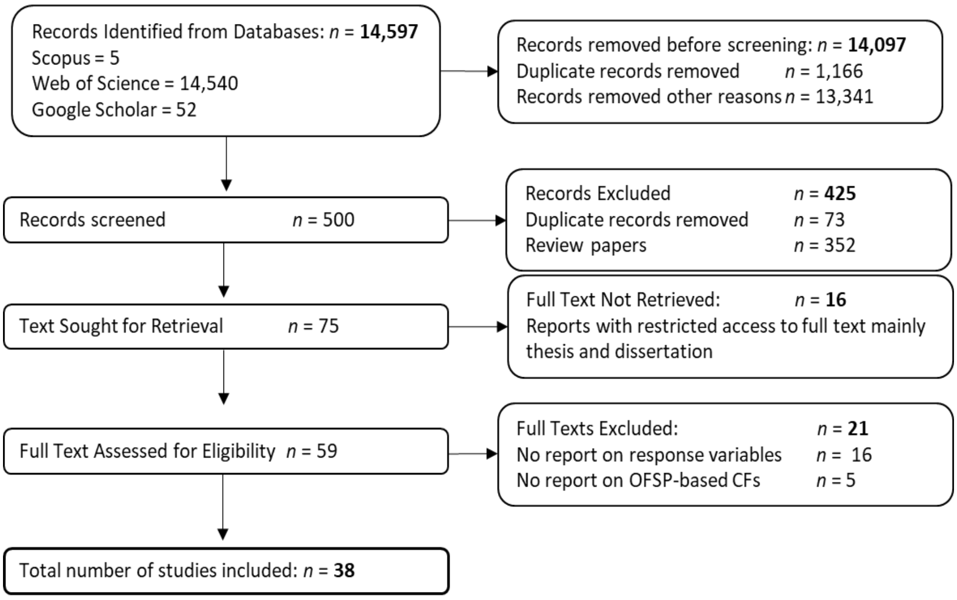

Figure 2. Database search results according to the PRISMA statement. Adopted from Page et al. (2022).

We analysed the relationships among four (4) response variables (vitamin A, viscosity, phytate, and aflatoxins) across 38 selected studies.

Results

Network visualisation (Figure 3) shows the depth of research focus and inter-study linkages across the response variables. Vitamin A was the most extensively studied, with strong interconnections among studies, whereas mycotoxins (aflatoxins) are notably underrepresented, with only 2.6% of reviewed studies addressing them in OFSP-based CFs across SSA.

This is expected because the focus of OFSP in complementary food formulation has been to address VAD (Mwanga & Ssemakula, 2011). In contrast, phytate and viscosity have fewer associations with vitamin A, suggesting a more specialised research focus or a lack of studies examining their relationship with vitamin A. Several studies, including Olaniran et al. (2024) and Amagloh & Coad (2014), addressed multiple response variables, highlighting their broader research scope and multidisciplinary relevance.

Beta-carotene and Vitamin A

Traditionally, cereals and legumes used in CF formulations are either devoid of provitamin A or rarely fortified with a vitamin or mineral premix at the household level (Gibson et al., 2010), which may contribute to the high prevalence of VAD among infants in low-income regions of SSA. In most African countries, prototypes of Weanimix [a composite blend of maize (75%), soybean (15%), and groundnut (peanut) (10%)] are considered adequate household-level CFs because they have relatively higher energy and protein densities than CFs made from maize, millet, or sorghum alone (Lartey et al., 1999). However, cereal–legume blends alone are low in many micronutrients, particularly in vitamin A [8.3 mg retinol equivalents (RE)/100 kcal] (Lartey et al., 1999) compared to 60 RE/100 kcal, which is the lowest vitamin A level specified in the Codex Standard (CS) (CODEX STAN 074–1981) for foods for older infants and young children (Codex Alimentarius Commission, 2006).

Antinutrient (Phytic acid)

The high phytic acid content of staples, particularly cereals and legumes, is a major nutritional concern (Bektaş and Ertop, 2021). Phytic acid is an antinutrient that binds to essential minerals, such as iron, zinc, and calcium, reducing their bioavailability and contributing to widespread micronutrient deficiencies in children (Hurrell & Egli, 2010; Sandberg, 2002). Hurrell et al. (2003) indicated that the phytate content in processed cereal- and legume-based products ranges from 68 to 1536 mg/100 g, with phytate-to-iron molar ratios often exceeding the recommended level of <1.0, thereby impairing iron absorption.

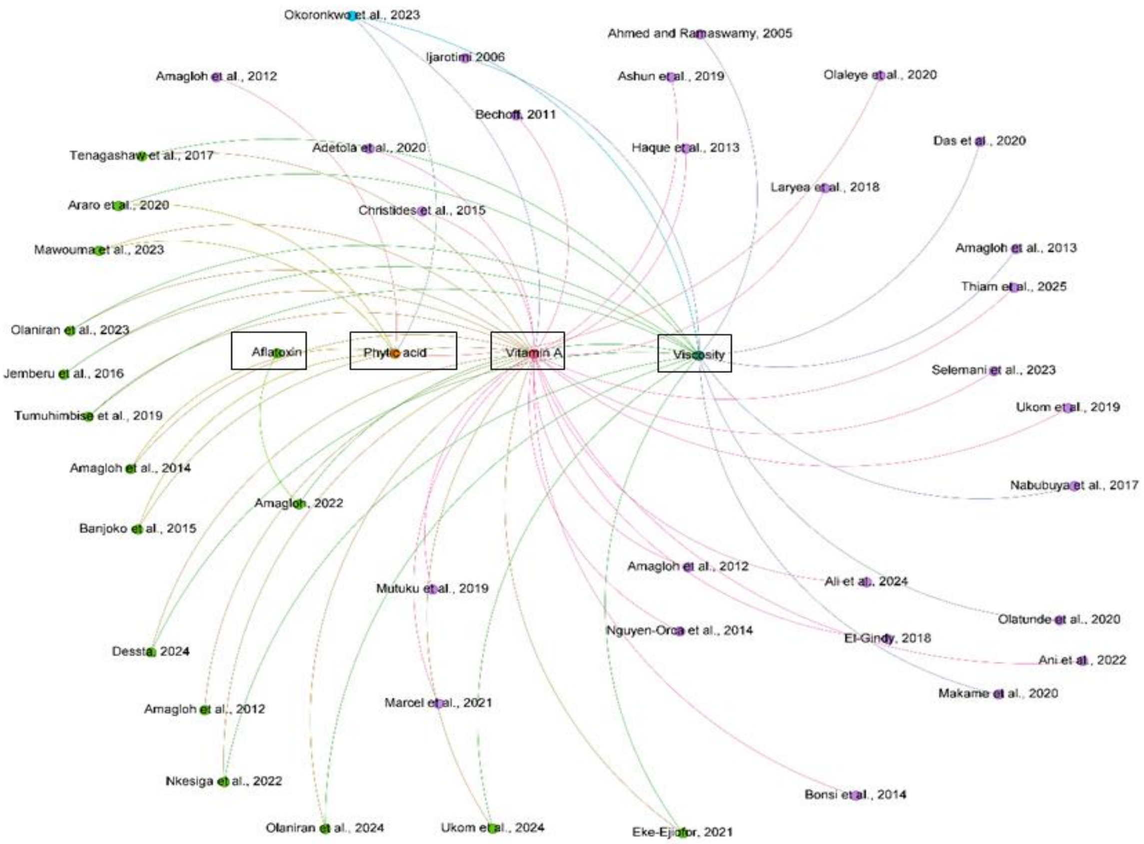

Figure 3. Network of studies reporting aflatoxins, phytic acid, vitamin A, and viscosity in OFSP-based CFs.

Various processing methods have been explored to mitigate the inhibitory effects of phytic acid. The complete enzymatic degradation of phytic acid with exogenous phytase has been shown to significantly enhance iron absorption by up to 10.55% (Hurrell et al., 2003). In general, household processes, such as fermentation, have been reported to activate endogenous phytases, substantially reducing phytic acid content and improving mineral bioavailability (Gupta et al., 2015). However, the abundance of endogenous phytase varies across cereal types. Notably, wheat contains high intrinsic phytase activity in the aleurone layer. Acidic conditions created during fermentation, along with other factors, such as optimal temperature and moisture, increase phytase activity and effectively degrade phytate (Leenhardt et al., 2005). In contrast, maize, millet, and sorghum contain low phytase activity. Thus, traditional fermentation alone is insufficient to degrade phytic acid in these cereals unless exogenous phytase is added or specific microbial strains capable of producing phytase are used during fermentation (Li et al., 2024).

In addition to reducing phytic acid levels through processing, another strategy to mitigate the inhibitory effect of phytate is to add exogenous ascorbic acid (He et al., 2018), as in some industrial products. Ascorbic acid is included in the micronutrient mix used for product fortification. Ascorbic acid does not directly reduce phytate; however, it improves mineral absorption, especially that of Fe, by reducing Fe+3 to Fe+2 (with a low affinity for phytic acid) and/or binding with Fe in gastric juice, thus preventing its reaction with phytic acid (Hurrell, 2004).

While these approaches to lowering phytic acid levels are valuable, a more effective strategy is to formulate CFs using ingredients that naturally contain little to no phytic acid. The amount of these compounds in starchy roots, such as OFSP, is lower than that in other food crops (Li et al., 2024; Sandberg, 2002). If raw materials with relatively low phytate content, such as OFSP, are used, less effort is required to hydrolyse phytic acid; hence, more Fe, Zn, and Ca become bioavailable. These formulations ensure better nutrition for infants and young children (IYC) in many parts of the world where eating a wide variety of foods is not realistic. Moreover, OFSP contains ample ascorbic acid, which can reduce the inhibitory effect of phytic acid. Grace et al. (2014) reported an ascorbic acid content of 870 µg/g (db) for OFSP.

Mycotoxins

Aflatoxins, a type of mycotoxin, are naturally occurring secondary metabolites produced by *Aspergillus* species, notably *Aspergillus flavus* and *Aspergillus parasiticus* (Yu et al., 2002). Maize, groundnuts, millet, and sorghum, which are key CF ingredients in SSA, are more susceptible to mycotoxin contamination resulting from poor postharvest management practices (Opoku et al., 2018). Additionally, high temperatures and humidity in SSA support the growth of *Aspergillus niger* or *flavus* (Wild & Gong, 2010). A survey in SSA found that dietary aflatoxin exposure from maize and groundnuts is a public health concern (Falade et al., 2022). Ingestion of aflatoxins has been associated with stunted growth in children, weaker immune systems, and an increased risk of liver cancer (Gong et al., 2016).

The risk of exposure to aflatoxins is greater in infants and young children because their bodies are less efficient at eliminating these toxins (Sherif et al., 2009). Prolonged exposure to aflatoxins can result in slowed growth and small stature (Gong et al., 2004; Rasheed et al., 2021), impaired immunity (Jiang et al., 2008), damaged livers, increased cancer risk (Claeys et al., 2020), and neurodevelopmental effects (Janik et al., 2020). Unfortunately, CFs across SSA have been reported to be contaminated with mycotoxins, pesticides, heavy metals, and microbial contaminants (Figure 4).

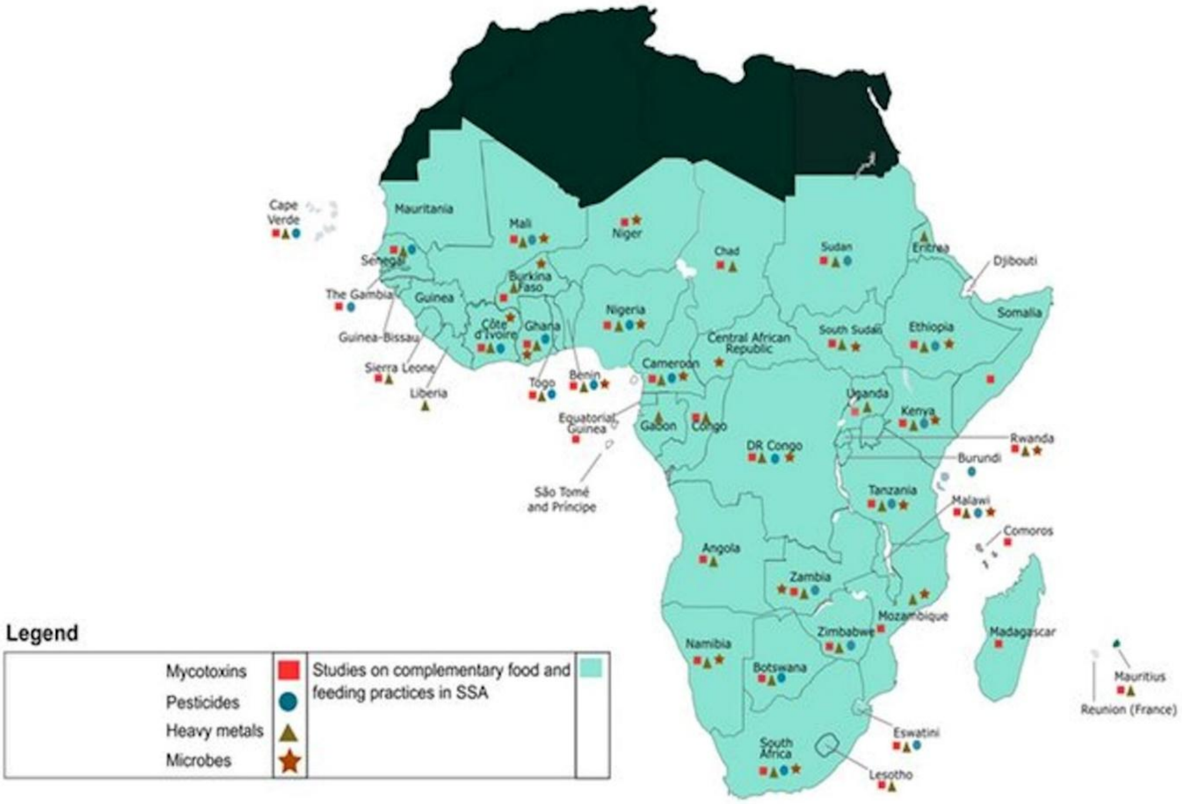

Figure 4. Distribution of microbial and chemical contaminants in CF blends across SSA from 2014 to 2023. Adopted from Ogunniran et al. (2024).

Several studies have assessed aflatoxin contamination in CFs, including a longitudinal study in Benin, West Africa, which identified a substantial link between aflatoxin exposure and growth impairment in children under five years (Gong et al., 2004). Kimanya et al. (2010) investigated aflatoxin exposure among Tanzanian infants through weaning foods, finding significant risks of chronic exposure. Amagloh (2022) found that 38% of cereal–legume CF blends (n = 23) sampled across markets in Ghana and Uganda had total aflatoxin levels exceeding the acceptable limit of 10 ppb. According to Ojuri et al. (2019), mycotoxins were detected in almost all household-formulated CF samples, whereas contamination was detected in 42% of industrially processed foods in Nigeria. Furthermore, several studies have reported aflatoxin contamination in CFs across SSA, including Ghana (Opoku et al., 2018), Zambia (Alamu et al., 2018), Ethiopia (Eshete et al., 2020), Rwanda (Grosshagauer et al., 2020), Tanzania (Mollay et al., 2022), Malawi (Grosshagauer et al., 2020), Benin (Gong et al., 2004), Uganda (Asiki et al., 2014), and the Gambia (Turner et al., 2007). Ensuring the safety of cereal–legume composite blends for infants and children by reducing mycotoxin contamination is crucial. All value chain actors should adopt good management practices to minimise the growth of mycotoxin-producing fungi, both pre- and postharvest. Moreover, using activated charcoal as a chemical method can trap mycotoxins and fungi that attack toxin-producing moulds, thereby lowering the number of toxins produced (Ahn et al., 2022). Additional measures, such as chemical detoxification and frequent testing of both inputs and outputs, help control mycotoxins (Liu et al., 2020). Utilising these multiple strategies can enhance food safety and nutrition in CFs.

Formulating CFs with food crops that are less susceptible to mycotoxin contamination is a cost-effective approach. Aflatoxins produced by some fungi (*Aspergillus* spp.) have a minimal effect on OFSP, unlike in crops such as maize and groundnuts (Temba et al., 2017). Because OFSP is less likely to contain aflatoxins, it is a safer option for use in CF, especially in areas such as SSA, where aflatoxins pose a significant threat to food safety. This strategy ensures the dietary availability of provitamin A and the safety of CF products (lower phytate levels and reduced risk of aflatoxin contamination), especially in rural households.

Apparent Viscosity

The apparent viscosity of CFs is an essential factor in infant feeding and nutrition, as it influences the consistency, ease of swallowing, and digestibility (Nabubuya et al., 2017). An appropriate apparent viscosity ensures that the food is neither too thick nor too thin, making it ideal for infants transitioning from liquid to solid foods and influencing nutrient availability and energy density (Makame et al., 2023). Porridges with an apparent viscosity between 1000 and 3000 cP (similar to the consistency of yoghurt) have been reported to have a suitable consistency for the first solid foods for babies (Makame et al., 2023). However, it is not easy to attain this ideal apparent viscosity with cereals unless they are malted, sprouted, toasted, or pre-hydrolysed enzymatically (Codex Alimentarius Commission, 1991; Griffith et al., 1998). The starch gelatinisation process disrupts the amylopectin/amylose crystallites within the crystalline lamellae, leading to structural breakdown and an increase in apparent viscosity (Ahmed & Ramaswamy, 2006). To make consumption easier, thick porridge is diluted with water, which significantly reduces its overall nutritional value by thinning its nutrients (Amagloh, 2022).

Several methods have been investigated to achieve optimal consistency and nutrient retention in non-commercial CFs. For instance, CF ingredients can be substituted (Abasiekong et al., 2023), fermentation can be employed (Moriconi et al., 2024), germination can be conducted (Forsido et al., 2020), and newly developed ingredients can be used. Efforts to substitute ingredients include sweetpotato (Amagloh, 2022; Ijarotimi & Ashipa, 2006; Nandutu & Howell, 2009; Olaniran et al., 2023); cassava (Chilungo et al., 2024); plantains (Opara et al., 2012); and combinations of these (Dessta & Terefe, 2024). Ayele et al. (2022) combined maize, red kidney beans, false banana (kocho), and pumpkin fruit to make CF with an acceptable apparent viscosity of 1225.3 cP. Another study showed that adding African breadfruit, soybean, and maize produced a gruel with an apparent viscosity greater than 5,770 cP, far higher than the recommended value (Abasiekong et al., 2023). Germination has been effectively used to obtain the appropriate consistency for sorghum porridge (Forsido et al., 2020). Porridges made from OFSP tend to be less viscous than those made from cereals, allowing nutrients to be maintained without the addition of extra water (Eke-Ejiofor et al., 2021). Although OFSP is nutritionally valuable, research on CF formulations using OFSP is limited to only a few regions in SSA.

OFSP-based Complementary Foods: A Solution to VAD among Infants in SSA

Infants in SSA continue to face VAD, contributing to illness, growth issues, and vision problems. Biofortified OFSP, rich in provitamin A carotenoids, offers a promising solution. The scientific literature outlines various CF formulations, showing that OFSP-based options consistently contain more vitamin A than standard cereals or market products. Studies across countries have confirmed that OFSP formulations, especially flours and extruded items, retain vitamin A most effectively. Notably, they deliver 5.3–6.2 times more vitamin A than Nestlé Cerelac and meet the WHO recommended daily intake of 400 µg for infants (Abuengmoh et al., 2024). In addition, Adetola et al. (2020) reported even higher values (2057–2064 µg RAE/100 g) in OFSP–soybean–carrot blends. Studies in Ghana (Amagloh & Coad, 2014) show that OFSP-based CFs also met the WHO reference daily intake (RDI), with values as high as 1112.70 µg RAE/100 g, about six (6) times higher than Cerelac. Other studies across the subregion, including Nigeria, Ghana, Ethiopia, and Uganda, have reported that OFSP-based CFs constantly exceed WHO vitamin A standards, with values ranging from 1989.80 to 6283.33 µg RAE/100 g, significantly outperforming cereal–legume blends (Ani et al., 2022; Ashun et al., 2019; Bonsi et al., 2014; Dessta & Terefe, 2024; Okoronkwo et al., 2023; Tumuhimbise et al., 2019).

Some formulations incorporating OFSP, despite showing increased vitamin A levels, did not meet the WHO (RDI) of 400 µg RAE/100 g. Notable among these studies are Haque et al. (2013) in Bangladesh, Jemberu et al. (2016) in Ethiopia, Laryea et al. (2018) in Ghana, Marcel et al. (2022) in Tanzania, Mawouma et al. (2023) in Cameroon and Mukutu et al. (2019) in Kenya.

Processing Methods and Vitamin A Retention

Vitamin A retention in CF formulations is strongly influenced by processing methods. Although OFSP is rich in provitamin A carotenoids, these nutrients are susceptible to degradation due to heat, light, and oxygen, as well as processing conditions (Bechoff et al., 2010). Techniques, such as drying, milling, extrusion, and cooking, can either improve or diminish the bioavailability of vitamin A precursors (Bechoff et al., 2011). Thus, selecting appropriate processing methods is essential for preserving β-carotene and maximising the nutritional value of OFSP-based foods.

Oven-toasting and roller-drying produced moderate vitamin A levels in ComFA made from cream-fleshed sweet potato with orange streaks, meeting infant recommended dietary allowance (RDA) (Amagloh, et al., 2012a), as shown in the Appendix, Table 1. In contrast, extrusion showed variable retention: at 70°C, vitamin A was highest in the control but lower in the formulations; at 90°C, degradation increased. A prior study has also reported nutrient losses under high-temperature, low-moisture extrusion (Nkesiga et al., 2022). These findings underscore the thermal sensitivity of provitamin A and suggest that lower-temperature methods are more suitable for preserving its content. Fermentation offers a promising alternative, enhancing the bioavailability and stability of vitamin A in OFSP-based CFs (Song et al., 2021).

Fermentation enhances vitamin A retention and bioavailability in OFSP-based complementary foods by breaking down anti-nutritional factors, such as phytates, and improving β-carotene absorption (Hotz & Gibson, 2007). It operates at mild temperatures (20–40°C), reducing thermal degradation compared to high-heat methods (Bechoff et al., 2010). Fermentation also extends shelf life by lowering pH and inhibiting spoilage, further protecting vitamin A (Adams, 2001). These advantages make it a valuable low-cost strategy for producing nutrient-rich foods for infants and young children, especially when OFSP varieties are extensively used.

Phytic Acid

Phytic acid levels vary widely across CF formulations and processing methods. Traditional cereal-based CFs, such as Weanimix, contain significantly more phytic acid, up to four times higher than OFSP-based variants, as shown in Appendix Table 2 (Amagloh et al., 2012b), potentially hindering mineral absorption. Commercial products, such as Cerelac, typically show lower levels due to industrial processing. OFSP-based CFs have a moderate phytic acid content, as reported previously by Amagloh and Coad (2014). However, without clear thresholds, their nutritional impact remains uncertain. To improve mineral bioavailability, techniques such as fermentation or enzymatic treatment are recommended to reduce phytic acid levels.

Studies in Nigeria and Cameroon have indicated that sweetpotato-based CFs, particularly when blended with legumes such as soybeans or fonio, tend to have lower phytic acid levels than traditional cereal-based products (Mawouma et al., 2023; Okoronkwo et al., 2023). For example, a 50% fonio/soybean–50% OFSP blend had a phytic acid level of 0.016 mg/100 g, close to that of Cerelac (0.006 mg/100 g; Table 2). Mashed sweetpotato alone showed moderate levels (35–47 mg/100 g), while OFSP-soybean blends consistently recorded low values (0.22–0.31 mg/100 g) (Uzo-Peters & Akinola, 2018). Overall, OFSP-based CFs offer a nutritional advantage by having a reduced phytic acid content compared to cereal–legume formulations.

Processing Method and Phytic Acid

Processing methods, such as extrusion, drum drying, and fermentation, significantly reduce phytic acid levels in CFs. A study conducted in Ethiopia showed that raw cereal–legume blends had higher phytic acid content (72.99–124.78 mg/100 g) than extruded or drum-dried products, with reductions of 10–20% observed (Araro et al., 2020) (Table 2). Higher extrusion temperatures (90°C) further lowered phytic acid levels (0.47–0.96 mg/100 g) than lower temperatures (1.10–1.79 mg/100 g) (Nkesiga et al., 2022). Unprocessed flour-based products contained higher antinutrient levels (7.49–10.79 mg/100 g), emphasising the importance of heat processing.

Extrusion and drum drying reduce phytic acid (IP_6) by hydrolysing it into lower inositol phosphates (IP_2 – IP_5). Although these derivatives are less potent than IP_6, they exhibit mineral-binding properties, which means that their presence can continue to inhibit nutrient absorption. If analytical assays measure only IP_6, they may underestimate the total antinutrient effect, as IP_2–IP_5 are not accounted for. This limitation is critical when evaluating the actual nutritional impact of processed CFs. A more comprehensive assay is necessary to accurately assess phytate's inhibitory effects and ensure proper mineral bioavailability in fortified or processed foods, as it detects all IP derivatives (Amagloh et al., 2012a). However, some prior work has suggested that thermal processing methods are ineffective in reducing the phytic acid content because of its relative heat stability (Sathe & Venkatachalam, 2001). Moreover, thermal processing methods denature the intrinsic phytase capable of dephytinisation (Sandberg et al., 1987). Fermentation is regarded as an efficient and cost-effective alternative to extrusion (Sathe & Venkatachalam, 2001) and fortification, particularly in resource-limited settings. Unlike extrusion and fortification, which are expensive and require specialised equipment and additives, fermentation uses simple techniques, native microorganisms, and minimal resources. It reduces phytic acid levels by up to 88% through enzymatic activity while preserving heat-sensitive nutrients, such as β-carotene (Sandberg, 2002). Lactic acid bacteria break down phytates, thereby improving the absorption of Fe, Zn, and Ca (Sharma et al., 2020). This makes fermentation a practical solution for enhancing the nutritional quality of CFs, especially in low-income regions where affordability and accessibility are critical.

Porridge Rheology and Apparent Viscosity

Study in Ghana (Amagloh, 2022) have explored different OFSP-based formulations. These included combinations of soy, yellow maize, peas, rice, and sorghum, with viscosities ranging from 1536 to 7272 cP. Most formulations, such as the OFSP–soy–yellow maize combinations, had viscosities that met infant consistency standards (ranging from 1536 to 2208 cP) (Appendix, Table 3). However, the OFSP-rice-soy combinations had viscosities ranging from 2999 to 3631 cP, whereas the OFSP-sorghum-soy combinations, 5568 to 7272 cP, exceeded the appropriate range and were considered unsuitable for infants. In Nigeria, various formulations were tested, including those containing OFSP with soybean, groundnut flour, and other grains. The formulations, which varied the proportion of OFSP, soy, and groundnut flour, produced viscosities ranging from 224.1 to 6159 cP, depending on the mixture (Eke-Ejiofor et al., 2021). Most of these formulations met the consistency requirements for infants, although higher concentrations of groundnut flour decreased viscosity.

Generally, while many OFSP-based formulations meet the required viscosity standards for infant feeding, others, particularly those with higher concentrations of certain ingredients or specific grains, exhibit excessive viscosity. This highlights the need to carefully select ingredient ratios to ensure appropriate consistency in CFs for infants.

Aflatoxin Contamination Risk in OFSP vs. Cereal-based Complementary Foods

Few studies have examined aflatoxin levels in OFSP-based CFs. The data presented by Amagloh (2022) offer a comparative analysis of aflatoxin concentrations in OFSP and cereal–legume-based CF products, highlighting potential differences in contamination levels influenced by ingredient composition (Appendix, Table 4).

None of the blends reported in this study met the Codex cut-off limit of 5 μg/kg of aflatoxin concentration for cereal-based foods for infants and young children (Codex Alimentarius, 2023). However, using the African median permissible limit of 10 μg/kg for processed foods (van Egmond et al., 2007), 90% of the OFSP-based foods examined in this study met the threshold, whereas almost 47% of the cereal–legume-based CFs had aflatoxin levels above the threshold.

OFSP-based samples included OFSP + soy + yellow maize, OFSP + maize + peas, OFSP + rice + soy, and OFSP + sorghum + soy. Across these samples, aflatoxin concentrations ranged from 5.14 to 10.72 µg/kg (Amagloh, 2022). The cereal-legume-based samples included a diverse range of formulations, such as millet + soy, maize + soy, rice + soy, and more complex blends, such as rice + millet + maize + wheat + oat + soy + bean + peanut. Aflatoxin concentrations in these samples varied widely, from 5.33 to 56.77 µg/kg (Amagloh, 2022), reflecting the diversity of ingredients and potential sources of contamination.

The OFSP-based CFs generally recorded lower aflatoxin contamination (7.82 µg/kg) than the cereal-legume-based CFs, which recorded nearly twice as much as the OFSP-based CFs (Amagloh, 2022) (Table 4). This difference could be ascribed to the ingredient profiles: OFSP-based formulations often incorporate raw materials, such as rice and sorghum, which are less susceptible to aflatoxin contamination, while cereal-legume blends frequently include maize and peanuts, both of which are well-documented to be highly susceptible to *Aspergillus* contamination (Williams et al., 2004). For this reason, improving how foods are stored, implementing a system for grading raw materials, drying them, and selecting less vulnerable nuts can decrease aflatoxin in CFs (Hell et al., 2008). Because young children who ingest aflatoxin may suffer from malnutrition and low immunity (Gong et al., 2004), more attention should be given to improving the safety of OFSP- and cereal-legume-based CFs.

Controlled fermentation can enhance the safety of contaminated food products containing aflatoxins through microbial degradation, binding, and mould inhibition. Lactic acid bacteria fermentation is mainly effective for processed items, such as purees and flours, reducing aflatoxin levels while extending shelf life and nutritional quality (Wafula et al., 2022). However, effectiveness varies depending on the microbial strains and metabolites (such as mycotoxins), as well as fermentation conditions. Therefore, fermentation can be combined with proper pre-harvest, curing, and storage practices to prevent recontamination.

Limitations of OFSP-based CFs

Within the limits of this review, it is evident that OFSP-based CFs offer a sustainable solution to ameliorating childhood VAD (but not iron deficiency) due to their high β-carotene content, suitable viscosity, lower phytic acid levels, and reduced risk of aflatoxins ingestion. Studies using Caco-2 cell models suggest that Fe absorption from OFSP-based formulations is suboptimal, requiring fortification or co-consumption with enhancers, such as vitamin C or animal-source foods, to improve bioavailability (Christides et al., 2015). Furthermore, there is emerging evidence that daily consumption of galacto-oligosaccharides markedly enhances Fe absorption by approximately 62% from a 5 mg dose of ferrous fumarate combined with sodium iron EDTA in Kenyan infants (Paganini et al., 2017). This also suggests that prebiotics, such as galacto-oligosaccharides, can potentially improve iron bioavailability in young children, especially when delivered through micronutrient powders, and could contribute to better management of iron deficiency anaemia in vulnerable populations.

Priority Research Gaps and Future Directions

This narrative review identifies OFSP-based CFs as a sustainable food-based approach to address VAD in infants and young children across vulnerable populations in the SSA region. However, some research gaps remain to be investigated further. These include, but are not limited to, the following:

- Randomised controlled trials of infants and young children using the proposed OFSP-based formulations, such as ComFA, would provide empirical evidence to improve infants' health in SSA. More research is required to evaluate the long-term health outcomes of sustained OFSP consumption.
- There is a paucity of information on aflatoxin contamination in OFSP-based CFs. Future studies should examine different OFSP-based CF formulations across diverse SSA contexts to confirm OFSP resistance to aflatoxin contamination and establish safety guidelines.
- Vitamin A retention may vary significantly depending on the processing method, such as extrusion, fermentation, or heat processing. Comparative studies are required to identify inexpensive processing methods with maximum β-carotene retention.
- Although adequate nutritional data are available, the use of OFSP as an ingredient in CFs at the household level may still be underutilised. Future socioeconomic research should investigate the adoption levels of OFSP-based CFs by considering factors such as awareness, affordability, supply chain constraints, and cultural preferences.

Policy Implications and Scale-up Pathways

Based on the findings of this review, the following policy actions are proposed to maximise the potential of OFSP-based CFs in addressing childhood undernutrition and VAD in SSA, paving the way for a paradigm shift in infant and young child nutrition strategies across the region:

1. Promotion and adoption of OFSP-based CFs: Governments, non-governmental organisations, and public health agencies in SSA should prioritise the integration of OFSP into national nutrition strategies and complementary feeding programmes. Public health, education, and awareness campaigns targeting caregivers, health workers, and Community-based Health Planning and Services (CHPS) compounds, and other health facilities across Ghana, could promote OFSP-based CFs. The high provitamin A content of OFSP-based CFs makes them a sustainable and cost-effective intervention for combating VAD, which affects nearly half of preschool-aged children in the sub-region.
2. Government food safety regulations, enforced by authorities such as the Food and Drugs Authority and Ghana Standards Authority, should mandate the use of OFSP and other aflatoxin-low-risk ingredients in

CFs. The government could also fund schemes that encourage agro-processors to build infrastructure and purchase equipment, such as solar driers, to improve post-harvest handling and storage of agro-produce and minimise mycotoxin exposure.

3. While OFSP-based CFs are effective against VAD, they are insufficient to address iron deficiency without additional interventions (e.g., fortification, co-consumption with vitamin C or animal-source foods). Thus, governments and funding agencies should support ongoing research into the fortification of CFs and other OFSP-based food products with iron and zinc, or by combining OFSP with enhancers of mineral absorption.
4. To encourage cultivation and ensure that vulnerable populations have access to OFSP and related nutrition interventions, governments should implement agricultural policies that incentivise the cultivation and distribution of OFSP varieties, provide extension services, and facilitate access to planting materials for smallholder farmers. This would support nutrition and generate income, thereby improving rural livelihoods.
5. Governments should allocate resources to capacity building (such as training health workers) and the use of mass media to promote the adoption of OFSP-based CFs and optimal feeding practices. For monitoring and evaluation purposes, resources should also be allocated to track OFSP adoption, dietary intake, and health outcomes, particularly in regions with a high VAD and food safety concerns.

Effective scaling up of all these policies would require effective collaboration among the agriculture, health, research, and education sectors. For example, agricultural extension services can promote OFSP cultivation, whereas health programmes can integrate OFSP into nutrition counselling and feeding guidelines.

Conclusions

The benefits of using OFSP as a main ingredient in CFs on the health of IYC in SSA have been highlighted. The data reviewed showed that CFs made with OFSP are rich in provitamin A, making them an effective solution to help combat the public health issue of VAD, which affects nearly half of preschool-aged children in the area. In addition to being a rich source of β-carotene, a vitamin A precursor, OFSP is relatively low in phytic acid, which impairs iron, zinc, and calcium absorption, and has a lower risk of aflatoxin contamination (a risk factor for malnutrition). When combined with the appropriate ingredient (for example, soybean), OFSP forms a porridge with proper viscosity without the need to dilute it with excessive quantities of water. This reduces the dilution of nutrients and energy in the porridge served to infants. However, further research is needed to address iron deficiency in SSA, as an earlier study using an in vitro digestion/Caco-2 cell model without iron fortification or enhancers indicated suboptimal iron bioavailability. Despite these positive aspects, there are still difficulties in encouraging the use of OFSP-based CFs in SSA. Increased adoption requires specific steps, such as promoting OFSP among smallholder farmers' communities, improving its processing, and disseminating information through awareness campaigns.

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Conceptualisation: FCA, RAA, FKA; Methodology: RAA, FKA; Writing – original draft: FCA, RAA; Writing – review: FKA; Writing – editing: FCA, RAA, FKA. All authors have read and approved the final version of the paper and its submission and have given consent for publication.

Declaration of Generative AI and AI-Assisted Technologies in Scientific Writing

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The authors declare that they have no conflicts of interest.

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Appendix

Table 1. Vitamin A concentration in orange-fleshed sweetpotato and cereal-legume blends

Food type/Formulation	Processing method	Beta-carotene (µg RAE/100g)	Does it meet WHO RDI for Infants?	Country	Study
Boiled and Oven-dried Soy Flour+OFSP		685.63±0.04	Yes	Nigeria	(Abuengmoh et al., 2024)
Date palm+Boiled and Oven-dried Soy+OFSP		584.11±0.35	Yes		
Date palm+Boiled and Oven-dried/Sun-dried and toasted Soy Flour+OFSP		585.63±0.04	Yes		
Non-Sweetened Sun-dried and toasted Soy Flour+OFSP		679.28±0.09	Yes		
Sweetened Sun-dried and toasted Soy Flour+OFSP		588.24±0.08	Yes		
Nestle Cerelac (Control)		110.32±0.03	No		
OFSP(64.57%)+soybean(34.76%)+carrot(0.68%)		2064.00± 17	Yes	Nigeria	(Adetola et al., 2020)
OFSP(61.32%)+soybean(37.69%)+carrot(1.00%)		2057.00± 26	Yes		
Control		370	No		
Finger millet + OFSP		89.1	No	Ghana	(Amaglohet al., 2012)
OFSP + Soybean		89.3	No		
ComFA	Oven-toasted	128.50± 1.11	No		
ComFA	Roller-dried	111.10 ± 1.24	No		
Weanimix		ND			
OFSP complementary food		1112.70 ± 149.40	Yes	Ghana	(Amagloh & Coad, 2014)
CFSP complementary food		105.26± 1.86	No		
Weanimix		2.83± 0.98	No		
Cerelac		226.9± 28	No		
ComFA	Oven-toasted	13,178.80		Ghana	(Amagloh et al., 2012a)
Weanimix		746.32			
OFSP(60%)+Acha(10%)+Soybean(25%)_peanut(5%)		6283.33±0.40	Yes	Nigeria	(Ani et al., 2022)
OFSP(60%)+Acha(10%)+Soybean(20%)_peanut(10%)		5508.33±0.12	Yes		
OFSP(55%)+Acha(15%)+Soybean(25%)_peanut(5%)		4330.83±2.56	Yes		
OFSP(50%)+Acha(20%)+Soybean(20%)_peanut(10%)		5153.33±1.31	Yes		
OFSP(75%)+ Anchovey(75%)+Tomato powder(25%)+Onion powder(25%)		751.75±0.55		Ghana	(Ashun et al., 2019)
OFSP(100%)+ Anchovey(50%)+Tomato powder(25%)+Onion powder(25%)		1185.00± 0.57			
OFSP(125%)+Anchovey(25%)+Tomato powder(25%)+Onion powder(25%)		1118.83± 1.28			
KAN (Control)		649.08±0.28			
Maize+Soybean only		ND		Ghana	(Bonsi et al., 2014)
OFSTomvita(25%)		553.92			
OFSTomvita(50%)		963.00			
OFSMayvita(25%)		45.98			
OFSMayvita(50%)		459.83			
OFSP ComFa		1112.75±149.38		United Kingdom	(Christides et al., 2015)
CFSP ComFa		105.25±1.86			
Weanimix		11.17±0.98			
Cerelac		5.5 ± 1.32			
Maize flour only		0.00±0.00	No	Ethiopia	(Dessta & Terefe, 2024)
Maize(50%)+OFSP(35%)+sweet lupine(10%)+MLP(5%)		2267.50± 10.50	Yes		
Maize(45%)+OFSP(30%)+sweet lupine(15%)+MLP(10%)		2152.50±45.00	Yes		
Maize(40%)+OFSP(25%)+sweet lupine(20%)+MLP(15%)		341.67 ± 12.92	No		
OFSP(100%)-Control		^{I}32,160±1,640		Nigeria	(Eke-Ejiofor et al., 2021)
OFSP(90%)+SBF(5%)+Groundnut flour(5%)		^{I}22,770±2,60			
OFSP(85%)+SBF(10%)+Groundnut flour(5%)		^{I}28,540±110			

Food type/Formulation	Processing method	Beta-carotene (µg RAE/100g)	Does it meet WHO RDI for Infants?	Country	Study
OFSP(80%)+SBF(15%)+Groundnut flour(5%)		[ǂ]29,300±710			
OFSP(75%)+SBF(20%)+Groundnut flour(5%)		[ǂ]44,600±400			
OFSP(70%)+SBF(25%)+Groundnut flour(5%)		[ǂ]20,900±1220			
OFSP(65%)+SBF(30%)+Groundnut flour(5%)		[ǂ]11,080±260			
OFSP(60%)+SBF(35%)+Groundnut flour(5%)		[ǂ]30,690±620			
OFSP(55%)+SBF(40%)+Groundnut flour(5%)		[ǂ]20,720±840			
OFSP(50%)+SBF(45%)+Groundnut flour(5%)		[ǂ]21,190±170			
OFSP(0%)+PM(100%)+Q(0%)		405.00		Egypt	(El-Gindy, 2018)
OFSP(10%)+PM(60%)+Q(30%)		319.00			
OFSP(10%)+PM(50%)+Q(40%)		290.82			
OFSP(10%)+PM(40%)+Q(50%)		280.00			
OFSP(10%)+PM(30%)+Q(60%)		200.00			
OFSP(10%)+PM(20%)+Q(70%)		182.49			
Wheat(45%)+OFSP(25%)+SBF (10%)+milk(10%)+sugar(10%)		45.00		Bangladesh	(Haque et al., 2013)
Wheat(45%)+OFSP(20%)+SBF(15%)+milk(10%)+sugar(10%)		30.00			
Wheat(45%)+OFSP(15%)+SBF(20%)+milk(10%)+sugar(10%)		20.00			
Wheat(45%)+OFSP(10%)+SBF(25%)+milk (10%)+sugar(10%)		15.00			
Cerelac (control)		270.00			
Maize flour (50%)+BF(25%)+OFSP flour(25%)		25.58		Ethiopia	(Jemberu et al., 2016)
Maize flour(45%)+BF(25%)+OFSP flour(30%)		60.2			
Maize flour(40%)+ BF(25%)+OFSP flour(35%)		71.84			
Maize flour (100%)-Control		0.00			
OFSP flour(100%)		92.5±7.50		Ghana	(Laryea et al., 2018)
OFSP(50%)+millet(15%)+soybean(35%)		44.16 ± 1.67			
Weanimix		12.50± 0.83			
Commercial Complementary Food		27.50 ± 1.67			
Soybean(50%)+amaranth(20%)+PS(25%)+OFSP(5%)		180.50 ± 0.56		Tanzania	(Marcel et al., 2022)
Soybean(40%)+amaranth(20%)+PS(30%)+OFSP(10%)		186.40 ± 0.85			
Soybean(30%)+amaranth(35%)+PS(20%)+OFSP(15%)		197.10 ± 0.16			
Soybean(25%)+amaranth(25%)+PS(20%)+OFSP(30%)		232.20 ± 0.00			
Soybean(50%)+amaranth(40%)+PS(15%)+OFSP(25%)		224.50 ± 0.66			
Control-Soybeans + maize + groundnuts + millet flours.		148.50 ± 0.06			
Control-Soybeans+OFSP+ sorghum flours.		215.50 ± 0.39			
Mashed OFSP		70.35±2.14		Cameroon	(Mawouma et al., 2023)
Gruel fortified with mashed OFSP(20%)		1.22±0.09			
Gruel fortified with mashed OFSP(30%)		1.23±0.49			
Gruel fortified with mashed OFSP(40%)		2.05±0.35			
Control (unfortified gruel)		0.57±0.06			
Weaning food (100% OFSP:20% maize)		138.00		Kenya	(Mukutu et al., 2019)
Maize meal		36.00			
C0 (Product)	Extruded @ 70˚C	1044.70±0.55		Kenya	(Nkesiga et al., 2022)
C1 (Product)	Extruded @ 70˚C	710.45±0.32			
C2 (Product)	Extruded @ 70˚C	722.59±0.32			
C3 (Product)	Extruded @ 70˚C	721.67±0.32			
C4 (Product)	Extruded @ 70˚C	728.29±0.32			
C0 (Product)	Extruded @ 90˚C	1004.23±0.84			

Food type/Formulation	Processing method	Beta-carotene (µg RAE/100g)	Does it meet WHO RDI for Infants?	Country	Study
C1 (Product)	Extruded @ 90˚C	695.55±0.32		Nigeria	(Okoronkwo et al., 2023)
C2 (Product)	Extruded @ 90˚C	692.60±0.55			
C3 (Product)	Extruded @ 90˚C	678.92±0.55			
C4 (Product)	Extruded @ 90˚C	660.23±0.32			
ASOC = 50% fonio/soybean + 50% OFSP		2560.00±0.20			
AS = 100% fonio 100% soyabean;		1316.00 ± 0.02			
commercial product (Cerelac maize and soya)		1134.00 ± 0.60			
FMG(100%)		4980.00±100.00		Nigeria	(Olaniran et al., 2023)
OFSP(100%)		6150.00±200.00			
FMG(90%)+OFSP(10%)		5020.00±200.00			
FMG(80%)+OFSP(20%)		5310.00±300.00			
FMG(70%)+OFSP(30%)		5740.00±100.00			
FMG(60%+OFSP(40%)		6210.00±200.00			
FMG(50%)+OFSP(50%)		6570.00±200.00			
OFSP(50%)+cowpea(30%)+RBF(20%)		7.55 ± 0.096		Nigeria	(Olaniran et al., 2024)
OFSP(55%)+cowpea(30%)+RBF(15%)		7.62 ± 0.010			
OFSP(60%)+cowpea(30%)+RBF(10%)		8.06 ± 0.024			
OFSP(65%)+cowpea(30%)+RBF(5%)		8.35 ± 0.025			
OFSP(60%)+cowpea(40%)+RBF(0%)		7.86 ± 0.005			
OFSP(50%)+cowpea(30%)+RBF(15%)+sugar(5%)		7.62 ± 0.015			
OFSP(55%)+cowpea(30%)+RBF(15%)+sugar(5%)		7.77 ± 0.024			
OFSP(60%)+cowpea(30%)+RBF(5%)+sugar(5%)		8.14 ± 0.011			
PM(50%)+dates(15%)+OFSP(35%)		441.00±380.00		Tanzania	(Selemani et al., 2023)
PM(90%)+MLP(2.5%)+dates(7.5%)		308.00±535.00			
PM(95%)+MLP(2.5%)+dates(2.5%)		357.00±368.00			
PM(88%)+MLP(3%)+dates(9%)		434.00±117.00			
PM(95.5%)+MLP(2%)+OFSP(2.5%)		381.00±680.00			
PM(88%)+MLP(2%)+OFSP(10%)		497.00±797.00			
PM(95%)+MLP(2.5%)+OFSP(2.5%)		373.00±815.00			
OFSP, mash made with non-biofortified OFSP	Porridge	7230.60±288.30		Senegal	(Thiam et al., 2025)
OFSP1, mash made with OFSP biofortified with PL	Porridge	4226.50± 322.00			
OFSP2, mash made with OFSP fertilized with PL + EM + MF; PBF, porridge made with blended flour containing nonbiofortified millet, cowpea, and OFSP	Porridge	4319.00±836.00			
PBF	Porridge	1271.60±231.66			
PBF1	Porridge	2011.60±412.50			
PBF2	Porridge	3809.70±566.60			
OFSP flour(100%)		1989.8±1.20		Uganda	(Tumuhimbise et al., 2019)
OFSP flour(78%)+ALP(2%)+SMP(20%)		1447.3±1.10			
OFSP flour(72.5%)+ALP(2.5%)+SMP(25%)		563.8±0.40			
OFSP flour(65%)+ALP(5%)+SMP(30%)		343.9±0.20			
OFSP flour(55%)+ALP(10%)+SMP(35%)		145.7±1.40			

[Ɨ] Total carotenoids, assuming that half of the total carotenoids is beta-carotene; FMG-Fermented mixed grain. OFSP-Orange-fleshed sweetpotato, RBF, ripe banana flour, SBF-Soybean flour, MFP-Moringa leaf powder, PS-Pumkin seed, PM-pearl millet, MLP-Moringa leaf powder, PBF, porridge made with non-biofortified blended flour; PBF1, porridge made with BF1; PBF2, porridge made with BF2, PL-poultry litter, EM- efficient microorganisms; MF-mycorrhizal fungi, ALP-Amaranth leaf powder, SMP-Skimmed milk powder, QF- quinoa flour, BF-bean flour, RDI-Recommended daily intake. CFSP- cream-fleshed sweetpotato.

[Ɨ] values reported as total carotenoids.

Table 2. Phytic acid concentrations in orange-fleshed sweetpotato and cereal-legume blends

Food type/Formulation	Processing method	Phytic acid (mg/100 g)	Country	Study	Assay method
ComFA	Oven-toasted	2263.70±320.01	Ghana	(Amagloh et al., 2012)	Enzymatic, colorimetric
ComFA	Roller-dried	1949.70±208.40			
Enriched Weanimix		8032.70±356.81			
OFSP complementary food		229.85 ± 20.36	Ghana	(Amagloh & Coad, 2014)	Enzymatic, colorimetric
CFSP complementary food		78.62 ± 3.50			
Weanimix		438.10 ± 8.58			
Cerelac		66.92 ± 4.00			
ComFA	Extruded-cooked	0.19 ± 0.03	Ghana	(Amagloh et al., 2012b)	Enzymatic, colorimetric
ComFA	Roller-dried	0.20 ± 0.02			
ComFA	Oven-toasted	0.23 ± 0.03			
Enriched Weanimix		0.80±0.03			
Blend-1	Raw	94.64±1.94	Ethiopia	(Araro et al., 2020)	Spectrophotometric, colorimetric
Blend-1	Extruded	89.36±1.20			
Blend-1	Drum Dried	89.89±2.12			
Blend-2	Raw	124.78±2.96			
Blend-2	Extruded	101.39±1.22			
Blend-2	Drum Dried	102.57±1.03			
Blend-3	Raw	77.55±2.67			
Blend-3	Extruded	76.84±0.68			
Blend-3	Drum Dried	77.09±0.09			
Blend-4	Raw	82.36±1.01			
Blend-4	Extruded	67.19±1.62			
Blend-4	Drum Dried	67.53±1.45			
Blend-5	Raw	82.73±2.73			
Blend-5	Extruded	73.08±0.25			
Blend-5	Drum Dried	73.18±1.19			
Blend-6	Raw	79.22±0.52			
Blend-6	Extruded	66.36±1.47			
Blend-6	Drum Dried	66.48±0.33			
Blend-7	Raw	72.99±0.10			
Blend-7	Extruded	64.64±2.24			
Blend-7	Drum Dried	64.66±1.33			
OFSP ComFA		229.85±19.36	UK	(Christides et al., 2015)	Enzymatic, colorimetric
CFSP ComFA		8.62±3.50			
Mashed sweet potato		43.60±0.07	Cameroon	(Mawouma et al., 2023)	Spectrophotometric, colorimetric
Gruel fortified with mashed sweet potato at 20%		35.14±0.03			
Gruel fortified with mashed sweet potato at 30%		45.32±0.07			
Gruel fortified with mashed sweet potato at 40%		47.61±0.08			
ASOC = 50% fonio/soybean + 50% OFSP		0.016±0.01	Nigeria	(Okoronkwo et al., 2023)	Spectrophotometric, colorimetric
Commercial product (Cerelac maize and soya)		0.006±0.00			
AS = 100% fonio 100% soyabean		0.018±0.05			
C0 (Product)	Extruded @ 70˚C	1.79±0.02	Kenya	(Nkesiga et al., 2022)	
C1 (Product)	Extruded @ 70˚C	1.51±0.07			
C2 (Product)	Extruded @ 70˚C	1.10±0.02			
C3 (Product)	Extruded @ 70˚C	1.42±0.05			
C4 (Product)	Extruded @ 70˚C	1.47±0.01			
C0 (Product)	Extruded @ 90˚C	0.96±0.01			

Food type/Formulation	Processing method	Phytic acid (mg/100 g)	Country	Study	Assay method
C1 (Product)	Extruded @ 90˚C	0.47±0.00			Spectrophotometric, colorimetric
C2 (Product)	Extruded @ 90˚C	0.47±0.01			
C3 (Product)	Extruded @ 90˚C	0.80±0.01			
C4 (Product)	Extruded @ 90˚C	0.92±0.01			
C0 (Flour)		10.79±0.03			
C1 (Flour)		9.79 ± 0.01			
C2 (Flour)		7.49 ± 0.02			
C3 (Flour)		7.78 ± 0.03			
C4 (Flour)		8.80 ± 0.01			
SPF(60%)+SBF(30%)+SSF(10%)		0.31±0.00	Nigeria	(Uzo-Peters & Akinola, 2018)	Precipitation, colorimetric/ spectroscopic
SPF(60%)+SBF$_g$(30%)+SSF$_g$(10%)		0.24±0.01			
SPF(60%)+SBF(30%)SSF$_d$(10%)		0.25±0.00			
SPF(60%)+SBF$_g$(30%)+SSF$_{dg}$(10%)		0.22±0.00			
Nestle Cerelac (control)		0.10±0.00			

SPF-Sweet potato flour, SBF-Soybean flour, SSF-Sesame seed flour, SBFg-germinated soybean flour, SSFg-germinated sesame seed flour, SSFd-defatted sesame seed flour, SSFdg-germinated and defatted sesame seed flour, CFSP-cream-fleshed sweetpotato, OFSP-orange-fleshed sweetpotato, ComFa-complementary food for Africa

Table 3. Apparent viscosity comparison of orange-fleshed sweetpotato and cereal-legume complementary foods

Food type/Formulation	Processing method	Final Viscosity (cP)	Does it meet the appropriate consistency for Infants?	Country	Study
MaizeMaltodextrinSMPMicronut		1343.00	Yes	Ghana	(Amagloh, 2022)
MaizeMilletSoy		6640.00	No		
MaizeMilletSoyMicronut		13613.00	No		
MaizeMilletSoyPnut		10749.00	No		
MaizeMilletWheatRiceSoyPnut		3237.00	Yes		
MaizeSoy		8616.00	Yes		
MaizeSoyAmaranthBeetroot		5774.00	Yes		
MaizeSoyPnut		8023.00	No		
MilletSoy		7295.00	No		
OfspMaizePeas		1175.70	Yes		
OfspRiceSoy		3277.00	No		
OfspSorghumSoy		6293.00	No		
OfspSoyYellowmaize		1964.00	Yes		
Orangemaize		3978.70	No		
RiceSoy		7645.00	No		
RiceWheatSoy		10659.00	No		
WheatMaltodextrinSMPMicronut		2174.00	Yes		
WheatSoy		8123.00	No		
YellowMaizeWheatMilletSoyCoconut		11893.00	No		
ComFA	Extrusion-cooked	100.00-150.00	Yes	Ghana	(Amagloh et al., 2013)
ComFA	Roller-dried	50.00-100.00	Yes		
ComFA	Oven-toasted	50.00-100.00	Yes		
Weanimix		1600.00-1700.00	Yes		
Blend-1		2274.00±0.12	Yes	Ethiopia	(Araro et al., 2020)
Blend-2		2258.00±0.03	Yes		
Blend-3		2207.00±0.22	Yes		
Blend-4		2081.00±3.00	Yes		
Blend-5		1397.00±1.73	Yes		
Blend-6		1289.00±1.22	Yes		
Blend-7		2225.00±0.02	Yes		
202 (faffa)		2400.00±2.00	Yes		
Sweet potato mix (10%)		1.00-1.60	Yes	India	(Das et al., 2020)
Sweet potato mix (20%)		12.20-12.40	Yes		
Sweet potato mix (30%)		28.50-39.70	Yes		
Control (OFSP 100%)		6159.00±131.50	No	Nigeria	(Eke-Ejiofor et al., 2021)
OFSP(90%)+SBF(5%)+Groundnut flour(5%)		373.60±4.50	Yes		
OFSP(85%)+SBF(10%)+Groundnut flour(5%)		356.70±4.00	Yes		
OFSP(80%)+SBF(15%)+Groundnut flour(5%)		346.70±9.40	Yes		
OFSP(75%)+SBF(20%)+Groundnut flour(5%)		300.60±8.00	Yes		
OFSP(70%)+SBF(25%)+Groundnut flour(5%)		224.10±3.00	Yes		
OFSP(65%)+SBF(30%)+Groundnut flour(5%)		235.90±18.90	Yes		
OFSP(60%)+SBF(35%)+Groundnut flour(5%)		189.20±10.80	Yes		
OFSP(55%)+SBF(40%)+Groundnut flour(5%)		197.7±2.70	Yes		
OFSP(100%)		690.00	Yes	Nigeria	(Ijarotimi & Ashipa, 2006)
OFSP(90%)+SBF(10%)		650.00	Yes		

Food type/Formulation	Processing method	Final Viscosity (cP)	Does it meet the appropriate consistency for Infants?	Country	Study
OFSP(80%)+SBF(20%)		580.00	Yes		
OFSP(70%)+SBF(30%)		410.00	Yes		
OFSP(60%)+SBF(40%)		300.00	Yes		
OFSP(50%)+SBF(50%)		360.00	Yes		
Maize flour (50%)+BF(25%)OFSP flour(25%)		2395±46.67	Yes	Ethiopia	(Jemberu et al., 2016)
Maize flour(45%)+BF(25%)+OFSP flour(30%)		2213±50.91	Yes		
Maize flour(40%)+BF(25%)+OFSP flour(55%)		2038.50±47.38	Yes		
OFSP		156.00	Yes	South Africa	(Makame et al., 2020)
Maize		5038.00	No		
Sorghum		1761.00	Yes		
Teff		1668.00	Yes		
Cassava		3156.30	No		
Bambara		1491.00	Yes		
Cowpea		1491.00	Yes		
A1 (reference)		182.30	Yes		
NASPOT 10_30%	Fresh	2258±189.00	Yes		(Nabubuya et al., 2017)
NASPOT 10_35%	Fresh	2350±100.00	Yes		
NASPOT 10_40%	Fresh	2700±150.00	Yes		
NASPOT 10_30%	Stored	382±59.00	Yes		
NASPOT 10_35%	Stored	1150±50.00	Yes		
NASPOT 10_40%	Stored	1900±100.00	Yes		
Kakamega_30%	Fresh	2055±248.00	Yes		
Kakamega_35%	Fresh	2150±100.00	Yes		
Kakamega_40%	Fresh	2450±150.00	Yes		
Kakamega_30%	Stored	1194±1.40	Yes		
Kakamega_35%	Stored	1300±150.00	Yes		
Kakamega_40%	Stored	2800±150.00	Yes		
ASOC = 50% Fonio/Soybean + 50% OFSP		15400±0.00	No	Nigeria	(Okoronkwo et al., 2023)
Commercial product (Cerelac maize and soya)		8200±1.71	No		
AS = 100% Fonio 100% Soyabean		18400±3.36	No		
Sorghum(40%)+Mung bean(45%)+OFSP(15%)		2100.00	Yes		(Olaleye et al., 2020)
Sorghum(40%)+Mung bean(30%)+OFSP(30%)		936.00	Yes		
Sorghum(25%)+Mung bean(30%)+OFSP(45%)		660.00	Yes		
Sorghum(25%)+Mung bean(45%)+OFSP(30%)		600.00	Yes		
Sorghum(55%)+Mung bean(30%)+OFSP(15%)		876.00	Yes		
OFSP(50%)+cowpea(30%)+RBF(20%)		1851.67±7.64	Yes	Nigeria	(Olaniran et al., 2024)
OFSP(55%)+cowpea(30%)+RBF(15%)		3621.33±10.26	No		
OFSP(60%)+cowpea(30%)+RBF(10%)		2651.33±7.64	Yes		
OFSP(65%)+cowpea(30%)+RBF(5%)		3060.00±26.46	No		
OFSP(60%)+cowpea(40%)+RBF(0%)		1693.67±5.13	Yes		
OFSP(50%)+cowpea(30%)+RBF(15%)+sugar(5%)		892.33±5.13	Yes		
OFSP(55%)+cowpea(30%)+RBF(15%)+sugar(5%)		1980.33±2.08	Yes		
OFSP(60%)+cowpea(30%)+RBF(5%)+sugar(5%)		1221.00±3.61	Yes		
Millet(55%)+OFSP(30%)+SBF(15 %)		105.38±0.26	Yes	Nigeria	(Olatunde et al., 2020)
Millet(50%)+OFSP(30%)+SBF(20 %)		1204.00±0.13	Yes		
Millet(45%)+OFSP(30%)+SBF(25 %)		1554.00±0.14	Yes		

Food type/Formulation	Processing method	Final Viscosity (cP)	Does it meet the appropriate consistency for Infants?	Country	Study
Millet(40%)+OFSP(30%)+SBF(30%)		1282.00±0.15	Yes		
OFSP flour(100%)		191.50	Yes		(Tumuhimbise et al., 2019)
OFSP flour(78%)+ALP(2%)+SMP(20%)		122.50	Yes		
OFSP flour(72.5%)+ALP(2.5%)+SMP(25%)		120.00	Yes		
OFSP flour(65%)+ALP(5%)+SMP(30%)		118.00	Yes		
OFSP flour(55%)+ALP(10%)+SMP(35%)		116.50	Yes		
YM(100%)		293.04±2.30	Yes	Nigeria	(Ukom et al., 2024)
YM(70%+OFSP(20%)+AYB(10%)		207.50±13.90	Yes		
YM(70%)+OFSP(15%)+AYB(15%)		235.54±9.49	Yes		
YM(70%)+OFSP(10%)+AYB(20%)		250.38±16.80	Yes		

RBF- ripe banana flour, OFSP-orange-fleshed sweetpotato, SBF-Soybean flour, BF-Bean flour, YM-Yellow maize, AYB-African yambean, ALP-Amaranth leaf powder, SMP-Skimmed milk powder

Table 4. Aflatoxin concentration in OFSP and cereal-legume CFs

Product	Aflatoxin (μg/kg)	Does it meet the Codex Standard of 5 μg/kg?	Study
Maize_Millet_Soy	8.00±3.01	No	(Amagloh, 2022)
Maize_Millet_Soy_Micronut	29.30±7.01	No	
Maize_Soy	5.83±0.33	No	
Maize_Soy_Amaranth_Beetroot	7.02±2.02	No	
Maize_Soy_Pnut	23.17±0.55	No	
Millet_Soy	6.23±1.62	No	
Oat_Millet_Rice_Maize_Wheat_Soy_Pnut	5.33±0.61	No	
OFSP_Maize_Peas	9.02±2.14	No	
OFSP_Rice_Soy	5.14±0.10	No	
OFSP_Sorghum_Soy	6.38±0.14	No	
OFSP_Soy_Yellowmaize	10.72±0.21	No	
Rice_Amaranth_MilletS_oy	11.00±3.55	No	
Rice_Millet_Maize_Soy_Pnut	10.51±0.80	No	
Rice_Millet_Maize_Wheat_Oat_Soybean_Pnut	56.77±4.10	No	
Rice_Soy	6.11±1.91	No	
Rice_Soy_Pnut	32.29±3.15	No	
Rice_Wheat_Soy	7.27±0.36	No	
Wheat_Rice_Sesame_Soy_Pnut	5.76±0.16	No	
Yellow_Maize_Wheat_Millet_Soy_Coconut	9.05±1.18	No	