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Improving nutrition-sensitive value chains of African indigenous vegetables: current trends in postharvest management and processing

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The value chains of African indigenous vegetables (AIVs) are highly constrained by high postharvest losses (up to 50%) along the chain, largely occasioned by poor postharvest management and a lack of optimized processing technologies. The technologies and practices are key technical aspects that can transform the capacity of the chain by enhancing the overall value generated from the system. AIVs have recently experienced an increase in demand due to their high nutritional value and the opportunity they present to enhance rural incomes, since they are predominantly produced by smallholder farmers in rural and peri-urban areas. This implies that they can positively contribute to increased availability and hence supply of nutritious food within local food systems. Furthermore, the fact that half of the economic value of AIVs is potentially lost due to inappropriate postharvest management and inadequate processing demonstrates the potential that related interventions and transformations could have in enhancing and preserving value along AIV value chains. Currently, the approaches applied to reduce food waste, preserve nutritional quality, and add value to AIVs are largely traditional in nature. They require upgrading and need to be aligned toward achieving a nutrition-sensitive value chain. By looking at these as value creation processes, this mini-review examines the current postharvest management practices, highlights relevant new and innovative technologies and related challenges, and suggests potential options to improve the benefits for AIV value chain actors and thus contribute to a sustainable transformation of nutrition-sensitive food systems.

KEYWORDS

postharvest technology, processing, value chains, nutrition-sensitive, African indigenous vegetables

1. Background

Recent developments in the vegetable sector in Sub-Saharan Africa (SSA) have sought to increase the production and utilization of African indigenous vegetables (AIVs) (Imathiu, 2021; Bokelmann et al., 2022). AIVs are underutilized vegetables whose production and utilization are characterized by specific socioeconomic, technological, and market dynamics. AIVs include all plants that originate on the continent or have a long history of cultivation and domestication to African conditions and whose leaves, fruits, or roots are acceptable and used as vegetables through custom, habit, or tradition (Ambrose-Oji, 2009; Maundu et al., 2009; Uusiku et al., 2010). Examples of commonly consumed AIVs include, amaranth (*amaranthus cruentus)*, African nightshade (*Solanum scabrum*), African eggplant (*Solanum aethiopicum*), jute mallow (*Corchorus olitorius*), and okra (*Abelmoschus callei*). These vegetables are predominantly produced by rural and peri-urban smallholder women farmers, in a value chain characterized by poorly developed marketing systems concentrated in rural and peri-urban localities (Shayanowako et al., 2021). They are highly adapted to such local contexts and are prioritized locally for their nutritional and health benefits (Moyo et al., 2021). These vegetables do not only form an important part of the local food systems and diets in many rural African communities but they have also attracted wider global attention, leading to an increase in demand and production due to their high nutritional value and economic potential (Bokelmann et al., 2022). These observations imply that promoting AIVs can contribute to transformation of rural food systems, empowering smallholder farmers economically and strengthening the value chains for micronutrient-rich foods.

Despite increasing recognition of the potential of AIV value chains to enhance human nutrition and spur economic development, they remain generally underdeveloped and constrained by a number of factors such as (i) poor productivity, (ii) poorly organized marketing, (iii) lack of technologies and knowledge for sustainable processing, and (iv) high postharvest losses (Musebe et al., 2017; Owade et al., 2020; Hlatshwayo et al., 2021). Current literature indicates that up to 50% of the vegetables are lost at postharvest stage (Gogo et al., 2018b). On the other hand, although the actual proportion of leafy vegetables that is processed in SSA is not clearly documented, available literature shows that AIVs are predominantly consumed fresh (Maseko et al., 2018). The low level of processing is attributed to factors including; (i) lack of technology, (ii) lack of processing knowledge, and (iii) a low level of alternative utilization options for AIVs (Mazike et al., 2022). This translates into high levels of overall losses along the supply chains. For instance, Gogo et al. (2017) reported a loss of macro- and micronutrients and protein content between 3.2–29.4%, and chlorophylls and carotenoids between 70.9–90.9% and 70.4–91.9% respectively, along the supply chain of African nightshade in Kenya. This implies that besides the economic losses, poor postharvest management and a lack of processing also reduces the nutritional value of the AIVs.

Nutrition-sensitive value chains (NSVCs) are food systems that are more likely to improve nutrition by enhancing dietary diversity and nutritional quality. They are strategically positioned to enhance the supply of nutritious foods, add nutritional value, and enhance demand for nutritious foods along the chain (de la Pena et al., 2018). From several literature strands around NSVCs and AIVs (Brauw et al., 2015; Hodge et al., 2015; Wesana et al., 2018; Mazike et al., 2022), the potential role of postharvest management in transforming local value chains can be realized through four pathways: (i) reducing quantitative and qualitative food losses, (ii) extending shelf life and improving storage of vegetables, (iii) enhancing food safety, and (iv) optimizing preservation technologies for food nutritional quality. In this review, we summarize the actual knowledge on current postharvest management and processing practices, identify gaps, and indicate emerging approaches that could improve the nutritional outcomes of AIV value chains which contribute to food security.

2. Methodology

The study followed the narrative literature review approach as previously described by Ferrari (2015), and therefore synthesis of the review is presented in a narrative rather than statistical format. This approach was enhanced by including a systematic literature identification and search criteria so as to execute an effective search and minimize bias in the selection of articles for review. Briefly, the review criteria considered, (i) only articles that addressed the topics of postharvest management and processing of African indigenous vegetables, (ii) only peer reviewed articles published between 2003 and 2022; (iii) only articles in English language. To identify relevant available literature, specific search terms were utilized including "African indigenous Vegetables (AIVs) or African underutilized Vegetables (AUVs) or African Leafy Vegetables (ALVs)," "Processing," "postharvest management or postharvest technologies," "nutrition sensitive," "value chains," and "food systems." The literature was obtained through the Elsevier's Scopus, Web of Science, Google scholar, Science Direct and, Emerald Springer online search engines. As our general question is to evaluate how postharvest management and processing of AIVs can contribute to transformation of food systems by enhancing nutrition sensitivity, each section of the review provides an appraisal of current published results on the topic, giving an overview of the current knowledge, the gaps, and provides a rationale and directions for future interventions.

3. Results and discussion

3.1. Relevance of African indigenous vegetables toward nutrition

In the context of rural farming communities where AIVs are predominantly produced, they can play a key role in promoting nutrition as well as resilience and adaptability of the entire local food systems to changing climatic conditions. Being minimally reliant on external input for their production (Weinberger et al., 2011), highly dense in nutrient and health promoting properties (Neugart et al., 2017) as well as high adaptability to climate change (van Zonneveld et al., 2021) are key characteristics that underline the relevance of AIVs toward promoting nutrition sensitive value chains. Evidence from existing studies allude to these facts. For example, Francis et al. (2017) emphasized the need for a shift toward strategies that place an equal emphasis on human nutrition and health, as well as environmental sustainability in order to provide food and nutrition security. While, Cogill (2015), Neugart et al. (2017), and Mwanga et al. (2020) extensively reported the nutritional and health role of AIVs as essential sources of micronutrients and a relatively cheap source of plant based protein, especially for the low income rural and peri urban households, in addition to essential minerals and vitamins necessary for maintaining human health and strengthening resistance to disease and infection. AIVs have been reported to contribute up to 11–12% to the total daily dietary protein consumption while exotic vegetables contributed 4% (Gockowski et al., 2003; Mwanga et al., 2020). In Kenya, the dietary protein contribution of AIVs was found to be higher in rural areas (10% higher) than in peri-urban areas (Mwanga et al., 2020). Compared to some exotic vegetables, some AIVs have been reported to be superior sources of protein and micronutrients (Nyadanu and Lowor, 2015). Additionally, AIVs support a large number of small-scale farms with women significantly involved in all segments along the entire value chain in urban and peri-urban areas (Otieno et al., 2019). This is in addition to low capital requirements for entry into their value chains, that enables even the poorest households to participate (Weinberger et al., 2011).

Essentially, AIVs may offer new opportunities for development of nutrition sensitive, resilient and sustainable food systems and there is growing evidence toward this potential as aforementioned and as summarized in Table 1 below. They can widen the sources of health promoting compounds required for human health, increase diversity and quality of diets, are uniquely adapted to local environments and have potential to create local market niches in rural and peri-urban economies (Mabhaudhi et al., 2019). Additionally, they are important in terms of climate change, given their adaptive features that promote growth under marginal conditions, and the low cost of fertilizers and pesticides required in their production. Hence, promoting their cultivation aligns with sustainable agricultural practices (Shayanowako et al., 2021). All the above characteristics can drive better nutritional outcomes for communities as well as contributing to nutrition-sensitive and resilient local food systems.

3.2. Current knowledge of postharvest management and processing of AIVs

3.2.1. Current practices in postharvest management of AIVs and implications for sustainable and nutrition-sensitive value chains

The objectives of postharvest management are majorly: (i) to minimize food loss and waste, (ii) to preserve nutritional quality and safety of food, and (iii) to improve storability and prolong shelf life of products (Matrose et al., 2021). As such, the key components in postharvest management of fresh vegetables include; appropriate harvest time, temperature control, transportation, handling and postharvest treatments, preservation, packaging, and storage. Additionally, application of targeted postharvest treatments and use of preservation technologies also significantly contribute to food safety, reduce product physiological deterioration and prolong the shelf life and quality of AIVs (Deng et al., 2020).

Available research indicates that postharvest temperature control is important for reducing the physiological activity of fresh produce and thus preventing deterioration and product decay (Duan et al., 2020). However, current studies on AIVs show that cooling is predominantly conducted through keeping fresh produce under shades, sprinkling water on fresh produce, and covering with fresh leaves or bundling products to prevent transpiration losses (Sipho and Tilahun, 2020). However, these are measures that cannot adequately keep AIVs safe and fresh. Cold storage which reduces respiration, transpiration, and leaf senescence of fresh vegetables is largely not available at the producer, wholesale, and transporter stages of the chain, with refrigerated storage only applied in the urban retail supermarkets (Makule et al., 2022). This is mainly attributed to AIVs being predominantly produced in rural areas, by resource-constrained smallholder farmers, with limited access to electricity and cold storage facilities. In view of these constraints, it is recommended that cold storage for AIV value chains should be based on energy-efficient and cost-effective technologies. Integration of such emerging cost-efficient, postharvest, cold chain technologies can have many beneficial effects in terms of maintaining the nutritional value of AIVs along the chain. For example, evaporative cold storage has been found to enhance vitamin C retention in amaranth (Ambuko et al., 2017), while Sorour et al. (2022) showed that refrigerated storage maintained the mineral contents of spinach and jute mallow. Currently, AIVs are mostly sold without packaging, but rather simply graded and tied in bundles (Govindasamy et al., 2020). However, particularly when cooling facilities are not available or affordable, film packaging is known to be a good alternative to reduce deterioration of AIVs (Gogo et al., 2017), which needs to be explored in more detail. These observations clearly show that current postharvest management practices are limited and so lessen the possibility to establish sustainable and nutrition-sensitive value chains of AIVs.

3.2.2. Contextual issues in postharvest management of AIVs from a practical perspective

A number of constraints that affect postharvest management of AIVs have been documented. For instance, most rural areas lack electricity (Muhumuza et al., 2018), which is vital for processes such as refrigeration. The road infrastructure is poorly developed in most of these rural areas (Imathiu, 2021), which affects transportation and timely delivery of fresh produce to the market. There is also inadequate investment in postharvest and processing technologies (Makule et al., 2022), which limits availability and access to such technologies. These constraints are majorly attributed to the context under which AIVs are produced, being characterized by predominantly rural and peri-urban smallholder farmers, poorly organized marketing, middlemen (retailers) being major players, and reliance on non-specialized public transportation (Gogo et al., 2018b).

The aforementioned contextual realities therefore require that technologies promoted within the AIV value chains should be accessible, affordable, and sustainable. As such, research should

TABLE 1 Evidence of relevance of AIVs to nutrition and health.

Dimension of relevance	Key published findings	References
Dietary diversity	They contribute to increased diversity and quality of diets by supplying alternative plant sourced proteins, vitamins minerals, and carbohydrates.	Cogill, 2015
	They offer potential for diversifying dietary quality of other foods through food-to-food fortification.	Odunlade et al., 2017
Plant based proteins, vitamins and minerals	AIVs are rich in micronutrients such as iron (Fe), zinc (Zn), calcium (Ca), magnesium (mg). By providing a cheaper source of many essential vitamins and minerals, they can contribute to reducing micronutrient deficiencies.	Aworh, 2018
	They can provide significantly higher sources of proteins, carbohydrates, dietary fibers, potassium, calcium, magnesium, phosphorus, Vitamin A, Vitamin C and Vitamin E compared to some of their exotic counterparts.	Nyadanu and Lowor, 2015
	They contain substantial amounts of proteins that can be used in food formulations to replace animal-based proteins in human diets.	Rivero Meza et al., 2023
Household incomes	AIVs provide a source of livelihood, majorly to women farmers in rural and peri-urban communities.	Dinssa et al., 2016
	They contribute to diversification and stability of household incomes, creating local niche markets.	Krause et al., 2019
Climate change adaptation	AIVs are resilient with adaptive features that enable production even under marginal conditions.	Mabhaudhi et al., 2019
Human health and Non-communicable diseases (NCDs)	They are good sources of essential secondary metabolites and other health promoting compounds such as antioxidants, carotenoids, dietary fibers etc. These are critical for protection against common NCDs such as heart disease, and diabetes.	Neugart et al., 2017
	Some protein extracts from amaranth have anti-microbial, anti-inflammatory, antidiabetic, anti-hypertensive and anti-atherosclerotic activity.	Rivero Meza et al., 2023

provide alternatives that; (i) are less power intensive, (ii) are less expensive, and (iii) ensure safety and preserve nutritional quality. Examples of emerging technologies that could be suitable for AIV value chain contexts include, among others, evaporative cooling technologies, sustainable packaging materials, controlled drying for extended shelf life, solar coolers, and use of cold transportation systems (Ambuko et al., 2017; Cheptoo et al., 2020; Ameta et al., 2021; Amwoka et al., 2021; Mostafa et al., 2022). Additionally, networking among AIV value chain actors in terms of exchanging knowledge, demands, and requirements for quality and loss reduction may also contribute toward a more nutrition-sensitive value chain.

3.2.3. Current processing technologies for AIV preservation by smallholder farmers

Processing methods commonly used to add value to AIVs include drying, blanching, canning, boiling, fermentation, malting, milling, popping, roasting, steaming, and wet milling, depending on available processing equipment and whether the raw materials are leaves or seeds (Mazike et al., 2022). The most common method for processing AIVs is drying. Leafy vegetables which have been dehydrated by drying are light and can easily be re-converted into fresh-like form for consumption throughout the year (Singh and Sagar, 2010).

Open-air sun drying is the most common method in tropical countries, due to its affordability, especially for smallholder farmers in rural areas. But it has many drawbacks commercially because it is difficult to manage large quantities to achieve homogenous quality and food safety (Managa et al., 2020b). This is because the sun drying process greatly relies on ambient conditions, with produce very prone to contamination by dust, rain, wind, and pests (El Hage et al., 2018). The resultant low-quality products and nutrient losses compromise the nutritional and market value of dried AIVs. Solar drying technology has a greater advantage than direct sun drying and leads to better product quality and retention of nutrients, but requires more capital investment in the equipment (Yegon et al., 2021). Boiling and blanching leafy AIVs is often done prior to drying. Boiling is used by indigenous people to reduce or eliminate the bitterness of some vegetables, thus improving flavor and taste (Oulai et al., 2015). Blanching can be applied using steam or water. Blanching leafy AIVs improves color and carotene retention due to inactivation of enzymes, but it causes losses of vitamin C (Mkandawire and Masamba, 2014; Njoroge et al., 2015). Blanching green leafy vegetables in water containing potassium metabisulphite has been shown to effect better retention of vitamin C than blanching in water containing sodium carbonate or sodium chloride (Ranganathan et al., 2017). Managa et al. (2020a) further demonstrated that steam blanching and lemon juice addition retained more phenolic metabolites in African nightshade in comparison to untreated products. Fermentation of AIVs increases their storability duration, palatability, aroma, and texture and it increases the availability of proteins and vitamins such as folate (Muchoki et al., 2007; Wafula et al., 2016; Misci et al., 2021). Moreover, fermentation of AIVs followed by drying has been reported to result in lowered postharvest losses, improved taste, maintained quality, and increased product safety (Wafula et al., 2016). Traditionally, smallholder farmers have practiced natural fermentation but current studies have involved the use of starter cultures in cowpea leaves (Wafula et al., 2016). Studies have also shown successful fermentation of African kale (*Brassica carinata*) using lactic acid starter strains (Oguntoyinbo et al., 2016). Furthermore, canning technologies have been used as a preservative measure for many vegetables and can also be applied to AIVs to give consumers access to a wider choice of convenient, shelf-stable, value-added, and modern products that appeal to urban dwellers (Onyeorizi et al., 2017; Sigaqa et al., 2017). However, canning is capital intensive and would require high initial investment, hence it remains unaffordable for small-scale farmers and processors.

The value-added products from AIVs include dried vegetables, canned vegetables, fermented vegetables, and dried leaf powder that can be used for fortifying various meals or added into products such as biscuits, and pasta for nutritional enhancement (Mazike et al., 2022).

3.2.4. Adoption of AIV postharvest and processing technologies

In SSA, there is a double challenge of low level of investment in postharvest and processing technologies (Owade et al., 2020; Sugri et al., 2021) and high barriers to adoption (Stathers et al., 2020). Typically, the current technologies adopted and used by smallholder AIV farmers are identified as traditional in nature (Mazike et al., 2022). Moreover, there is generally slow progress in upgrading traditional food processing and preservation techniques in Sub-Saharan Africa (Aworh, 2008). The reasons for the limited uptake of such technologies are linked to; (i) lack of adequate knowledge, (ii) poor education and extension for dissemination, and (iii) economic, social, and cultural limitation (Shayanowako et al., 2021). For instance, solar-dried AIVs are of better quality in terms of nutritional content, hygiene, as well as appearance, color, and taste than open sun–dried AIVs. However, studies show that the solar-dried AIVs are still not widely known to many households, and related knowledge is relatively low compared to open sun drying (Kessy et al., 2018; Yegon et al., 2021).

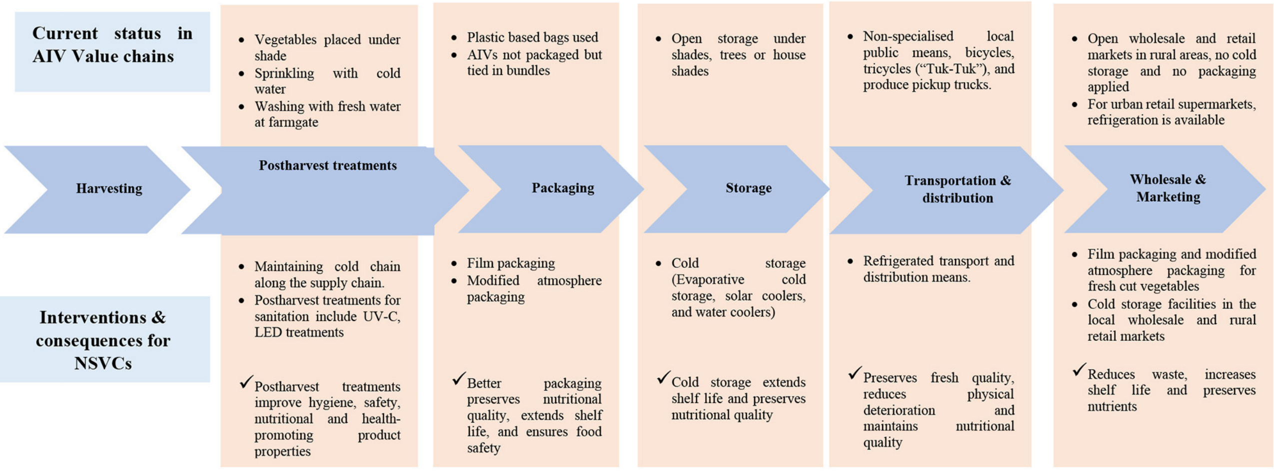
Traditional food processing aims to maintain the supply of healthy, nutritious food throughout the year, especially in times of scarcity while commercial processing seeks to generate income for the producer and seller (Bokelmann et al., 2022). Small-scale food industries, involving modest mechanization of traditional methods, with possibilities for replication in rural areas where the raw materials are produced, offer better prospects for success than large, fully mechanized processing plants (Uzoejinwa et al., 2016). In addition, small-scale plants have the advantage of being able to match processing capacity with raw material supply and are, therefore, less adversely affected by raw material shortages than large-scale food industries. Omulo (2016) found that value addition of traditional vegetables and establishment of an amaranth grain milling plant in western Kenya resulted in women farmers marketing their produce better, with significantly increased incomes and subsequent purchasing power.

3.3. Prospects for transformation of nutrition-sensitive AIV value chains

3.3.1. Prospects for transformation of nutrition-sensitive AIV value chains through improved postharvest management

In developing countries, food losses occasioned by poor postharvest management contribute to high economic and nutritional losses (Yahia et al., 2019). As such, postharvest and processing challenges are key bottlenecks to achieving nutrition-sensitive fruit and vegetable value chains (Keding et al., 2013). These observations imply that interventions that improve postharvest management along the value chain would contribute significantly toward food systems transformation, and improving food and nutrition security. Key interventions that can be undertaken toward enhancing nutrition-sensitive AIV value chains through appropriate postharvest management include (i) postharvest temperature control, i.e., appropriate cold chain along the supply chain and storage conditions, (ii) postharvest treatments for sanitation and improving nutritional and health-promoting product properties, and (iii) film packaging (Figure 1).

Essentially, integration of cold chains along the value chain of AIVs is expected to minimize produce losses and enhance



	Harvesting	Postharvest treatments	Packaging	Storage	Transportation & distribution	Wholesale & Marketing
Current status in AIV Value chains		• Vegetables placed under shade • Sprinkling with cold water • Washing with fresh water at farmgate	• Plastic based bags used • AIVs not packaged but tied in bundles	• Open storage under shades, trees or house shades	• Non-specialised local public means, bicycles, tricycles ("Tuk-Tuk"), and produce pickup trucks.	• Open wholesale and retail markets in rural areas, no cold storage and no packaging applied • For urban retail supermarkets, refrigeration is available
Interventions & consequences for NSVCs		• Maintaining cold chain along the supply chain. • Postharvest treatments for sanitation include UV-C, LED treatments	• Film packaging • Modified atmosphere packaging	• Cold storage (Evaporative cold storage, solar coolers, and water coolers)	• Refrigerated transport and distribution means.	• Film packaging and modified atmosphere packaging for fresh cut vegetables • Cold storage facilities in the local wholesale and rural retail markets
		✓ Postharvest treatments improve hygiene, safety, nutritional and health-promoting product properties	✓ Better packaging preserves nutritional quality, extends shelf life, and ensures food safety	✓ Cold storage extends shelf life and preserves nutritional quality	✓ Preserves fresh quality, reduces physical deterioration and maintains nutritional quality	✓ Reduces waste, increases shelf life and preserves nutrients

FIGURE 1
Possible intervention points for improved postharvest management in a nutrition-sensitive AIV value chain.

nutritional preservation. For instance, (i) use of passive evaporative cooling systems like charcoal and brick coolers, which have high energy efficiency at low costs (Ambuko et al., 2017); (ii) refrigerated cold rooms and transport means, which may be effective but relatively expensive (Maiorino et al., 2021); (iii) forced-air cooling, the effectiveness of which may be limited by the air flow configuration used, and thus may increase cost (Makule et al., 2022); and (iv) water cooling, including mobile coolers that may be immersion-type, conveyor coolers, and shower-type batch coolers, the costs of which are generally low, but with high energy efficiency (Elansari et al., 2019). These opportunities and advantages notwithstanding, in most developing countries in SSA there is insufficient infrastructure and skills to support the development and integration of low-cost cold chain technologies along agricultural chains (Sipho and Tilahun, 2020), particularly in rural and peri-urban areas where AIVs are predominantly produced.

On the other hand, some postharvest treatments have been shown to have nutritionally beneficial effects on vegetables. For example, Gogo et al. (2018a), showed that postharvest application of UV-C increases shelf life and promotes the nutritional and health-benefiting values of amaranth such as enhanced antioxidant capacity and induced accumulation of flavonoids and phenolics. Similarly, Jin et al. (2021) found a positive influence of light (LED) treatment on shelf life and antioxidant activity of freshly cut amaranth. Even though postharvest treatments of leafy AIVs have not yet been widely applied, research indicates that their application would enhance retention of nutritional value along the chain. It should be further noted that the application of these treatments at large scale or industrial levels is also yet to be demonstrated.

3.3.2. Prospects for transformation of nutrition-sensitive AIV value chains through improved processing and preservation

Limited product diversification, innovation, and value addition in the AIV value chain (Maseko et al., 2018), resulting in a lack of indigenous vegetables in modern commercialized and industrialized markets, has hindered the potential to make them more attractive, convenient, and accessible. Whereas preservation solves the problem of perishability of AIVs, it does not satisfy the needs of consumers who prefer consumption of freshly harvested AIVs. Therefore ways of ensuring that these consumers' needs are met need to be explored (Imathiu, 2021). Further research needs to identify the best methods for maintaining nutrients but at the same time diversifying value-added products using advanced food-processing technologies such as rolling, canning, extrusion, malting, and flaking (Mazike et al., 2022). Refractive window drying—which is used to dry heat-sensitive fresh produce and preserves their nutrients, color, flavor, aroma, and bioactive compounds, as well as the sensory quality—offers the possibility of high-value products from AIVs (Mahanti et al., 2021; Nyaguti et al., 2021). It should be noted that there is still a need to make investments in relatively low-cost, value-addition machinery and in facilitation of the requisite regulatory certification for processors in order to increase the competitive advantage of AIV-based products. Maseko et al. (2018) proposed the broadening of AIV consumption habits by promoting the use of developed vegetable products as snacks and accompaniments to beverages, rather than limiting them to accompanying sauces. Additionally, efforts should be channeled to informing consumers about the benefits of AIVs in order to create demand; to supporting farmers and processors by linking them with markets to ensure supply; and to providing supportive policies to facilitate the strategic positioning of AIVs (Shayanowako et al., 2021).

4. Conclusion

Current postharvest and processing technologies and practices along AIV value chains are limited, making AIVs highly susceptible to quantitative and nutritional losses. However, due to their high nutritional value, they are still very important to a nutrition-sensitive value chain. Transformation of the chain would require development and innovative adaptation of postharvest and processing technologies that are well-suited to the resource and socioeconomic context of AIV value chain actors, essentially considering limitations such as infrastructure, electricity supply, and economic feasibility. Additionally, the limited processing reveals an opportunity for product diversification through improved processing methods. These interventions would ultimately transform the AIV value chain by reducing food loss and food waste, creating more value for the value chain actors, and thus strengthening the chain's capacity to be nutrition-sensitive and to promote rural development. The major limitation of this study however is that we only considered literature published between 2007 and 2022, and only publications in English language were considered.

Author contributions

SE and RB wrote the background relevance of AIVs toward nutrition, conclusion, and abstract. SE wrote the methodology, current practices in postharvest management of AIVs, contextual issues in postharvest management of AIVs, and prospects for transformation of nutrition-sensitive AIV value chains through improved postharvest management. RB wrote section current processing technologies for AIV preservation and prospects for transformation of nutrition-sensitive AIV value chains through improved processing and preservation. AMO, DN, DM, and SH-K revised and edited the whole manuscript. All authors contributed to planning the contents of the manuscript and approved the final version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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