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Safety, regulatory and environmental issues related to breeding and international trade of edible insects in Africa

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Summary

Insect breeding or farming for food and feed is an emerging enterprise that can address the ever-growing demand for protein and curb high unemployment rates in Africa and beyond. However, for the sector to prosper, its value chain needs to be regulated to ensure sustainability and safety for consumers and the environment. Although a few African countries, such as Kenya, Uganda and Rwanda, have promulgated standards on the use of insects as food and feed, greater efforts are needed in other countries, and relevant policies governing the sector need to be formulated.

All over the globe, attention to the regulation of the edible insect sector is increasing, and more investment in the industry is foreseen. Safety issues such as identifying which species should be reared, substrate quality and traceability imposed by importing countries will be critical for expansion of the sector. This paper analyses safety, regulatory and environmental issues related to breeding and international trade of edible insects in Africa and provides case studies and recommendations for sustainable use of insects for food and feed.

Keywords

Animal feed – Enterprises – Global food and nutrition security – Healthy diets – Legislation – Protein – Standards – Sustainable Development Goals.

Introduction

Eating insects is a part of local culture for at least 2 billion people in about 113 countries [1, 2, 3, 4], and Africa accounts for over 120 million insect eaters [5]. Of the 2,111 edible insect species known globally [6], around 500 species have been reported in sub-Saharan Africa [7, 8]. In Africa, edible insects are mainly collected from the wild for household consumption and informal trade [9, 10, 11, 12]. Wild harvesting is unsustainable due to the seasonal availability of insects, habitat change and overexploitation [9]. Eating insects or feeding insects to animals is recommended because of their unique

nutritional profile, which equals or exceeds that of conventional foods [13]. Insects are an excellent source of protein, fatty acids, vitamins and minerals [14]. Besides traditional entomophagy (the practice of eating insects) in some parts of the world, increasing demand for alternative sources of nutrients for humans and animals has fuelled the need to farm edible insects [2, 5, 15].

Farming edible insects ensures continuous supply and offers alternative and cheaper protein sources compared to soy and fish meals [16, 17]. Adopting cost-effective technologies for rearing, harvesting, handling, processing, adding value and packaging is a significant game-changer to ensure constant availability of insect proteins and enhance profit margins for farmers and other stakeholders [7, 8]. Insects grow faster owing to high feed conversion efficiency and have fewer requirements for space and water than many conventional feed species. The carbon footprint of insect farming is much lower than that of conventional farming [2, 4, 18]. Insect farming is gender-friendly [15, 19, 20] and currently there are nearly 1,000 edible insect farms in Africa, with the industry projected to be worth up to US$ 8 billion by 2030 [5]. A recent World Bank report estimates that black soldier fly farming alone has the potential to replace 60 million tons of traditional feed production in Africa annually, leading to 200 million tons of recycled crop waste and 60 million tons of organic fertiliser production as well as creating 15 million jobs [5]. Therefore, the use of insects as food and feed may help to attain some United Nations Sustainable Development Goals and the aspirations of the African Union Agenda 2063 [21].

Although insect farming is considered an emerging enterprise in Africa [5, 15, 22], critical issues in the production chain require undivided attention if the sector is to prosper. Key among these is safety, within which the most debated issues are food hazards commonly associated with edible insects and their by-products. These issues may be related to how the insects have been reared, euthanised, handled, processed or packaged. Biological agents and chemical contaminants are among major health hazards associated with edible insects [2]. Safety issues surrounding insects for food and feed cut across environmental concerns, health, agriculture and trade.

Food safety regulations on edible insects are not fully realised in Africa owing to a wide range of challenges [23]. These challenges include: lack of awareness of the socio-economic dimension of food safety; lack of established hazard and critical point checklists/systems; limited data and information on health burden, especially food-borne diseases; limited compliance with international agreements on food safety and quality standards; limited enforcement of local, regional and international standards and global best practices; limited resources to support scientific risk analysis and upgrading of food safety regulatory systems; and poor food supply chains and traceability systems.

Several authors have acknowledged the lack of regulatory frameworks specific to insect farming and the use of insects as food and feed in many countries [18, 24, 25]. There is also a lack of harmonisation to improve policy and strengthen the trading environment, especially market linkages, to reduce constraints along the insect-based value chain [25]. Several regulatory bodies are nominally in charge; however, procedures and the motivation behind these safety measures on food are often unclear, are overlooked or fail to capture specific matters that concern the farming of insects as 'mini-livestock'. The lack of understanding of these regulatory and legislative measures vis-à-vis the diversity of edible insects (which belong to several insect orders with very different life cycles) hampers the sector. The objective of

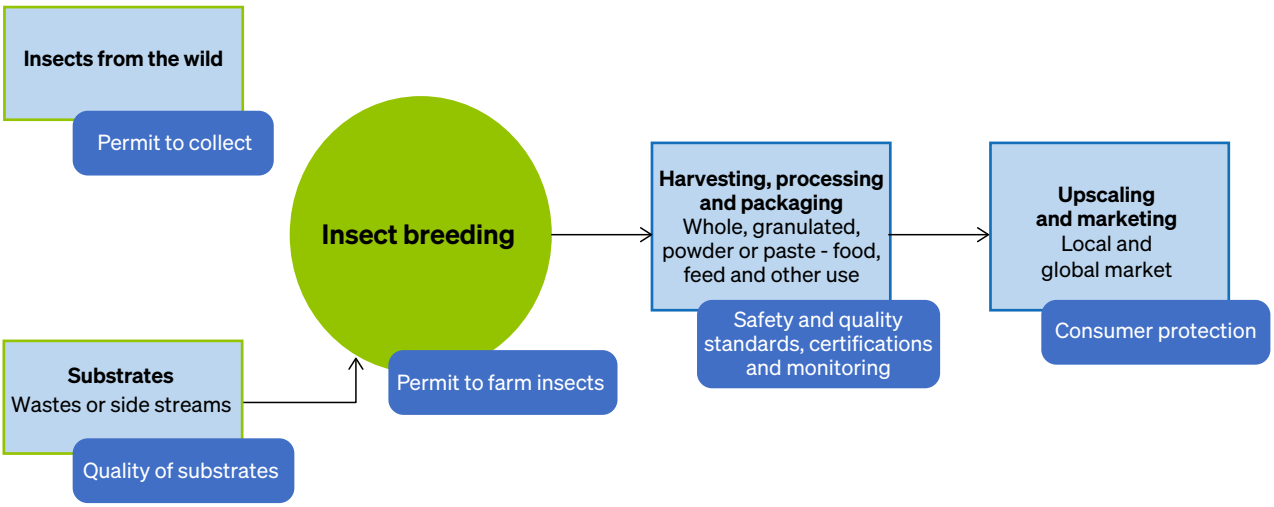


Figure 1

Classical flow chart for insect collection and production chain and regulatory issues in relation to safety

the present paper is to analyse the regulatory elements that govern safety issues in edible insect farming for national and international trade and provide an overview of legal procedure flow among regions and countries in Africa. The production chain and safety and regulation in relation to the environment and trade are summarised in Figure 1.

Environment-related issues

Over 500 insect species in Africa are recognised as edible, including crickets, grasshoppers, beetles, ants, termites, bees, locusts, caterpillars, cicadas, scale insects, planthoppers, dragonflies and leafhoppers, among other groups [4, 6, 7, 26]. These are mostly used as supplementary food items and provide significant nutritional and economic benefits to rural and urban communities [9]; although limited by seasonal availability, edible insects form an essential part of cultural diets. Most edible insect species are collected from the wild. Only a few species are commonly farmed in Africa and other parts of the world. For instance, cricket farming has been practised in Asia, Europe, the United States of America and Australia for decades and was introduced in African countries (Kenya, Uganda, Mali and Madagascar) around 2013 [27, 28].

The most critical environmental questions regarding edible insects relate to the right and the capacity to farm insects for commercial purposes and where to farm them. Given that insects are wildlife, they appear in the laws of many countries as natural resources, making it mandatory in most cases to obtain a permit and/or licence from competent authorities for exploitation [29]. Grabowski *et al.* [29] state that, except for Botswana, edible insects are not mentioned in national regulations, an omission that creates a complex, nation-specific situation as to which insects may be used legally and for what purpose. Regarding collecting insects from the wild, many countries, including those in East Africa, already have robust legislation that could be applied to insects [29]. Beyond overexploitation and the potential pest nature of insects, the correct taxonomic identity of insects to be farmed is also an important safety question that needs legal attention. The number of edible insect species represents a minor fraction of the total number of insect species.

Eating insects is often part of a community's cultural heritage and, following many generations of insect-eating, such communities have developed a deep knowledge of valuable insects. The existing lists of edible insects are not exhaustive as new edible species are frequently reported. Although culturally, gatherers, collectors and foragers identify insects based on the smell, sound, season and host plant [30], it is critical to establish national catalogues and guidelines to identify insects for consumption and/or farming. There is a need to profile insects that could be consumed and mass-reared to avoid misidentification (as some insects can be poisonous) and overexploitation.

Health-related issues

Pathogenic risks in edible insect farming systems and biological hazards

Various microorganisms may jeopardise the quality and safety of edible insects as food and feed, in some cases even posing a risk to human and animal health. While insect pathogens do not, in general, pose any threat to humans or vertebrate animals [31], other microorganisms in edible insects and insect-based products may enter the production chain via contaminated substrates and poor hygienic practices during production, handling, harvesting, storing, processing and packaging. Eilenberg *et al.* [32] outlined the necessity to distinguish clearly between insect pathogens, which are host-specific and thus can cause epidemics, and other unwanted microorganisms, which are opportunistic and can cause increased mortality and food contamination.

Insect pathogenic viruses are true specialists that pose a risk to the insects in production but not to humans or other vertebrates [33]. An epizootic outbreak of the cricket paralysis virus, *Acheta domesticus* densovirus (AdDNV), in commercial cricket farming facilities was reported in Europe and North America [34]. Although some species of crickets, including the European field cricket (*Gryllus bimaculatus*) and Jamaican cricket (*Gryllus assimilis*), are reportedly resistant to AdDNV [34], there is a need to establish early detection of the disease to prevent outbreaks of this pathogen in other regions, especially in Africa. Insect pathogenic viruses are not a concern for human health as they are host-specific to insects. Bacterial species belonging to the genera *Bacillus*, *Staphylococcus*, *Erwinia*, *Pseudomonas*, *Micrococcus*, *Lactobacillus*, *Acinetobacter*, *Streptococcus* and *Clostridium* have been widely associated with edible insects [2]. For instance, Leonard [35] identified five bacterial species (*Proteus penneri*, *Serratia marcescens*, *Bacillus thuringiensis*, *Staphylococcus sciuri* and *Enterococcus faecalis*) associated with long-horned grasshoppers (*R. differens*). During rearing, these bacteria can cause 53% to 66% mortality in third instar nymphs of *R. differens* [35]. Some of these bacteria are opportunistic and can even be potentially pathogenic to humans and livestock and can also reduce the shelf life of edible insect products. Endospore-forming and heat-resistant bacteria are also of major concern. High loads of microbial pathogens will raise health concerns and consequently affect the consumption and sale of edible insects and insect-based products at the local, national, regional and international scale. Food-spoilage fungi can lead to physical and nutritional quality loss and threaten consumers' health. Leonard [35] identified nine species (*Candida lusitaniae*, *Lichtheimia corymbifera*, *Trichoderma koningii*, *Fusarium equisetic*, *Mucor fragilis*, *Aspergillus niger*, *Epicoccum sorghinum*, *Clonostachys rosea* and *Penicillium commune*) that can cause significant mortality (60% to 86%) of third instar nymphs of *R. differens*. Additionally, harmful

yeasts *Candida*, *Pichia*, *Tetrapisispora* and *Debaryomyces* and pathogenic moulds *Aspergillus*, *Wallemia*, *Fusarium*, *Penicillium*, *Cladosporium*, *Phycomyces* and *Alternaria* may be present on the surface of edible insects reared, processed or packaged in hygienically poor conditions [2, 14].

If not hygienically handled, processed, stored or packaged, edible insects become vulnerable to moulds, especially *Aspergillus*, *Fusarium* and *Penicillium*, which produce mycotoxins that have a negative effect on human and animal health [36, 37]. Wastes or side streams such as agricultural materials, mainly grains and nuts used to feed the insects, may contain mycotoxigenic moulds or mycotoxins. These moulds and mycotoxins can reduce the survival of insects and accumulate in the final products [36]. Mycotoxins that can be traced in edible insects and their by-products include aflatoxin, zearalenone, ochratoxin, fumonisins and deoxynivalenol [36, 38, 39]. However, although these mycotoxins may be present in edible insects, they should not exceed the permissible level provided by the European Union (EU) [40].

The presence of protozoan parasites in edible insects is associated with the substrate quality and the processing they undergo [2]. Protozoans such as *Entamoeba histolytica* and *Giardia lamblia* have been found in edible insects [2]. *Coccidia* spp. can also be found in edible insects, especially those reared on poultry manure as feed substrate [2].

Pesticide residues and toxic, trace metals

Pesticide residues and toxic metals in reared insects can be associated with particular insect species, their source before being reared, the source and type of substrates used and contamination of the rearing unit [2, 39]. For instance, the bioaccumulation of cadmium has been reported in crickets and the black soldier fly (*Hermetia illucens*), as has arsenic in yellow mealworms (*Tenebrio molitor*) and lead in *R. differens* [39, 41, 42]. Prior to consumption, edible insects should not exceed certain maximum permissible levels of heavy metals (lead, cadmium, arsenic and mercury) and trace metals (iron, manganese, copper and magnesium) [2]. High concentrations of cadmium and mercury have been reported in yellow mealworms reared on substrates from treated agricultural side streams that accumulate fungicides (myclobutanil, diniconazole, metalaxyl, benalaxyl and epoxiconazole) [2].

Other substances

According to the Food and Agriculture Organization of the United Nations (FAO) [2], edible insects and insect products may contain, accumulate or release toxic substances. These substances include bioaccumulated organic compounds (organic contaminants, plasticisers and halogenated flame retardants), dioxin-like polychlorinated biphenyls, histamines and high levels of mineral oil hydrocarbons. Other undesirable contaminants such as antimicrobials, allergens and inherent anti-nutritional substances (phytic acids, tannins, saponins, phenolics, thiaminase, cyanogenic glycosides and oxalates) may accumulate in edible insect products during production and processing [2]. Poorly processed and packaged edible insect products may contain undesirable objects and hard parts of the insect such as wings, rostrum, stings and spines.

Allergies from eating insect-based products

Insects and crustaceans are related members of the phylum Arthropoda. Since allergic reactions to crustaceans are potentially severe, cross-reactivity and co-sensitisation of the immune system between edible insects, crustaceans and mites pose a potential health concern [43].

Food allergy due to consumption of edible insects has been described for silkworms, mealworms, caterpillars, locusts, grasshoppers, cicadas, bees and sago worms [45]. Indeed, cases of cross-reactivity/co-sensitisation between edible insects and crustaceans leading to food allergy have been clinically relevant, with an unknown underlying molecular mechanism attributed to allergens, specifically arginine kinase [44 and references therein]. There are opportunities for further research on allergies resulting from eating insects, including diagnostic allergy tests that could lead to the identification of vaccines.

National, regional and international regulatory frameworks for edible insects

As insect farming gains prominence, questions on safety are becoming increasingly important. Countries that are known to practise entomophagy lack regulatory policies for the food and feed sector that could potentially benefit insects. These countries rely on a precautionary approach or on information from the World Health Organization and FAO on insect-based diets [18]. Most studies have clearly shown that there are more stringent rules on the use of insects as novel food and feed ingredients in countries with no history of entomophagy but with food policies that prioritise food safety [18, 46]. Country-specific regulations have also been formulated in some countries [47].

Traditionally, collected insects are eaten raw, dried, roasted, smoked, stewed, fried or boiled. Certain additives (e.g. salt, honey and spices) can enhance palatability and shelf life during storage. Insects are consumed whole, degutted or transformed into powder or paste. These indigenous methods of handling insect products are often substandard in terms of food safety [11, 37].

Insect entrepreneurs are becoming increasingly accountable for issues relating to sources of their insect products,

equivalence and instrumentation used. Equivalence implies that a unit of insect products in a specific location or from a certain producer is the same as a unit from anywhere in the entire geographical area and costs the same. Achieving equivalence requires adequate instrumentation, usually handled by the Ministry responsible for trade or industry, to protect the consumer's interest. Over time, efforts have been made to develop these parameters; since insect farming starts from choice of substrate, substrate homogeneity and growth parameters are essential for insect production as these aspects determine the final product's nutritional value and hence its commercial value. On the other hand, there might be genetic variabilities in insects' performance, which could inspire breeding initiatives for more profit.

Based on food safety, insects as food and feed should be free from biological, chemical and allergenic compounds that are potentially harmful to humans and animals [48]. Edible insects should be free of or should have the minimum recommended levels of toxigenic and pathogenic fungi (*Aspergillus*, *Fusarium* and *Penicillium*), bacteria (*Staphylococcus*, *Bacillus* and coliforms) and heavy metals (chromium, lead and cadmium) [49, 50]. These legal regulations should guide trading, ensuring insects are sustainably harvested from the wild to limit overexploitation or sustainably farmed and marketed freely countrywide, regionally and globally. Considering food safety, consumer acceptability and environmental sustainability, legal regulations can be tailored to culture and/or harmonised regionally or globally.

In Africa, standards have been developed in Malawi, Tanzania, Kenya and Uganda [48]. Moreover, these countries have set the stage for benchmarking by other African countries. Rwanda is currently drafting similar standards to support individuals and industry players interested in edible insects to invest in the sector. These standards do not restrict the insect types or substrates for rearing.

With the increased globalisation of food markets, African countries should have internationally recognised food standards to participate in international trade. Most African countries rely on traditional food control systems, and food safety legislation aligning with international requirements, namely the *Codex Alimentarius*, has been the least adopted [51]. Thus, the World Trade Organization/Sanitary and Phytosanitary (WTO/SPS) Agreement specifies national standards that agree with the *Codex*. Additionally, good hygienic practices, good manufacturing practices, and use of the hazard analysis and critical control points (HACCP) system are recommended to ensure food safety and quality assurance in the region [51]. The FAO [2] has partnered with regional economic communities and trading blocs – namely, the Common Market for Eastern and Southern Africa, the East African Community, the Southern African Development Community, the Economic Community of Central African States, the West African Monetary and Economic Union, the Central African Economic and Monetary Community and the Economic Community of West African States – to assess national food control systems and to strengthen food trade, national SPS capacity, functioning of international standard-setting bodies, regulatory cooperation policies, leveraging private sector engagement and harmonising food standards to include COVID-19-related protocols. Jaffee *et al.* [52] provide an executive summary of a situation analysis, reporting that most African countries can be considered to be in either 'traditional' or 'transitioning' stages towards 'modernising' food systems. While African countries are in the 'transitioning' stages of recognising edible insects as 'foodstuffs' or 'animal feed', it is expected that most existing food laws and policies would apply to edible insects as well.

Edible insects are not listed in the *Codex Alimentarius*, which is considered a global problem [53]. There are limited attempts to incorporate diversity of edible insects into the *Codex*, especially food safety aspects [54]. Until they are added to the *Codex* as foods rather than impurities, there will be an insurmountable barrier to becoming legally well-accepted foodstuffs, regardless of what consumers accept. Another international food safety management system, HACCP, provides an international guideline that is systematic and science-based to regulate food safety, especially microbial load, throughout the food chain. It has been adopted widely by regulatory authorities because of its perceived benefit in increasing international food trade [47].

Several regional regulations and regulatory bodies have been established to address edible insects. For example, EU regulations under the European Food Safety Authority were established by the European Commission to regulate food safety for edible insect-based products in the European market [55]. The EU considers farmed insects livestock and therefore applies livestock health and biosecurity measures and regulations to farmed insects [2]. So far, only seven insect species – *H. illucens*, *Musca domestica*, *T. molitor*, *G. assimilis*, *Alphitobius diaperinus*, *G. sigillatus* and *A. domesticus* – have been authorised as feed for farmed and companion animals in EU markets [53, 56]. Applications for authorisation as 'novel foods' have been made for about 17 insect species. In 2021, the migratory locust (*Locusta migratoria*), the cricket *A. domesticus* and the yellow mealworm were the first insects authorised by the EU as 'novel food' for human consumption and marketing [57]. The lesser mealworm *A. diaperinus*, the cricket *G. sigillatus*, the black soldier fly and the honey bee drone brood *Apis mellifera* (male pupae) are at an advanced stage of authorisation [57].

However, in the case of EU standards, insect species used for food and feed must be reared on a substrate that fulfils certain prescribed safety conditions for insect production [53, 56, 57]. According to the EU, insects used as food and feed

should not be reared on waste streams [2, 57]; however, insects meant for biomass conversion for economic gains can be reared on waste streams [2]. Though EU restrictions are designed to eliminate the risk of prion contamination of edible insects, those restrictions limit the use of insects to close nutrient loops, which is also the case for Africa. Thus, policies and laws are needed that allow insect harvesters, small- and large-scale insect farmers and processing industries to obtain accreditation and market their products [48].

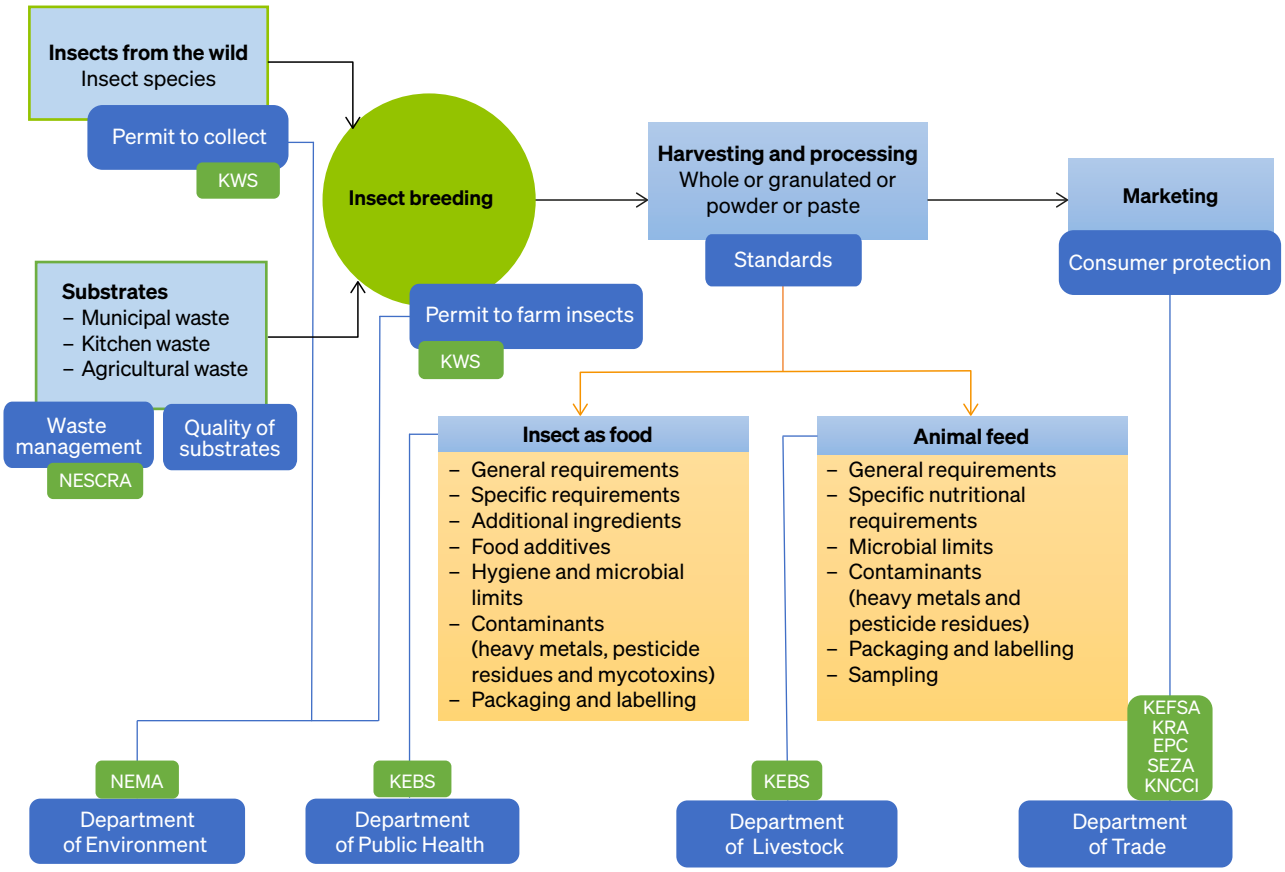
Comparative regulatory framework on edible insects in Kenya, South Africa, Zimbabwe, Nigeria, Cameroon, Zambia, Ghana and Burkina Faso

Kenya

The Government of Kenya has ensured that safe food trade practices are consistent with WTO/SPS measures and other international standards [58]. Kenya has agencies that implement food laws operating under the Ministries of Public Health and Sanitation; Industrialization, Trade and Enterprise Development; Agriculture, Livestock and Fisheries; and Environment and Forestry. These agencies include the Kenya Bureau of Standards, Weights and Measures Department, Kenya Agricultural and Livestock Research Organization, Department of Public Health (DPH) and Kenya Food Safety Authority [59]. The regulation of the insect production chain in Kenya is summarised in Figure 2.

Food safety is part of a broader national food and nutrition policy [58]. The Ministry of Health and Sanitation coordinates the food safety legal frameworks through the DPH. These legal frameworks guide provisions on food safety measures along the food chain (farm to fork); the nature, substance and quality of food; packaging, labelling and advertising; and food standards. The DPH oversees the enforcement of the Public Health Act and the Food, Drugs and Chemical Substances Act.

Different authorities have formulated the Kenya Environmental Sanitation and Hygiene Policy (KESHP), among them the Ministry of Health, the Environmental Sanitation and Hygiene Inter-Agency Coordinating



EPC: Export Promotion Council
KEBS: Kenya Bureau of Standards
KEFSA: Kenya Food Safety Authority
KNCCI: Kenya National Chamber of Commerce and Industry
KRA: Kenya Revenue Authority
KWS: Kenya Wildlife Service
NEMA: National Environment Management Authority
NESCRA: National Environmental Sanitation Coordinating and Regulatory Authority
SEZA: Special Economic Zones Authority

Figure 2

Regulatory procedure for the insect collection and production chain and emergencies in relation to safety in Kenya

Committee, all 47 county health departments, the Ministry of Environment and Natural Resources, and the National Environment Management Authority (NEMA) [60]. The national government and the Ministries of Health, Environment and Natural Resources, trade and industry, and county governments, through collaboration with the National Environmental Sanitation Coordinating and Regulatory Authority, NEMA and the Water Services Regulatory Board, are mandated to ensure implementation of KESHP for solid and liquid waste management [60]. The county governments have been vested with the responsibility of implementing the food safety and hygiene aspect of KESHP through controlling sale of prepared foods, ensuring that market facilities for handling, display and preservation of meat, fish and other perishable foods meet the required hygienic standards to prevent contamination and decomposition, and regularly inspecting all food outlets and slaughterhouses [60].

The Kenya Bureau of Standards (KEBS) has been mandated to practically ensure that food standards meet the international standards of the International Organization for Standardization and the Codex Alimentarius Commission, following the philosophy of WTO/SPS. The KEBS, in consultation with other relevant agencies through an established technical committee, has issued standards for insects used as food and feed. These standards provide specific requirements for the edible insect as a whole insect, an insect product and powdered insect products either sourced from domesticated farms or wild.

The KEBS (via Kenya Standard [KS] 2922-1:2020 and KS 2922-2:2020) requires that edible insect products meet a set of general and specific requirements and specifications of additional ingredients [61]. The standards specify the inclusion of approved food additives, hygiene of prepared and packaged products, and limits of pathogenic microbes and contaminants (heavy metals and mycotoxins) in dried insect products [61]. Packaging and labelling should practically conform with the Weights and Measures Act and Standards Act with adherence to the following specifications: KS EAS 38 (Labelling of pre-packaged foods), KS EAS 803 (Nutrition labelling), KS EAS 804 (Claims) and KS EAS 805 (Use of nutrition and health claims) of the laws of Kenya [61]. Additionally, the use of insects as animal feed follows standards set by Kenya in 2016 (KS 2711:2016) that recognise insect products as either whole, ground or defatted insect meal [62]. The standards specify the general requirements, nutritional requirements and microbial requirements; limits of heavy metals, pesticide residues and aflatoxins; requirements for packaging and labelling; and a sampling procedure to ensure compliance. A code of practice for producing and handling insects for food and feed (KS 2921:2020) has also been published [63]. The code specifies requirements for sustainable establishment and operation of wild-harvested or domesticated insect farming, production, harvesting and post-harvest handling of insects for food and feed.

The Ministry of Industrialization, Trade and Enterprise Development creates an enabling environment for a globally competitive, sustainable industrial, enterprise and cooperative sector through appropriate policy, legal and regulatory frameworks. The Ministry collaborates with other agencies, such as the Kenya Revenue Authority, the Special Economic Zones Authority, the Export Promotion Council and the Kenya National Chamber of Commerce and Industry [64]. Formulation of the national trade policy has enhanced Kenya's efficiency in domestic, regional and international trade [64].

Collection, transport and farming of edible insects must conform with the Wildlife (Conservation and Management) Act, which protects and conserves wildlife in Kenya. Harvesting insects from the wild for large-scale farming requires permission from the Kenya Wildlife Service. Before a permit is issued, the requestor must provide an order of conformity to wildlife domestication processes and approval of livestock transport and the method of transport. The Ministry of Environment through NEMA may also regulate policies related to the environment through the 1999 Environmental Management and Co-ordination Act.

South Africa

In South Africa, four government departments oversee food safety and quality legislation (Table I). Niassy *et al.* [24] analysed the legislation flow in South Africa. The status quo remains, and insect farming, especially of the black soldier fly, is gaining momentum and a regulatory framework is needed to support this.

Zimbabwe

The Ministry of Environment and Tourism of Zimbabwe has comprehensive environmental legislation concerning environmental issues, including the 1941 Natural Resources Act; 1949 Forest Act, covering control of trade in forest produce and illegal use of forest resources; Environmental Management Act, on management of natural resources and protection of the environment; and Parks and Wild Life Act, on the preservation, conservation, propagation and control of wildlife, fish and plants. These regulations apply to wild-harvested edible insects. The Forest Act regulates the harvest of wild-harvested insects. This Act is supported by the country's cultural heritage law, which empowers traditional chiefs to govern the collection and trade of edible insects within their areas of jurisdiction. This law is closely connected to the conservation of habitats, including forests and water bodies, through the Environmental Management Act and the Parks and Wild Life Act, implemented by the Environmental Management

Table I

Legislative bodies and legislation related to edible insects in South Africa

Department	Responsibilities	Acts/Laws
Department of Agriculture, Land Reform and Rural Development	Regulates safety and quality of agriculture and animal products	Agricultural Product Standards Act, 1990 Animal Diseases Act, 1984 Animal Identification Act, 2000 Animal Improvement Act, 1998 Animals Protection Act, 1962 Fertilizers, Farm Feeds, Agricultural Remedies and Stock Remedies Act, 1947 Meat Safety Act, 2000 Performing Animals Protection Act, 1935
Department of Health	Ensures all foodstuffs for human consumption are safe. Also acts as a contact point for Codex and therefore has adopted standards and guidelines provided by Codex Alimentarius Commission	Foodstuffs, Cosmetics and Disinfectant Act, 1972, which specifies the manufacturing, labelling, sale and importation of foodstuffs National Health Act, 2003, which addresses the hygiene aspect of foodstuffs International Health Regulations Act, 1974, which provides hygiene requirements of foodstuffs at ports and airports
Department of Trade and Industry	Acts through the South African Bureau of Standards to control foodstuffs such as canned meat, fishery, meat and other animal products	Standards Act, 1993

Agency and the Parks and Wildlife Management Authority, respectively.

The Ministry of Health and Child Care is mandated to ascertain the quality and safety of food through a number of acts. The Public Health Act provides that all abattoirs must be registered and that slaughtering of all animals and birds meant for human consumption should be licensed by the local authority. All premises involved in the sale, manufacture, production, processing or treatment of food are inspected and certified in accordance with the Food and Food Standards Act. The Standards Association of Zimbabwe (SAZ) has set safety standards for regular foods. It regulates the quality, risks and hazards associated with food and feed and monitors residue levels (heavy metals), critical microbial levels, packaging and adherence to shelf-life recommendations.

Several studies are currently under way to develop policy recommendations regarding insects as food. There are no specific standards for edible insects in Zimbabwe; however, standards related to regular food would apply to edible insects.

The AgriFoSe2030 programme project on edible insects for food in Zimbabwe is working with SAZ to generate scientific evidence for informing food standards guidelines for four insect species, namely the mopane worm (*Imbrasia belina*), termites *Macrotermes* spp. (alates and soldiers), edible beetle *Eulepida mashona* and the edible stink bug (*Encosternum delegorguei*). Recommendations will be made in relation to specific harvesting, processing, packaging and consumption practices.

The National Biotechnology Authority plays an oversight role in monitoring all food consumed in Zimbabwe for contamination by genetically modified substances.

Concerning insects as feed, the Ministry of Lands, Agriculture, Fisheries, Water, Climate and Rural Resettlement regulates registration of animal feeds, including those with insect proteins. The same Ministry issues export and import permits for edible insect trade.

Nigeria

Usman and Yusuf [25] noted that Nigeria, the most populous country in Africa and one with a rich diversity of edible insects, has no specific regulations on use of insects for food and feed, although over 20 species are reportedly consumed in the country. However, several Ministries, departments and agencies could regulate the safety of insects as food. The Federal Ministry of Health is at the forefront in formulating national policies, guidelines and regulations regarding food safety and quality. Food quality and safety, general public health surveillance and complaints in the 36 states of Nigeria are supervised by the state Ministries of health in collaboration with the local government authorities [23]. Other Ministries, including the Federal Ministry of Industry, Trade and Investment, Federal Ministry of Environment and Federal Ministry of Science, Technology and Innovation, are also critical in regulation related to edible insects (Table II).

To develop a clear and comprehensive framework for policies on edible insects in Nigeria, Usman and Yusuf [25]

Table II

Legislative bodies and legislation related to edible insects in Nigeria

Ministries/ Departments	Agencies	Responsibilities	Acts/Laws
Federal Ministry of Health	National Agency for Food and Drug Administration and Control (NAFDAC) is one key food regulatory body established by Decree 15 of 1993 (now NAFDAC Act Cap N1 Laws of Federal Republic of Nigeria, 2004)	Regulates and controls the importation, manufacture, exportation, advertisement, distribution, sale and use of food, drugs, cosmetics, chemicals, detergents, medical devices and packaged water. In 2013, NAFDAC created the Directorate of Food Safety and Applied Nutrition to intensify food control activity and professionalism [23]	Food and Drugs Act
	National Primary Health Care Development Agency	Mandated to provide education on approved methods of food preparation, handling, consumption and food and nutritional security needs for healthy lives	Public Health Services Acts
Federal Ministry of Industry, Trade and Investment	Standards Organisation of Nigeria (SON)	Complements the mandate of NAFDAC by specifying standards for packaging materials. Standardises and regulates the quality of all products in Nigeria	SON Act No. 14, 2015
	Federal Produce Inspection Service	Supervises the exportation of agricultural commodities, including checking on quality, weight, fumigation and packaging standards	Produce (Enforcement of Export Standards) Act
Federal Ministry of Environment	National Environmental Standards and Regulations Enforcement Agency (NESREA)	Protects the environment by conserving biodiversity and natural resources through enforcing environmental standards, regulations, rules, laws, policies and guidelines	NESREA Act, 2007 (now Cap. N164, Laws of Federal Republic of Nigeria, 2010)
Federal Ministry of Science, Technology and Innovation	Federal Institute of Industrial Research Oshodi, Sheda Science and Technology Complex and National Biotechnology Development Agency	Provide scientific research and developmental support to food safety policies, linkages and programmes; develop innovative technologies for food processing and handling	
	Federal Competition and Consumer Protection Commission (previously Consumer Protection Council)	Creates consumer awareness, protects consumers from unscrupulous practices and exploitation, and bans the sale of unsafe foods	Consumer Protection Council Act, 2004

proposed a top-to-bottom approach involving all stakeholders, consolidating players and government departments/ agencies that should deal with such legislation to ease its implementation.

Cameroon

Cameroon's biodiversity is among the richest in Africa, and the country is a hotspot for edible insect consumption [7, 65, 66]. While insect rearing is rapidly gaining interest as both feed (black soldier fly for fish farming) [67] and food (palm weevil grubs), legislation is silent and not adapted to the strong trend observed in urban regions. Laws mentioning safety inspection of animal products are old (1986 and 2000), resulting in the failure of businesses to meet regulatory standards for export, although Cameroon has been a major player in non-timber forest products since the enactment of the 1994 Forestry Law. Food system regulations copied from Western philosophy need to be customised and adjusted for sustainable livelihoods.

Zambia

Insect trade in Zambia is a reliable alternative source of income and livelihood for rural and urban communities [68]. Mopane worm caterpillars could contribute up to 62% of total income for rural households [69]. Stull *et al.* [70] have emphasised the nutritional value of insects and the need for insect farming to alleviate poverty. However, insect farming is very much in its infancy. A conducive regulatory environment is crucial to ensuring the safety of insects as food and feed.

Despite its high diversity of edible insects, Zambia has no specific regulations on the use of insects as food and feed. Several institutions can deal with the regulatory aspects. Among them, the Zambia Environmental Management Agency issues environmental certificates, permits and approvals, undertakes environmental monitoring in case of overharvesting of insects by cutting trees and branches, and enforces regulations; the National Biosafety Agency can also attend to such matters, as can the Ministry of Agriculture and Cooperatives.

Recently, the New Deal government introduced a Ministry of Green Economy and Environment. This is the most appropriate and promising Ministry to deal with regulatory framework issues on the environment, insect farming and trade of insects as food and feed in the country.

Ghana

In Ghana, there are nine major edible insects: the African palm weevil larvae (*Rhynchophorus phoenicis*), termite *Macrotermes bellicosus*, ground cricket *Scapteriscus vicinus*, field cricket *Gryllus similis*, house cricket *A. domesticus*, grasshopper *Zonocerus variegatus*, locust *L. migratoria*, and beetles *Cirina butyrospermi* and *Phyllophaga nebulosa* [13, 71]. However, the production of these insects in Ghana is on a small scale. In most areas in Ghana, insects are commonly consumed as food, and some people have expressed food safety concerns about eating insects. The Food and Drugs Authority, on the other hand, has implemented regulations that govern the production of novel food items under Section 6 of the 1992 Food and Drugs Act (http://elibrary.jsg.gov.gh). However, Ghana's environmental protection agency lacks measures that govern and regulate insect farming.

Burkina Faso

Edible insects are considered non-timber forest products and regulated under forest and environmental legislation. However, the legislation is not specific to edible insects given that most edible insects are considered pests that do not require protection. Indeed, the *C. butyrospermi* caterpillar, also referred to as 'Chitoumou', is a pest to the shea butter tree, and its collection and processing as traditional food are accepted. Therefore, there are no food system regulations that incorporate insects. As in Ghana, the only safety requirement for trading edible insect products is to provide laboratory test results and a registration certificate. The importing entity is left with most of the responsibility during importation into international markets.

The Insects as Feed in West Africa project implemented by CABI aimed to develop appropriate fly larvae and termite production and utilisation methods for smallholder farming systems in Burkina Faso, based on waste material. The project also attempted to engage stakeholders, the general public, the scientific community and policy-makers to share innovation. However, insect farming for food and feed is in its infancy; hence, comprehensive regulation is required.

Conclusions

The safety issues related to insect farming are at the junction of environmental, social, health and economic concerns. This study reveals that most African countries have not developed safety regulations for insect breeding, although legal instruments pertaining to food laws would be relevant. The EU has introduced legislation specific to the type of insect and the substrate quality used to farm insects as food or feed. In Africa, Kenya, Uganda, Tanzania and Malawi are exceptions in having standards for use of insects as food and feed. This encouraging step may serve as an example, but the law is not adapted to the complexity of the production chain, and the socio-economic aspects that govern the introduction of insects in the food system are not taken into account. The lack of enforcement and capacity to enforce are also major issues.

Safety concerns may require regulations in terms of capacity and location to protect community safety through certification. Benin's certification process through the Agence Béninoise de Sécurité Sanitaire des Aliments (ABSSA) is one of the most comprehensive examples, encompassing all the safety dimensions of the insect food or feed production chain (environment, health, agriculture and trade) to protect the consumer. Under the ABSSA process, an entrepreneur undergoes three technical visits as well as sampling and testing of the products, after which a certificate is issued.

Insect farming has bright prospects in Africa, as it is an efficient response to the global market for low-cost alternatives to protein and youth unemployment. The findings of this study should encourage national and regional food systems to integrate safety measures in insect farming into food and feed regulations, borrowing from emerging countries such as Kenya and Uganda, while harmonising these policies at the global level for a more dynamic sector.

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Questions de sécurité et enjeux réglementaires et environnementaux liés à l'élevage et au commerce international d'insectes comestibles en Afrique

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Résumé

Les élevages et les fermes d'insectes destinés à l'alimentation humaine et animale sont de nouvelles entreprises qui pourraient répondre à la hausse continue de la demande en protéines tout en réduisant les taux élevés du chômage en Afrique et ailleurs. Néanmoins, pour que ce secteur puisse prospérer, sa chaîne de création de valeur doit être réglementée afin de garantir sa durabilité et son innocuité pour les consommateurs et l'environnement. Si un petit nombre de pays africains dont le Kenya, l'Ouganda et le Rwanda ont élaboré des normes applicables à l'utilisation des insectes pour l'alimentation humaine et animale, dans d'autres pays les efforts doivent se poursuivre et des politiques appropriées doivent être mises en place pour régir ce secteur.

Partout dans le monde, la réglementation du secteur des insectes comestibles fait désormais l'objet d'une attention considérable et des investissements accrus dans la filière sont attendus. Les questions de sécurité telles que l'identification des insectes à élever, la qualité du substrat et la traçabilité exigée par les pays importateurs seront cruciales pour le développement du secteur. Les auteurs analysent les questions de sécurité et les enjeux réglementaires et environnementaux liés à l'élevage et au commerce international d'insectes comestibles en Afrique et présentent des études de cas et des recommandations pour une utilisation durable des insectes destinés à l'alimentation humaine et animale.

Mots-clés

Alimentation animale – Alimentation saine – Entreprises – Législation – Normes – Objectifs de développement durable – Protéine – Sécurité alimentaire et nutritionnelle mondiale.

Cuestiones reglamentarias, ambientales y de inocuidad, relacionadas con la cría y el comercio internacional de insectos comestibles en África

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Resumen

La cría o producción de insectos con fines de alimentación humana o animal es una actividad incipiente que puede ayudar a responder a la siempre creciente demanda de proteínas y a contener las elevadas tasas de desempleo de África y otras regiones. Para que el sector prospere, no obstante, es preciso reglamentar su cadena de valor a fin de asegurar su sostenibilidad y su inocuidad para el consumidor y el medio ambiente. Aunque unos pocos países africanos, como Kenia, Uganda o Ruanda, tienen promulgadas normas sobre el uso de insectos para la alimentación humana o la producción de piensos, aún hay que redoblar esfuerzos en otros países y formular políticas que ordenen el sector.

En todo el planeta se presta hoy una atención sin precedentes a la regulación del sector de los insectos comestibles, un sector que previsiblemente va a recibir cada vez más inversiones. Las cuestiones ligadas a la inocuidad, como la identidad de los insectos que se van a producir, la calidad del substrato o la rastreabilidad impuesta por los países importadores, serán fundamentales para el desarrollo del sector. Los autores analizan las cuestiones reglamentarias,

ambientales y de inocuidad que se plantean en relación con la cría y el comercio internacional de insectos comestibles en África, presentan ejemplos concretos y formulan recomendaciones para un uso sostenible de los insectos con fines de alimentación humana o animal.

Palabras clave

Alimentación saludable – Empresas – Legislación – Normas – Objetivos de Desarrollo Sostenible – Piensos animales – Proteína – Seguridad alimentaria y nutricional mundial.

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