Legislation and legal frame work for sustainable edible insects use in Nigeria

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Abstract

Insects are vital source of protein, and have many advantages as food and feed, when compared to livestock. They are relatively easy to rear and require only small portion of land (mini livestock), uses less water and feed resources, thus saving agricultural land for growing crops and ensuring less emission of greenhouse gases in the atmosphere. However, lack of clear legislation guiding the rearing, consumption and commercialization of edible insects in most countries Nigeria inclusive, hinder the development of edible insects to levels that their potentials could be harnessed for the benefits of the environment, sustainable development and integration as part of a climate smart and or nutrition sensitive agriculture. Here we showed the diversity of edible insects in Nigeria, motivated for enacting legislation on their uses and suggested a pathway to develop the sector by boasting consumer confidence, upscaling, marketing strategies and exports in a sustainable way.

Keywords: Insect for food and feed, legal framework, sustainable use, Nigeria

1. Introduction

The practice of eating insects, which is known as entomophagy (DeFoliart, 1999) dates as far back as several centuries BCE in ancient Far Eastern civilizations, especially China. Insects are vital source of protein, equivalent in terms of nutritious value to meat, fish, milk, and eggs (van Huis, 2013). Due to their valuable nutritional content, edible insects are used as supplement or alternative to a variety of diets. In addition to their nutritional contents, there are many advantages associated with using insects for food and feed, when compared to livestock. For example, insects are relatively easy to rear and mass produce, require only small portion of land (mini livestock), uses less water and feed resources, thus saving agricultural land for growing crops (Paoletti, 2005). Similarly, insects can be reared on bio-waste and by-products such as household waste, slaughterhouse by-products, animal manure, intestinal content, garden waste, and on human manure or sewage sludge (van Huis, 2013). Most edible insect species have lower environmental impacts than conventional livestock (Oonincx and de Boer 2012; Halloran *et al.,* 2017). Meaning that eating insect will reduce livestock consumption, which in effect is a reduction in the emission of methane- a class of greenhouse gas (GHG).

However, lack of clear legislation guiding the rearing, consumption and commercialization of edible insects in most countries Nigeria inclusive, hinder the development of edible insects to levels that their potentials could be harnessed for the benefits of the environment, sustainable societal development and integration as part of a climate smart and or nutrition sensitive agriculture. Hence, the need to develop specific legislation on edible insect in Nigeria generally hinges on the importance of consumption of insects as alternative and sustainable source of protein, a means of attaining sustainability through food security, resolving conflicts over limited land resources and a means of mitigating climate change through sustainable production and reasonable consumption. Here we discuss the importance of edible insects in the Nigerian context, the need to realign and develop legislation around the use of edible insects and finally proposed how such legislation should be developed.

2. Edible insects and their uses in the traditional Nigerian context

The most common edible insects consumed in Nigeria belong to the following insect orders, Lepidoptera, Orthoptera, Coleoptera, Isoptera and Hymenoptera (Kelemu *et al.,* 2015). From these orders, up to 20 species are reported to be commonly consumed (Table 1) in different parts of Nigeria and by different ethnic groups. The variegated grasshopper (*Zonocerous variegatus* L.), larva of the African palm weevil (*Rhynchophorus phoenicis* Fabricius), the larger termite (*Macrotermes bellicosus* Smeathman), honey bee larva (*Apis mellifera adansonii* Latreille), larva of the African silkworm (*Anaphe venata*) and the giant cricket (*Brachytrupes membranaceus*) are the most consumed species (Kelemu 2015; Adeoye *et al.,* 2014; Alamu *et al.,*2013) (Table 1). In Nigeria, edible insects are consumed in different ways depending on the species, stages and tradition of the people. A list of some commonly eaten insects in Nigeria identified by their local names, their stages of consumption and the location of consumers is shown in Table 2. For example, Locusts and crickets are eaten by most people living in villages (Adeoye *et al.,* 2014) as snacks, which are usually deep-fried with oils from the insects when they are in season. Off-season, these snacks are available preserved in salt, sun dried or grinded into flour and served as delicacies for special occasions (Adeoye et. al 2014; Van Huis 2003; Adeoye *et al.,* 2014) As a source of income, the roasted or grilled locust and crickets are sold usually on market days (Van Huis 2003). Some ethnic groups such as the *Babur* of Borno State Nigeria always receive the appearance of locust and grasshoppers with joy (Alamu *et al.,* 2013). However, it is noteworthy that urbanization has significantly impacted on the consumption of insects in Nigeria. With practices, such as locust consumption frowned upon in highbrow areas of big cities where they are viewed and associated with primitive behaviors (Ponzetta and Paoletti 1997). Again, there are other basic human emotions, deeply rooted in culture or religion that associates insect with disgust, nuisance, source of destruction and as disease vectors (Megido *et al.,* 2014).

Table 1. Common edible insects consumed in Nigeria their taxonomic orders, common names and life stages used

Species	Order	Common name	Stage(s) consumed	Reference
Rhynchophorus phoenicis	Coleoptera	African palm weevil	Larva, pupa, adult	Kelemu *et al.,*2015; Adeoye *et al.,*2014; Okore *et al.,*2014; Alamu *et al.,*2013; Banjo *et al.,*2006
Heteroligus meles	Coleoptera	Yam beetle	Larva, pupa, adult	Okore *et al.,*2014; Agbidye *et al.,*2009; Alamu *et al.,*2013
Oryctes boas	Coleoptera	Rhinoceros beetle	Larva	Kelemu *et al.,*2015; Adeoye *et al.,*2014, Alamu *et al.,*2013; Banjo *et al.,*2006
Analeptes trifasciata	Coleoptera	Long-horned beetle	Larva	Banjo *et al.,*2006; Adeoye *et al.,*2014;
Sitophilus oryzae	Coleoptera	Rice weevil	Larva, pupa, adults	Okore *et al.,*2014
Nezara viridula	Hemiptera	Green stink bug	Adult	Agbidye *et al.,*2009; Adeoye *et al.,*2014
Apis mellifera adansonii	Hymenoptera	Honey bees	Brood (Egg, larva, pupa); adult	Kelemu *et al.,*2015; Adeoye *et al.,*2014; Alamu *et al.,*2013; Okore *et al.,*2014; Banjo *et al.,*2006
Macrotermes belliccosus	Ispotera	Termites	Wing adult, queen	Kelemu *et al.,*2015, Adeoye *et al.,*2014, Alamu *et al.,*2013; Banjo *et al.,*2006
Mactotermes natalensis	Isoptera	Termites	Wing adult, queen	Kelemu *et al.,*2015; Adeoye *et al.,*2014; Alamu *et al.,*2013; Agbidye *et al.,*2009; Banjo *et al.,*2006
Leuconodes laisalis	Lepidoptera	Egg fruit borer	Larva	Okore *et al.,*2014
Anaphe venata	Lepidoptera	African silkworm	Larva	Kelemu *et al.,*2015; Adeoye *et al.,*2014; Alamu *et al.,*2013; Banjo *et al.,*2006
Anaphe recticulata	Lepidoptera	African silkworm	Larva	Alamu *et al.,*2013; Banjo *et al.,*2006; Ashiru 1988
Cirina forda	Lepidoptera	Pallid emperor moth	Larva	Adeoye *et al.,*2014;Alamu *et al.,*2013; Agbidye *et al.,*2009; Banjo *et al.,*2006
Cirina butryospemi	Lepidoptera		Larva	Kelemu *et al.,*2015; Fasoranti and Ajiboye 1993
Cyrtacanthacris aureginosa	Orthoptera	Short horned grasshopper	Adult	Fasoranti and Ajiboye 1993; Adeoye *et al.,*2014; Alamu *et al.,*2013; Banjo *et al.,*2006
Brachytrupes membranaceus	Orthoptera	Giant cricket	Adult	Adeoye *et al.,*2014; Okore *et al.,*2014; Alamu *et al.,*2013; Agbidye *et al.,*2009; Banjo *et al.,*2006; Fasoranti and Ajiboye 1993
Zonocerus variegatus	Orthoptera	Stink locust	Adult	Kelemu *et al.,*2015; Adeoye *et al.,*2014; Agbidye *et al.,*2009; Banjo *et al.,*2006
Nomadacris septemfasciata	Orthoptera	Red locust	Unspecified	Kelemu *et al.,*2015
Gryllotalpa africana	Orthoptera		Adult	Agbidye *et al.,*2009
Musca domestica	Diptera	House fly	Larva	Okore *et al.,*2010

Table 2. List of some commonly eaten insects in Nigeria identified by their local names, stages of consumption and the location of consumers.

Species	**English name**	**Local name**	**Order**	**Stage(s) consumed**	**Location of consumers**	**Reference**
*Cirina forda*Westwood	Pallid Emperor moth	Yoruba: Kanni, Munimuni	Lepidoptera	Larvae	Nasarawa State Gombe State Oyo State	Agbidye *et.al.*,2009
Bunaea alcinoe Cram	Emperor moth	-	Lepidoptera	Larvae	Kogi State Yobe State Kebbi State	
Rhynchophorus Phoenics	Palm weevil	Yoruba: Ipe, Itun	Coleoptera	Larvae	Bayelsa State Osun State	
Oryctes boas *Oryctes monocerus* Oliver	Snout beetle	Yoruba: Ogongo	Coleoptera	Larvae	Rivers State Ogun State	
Analeptes trifasciata	Rhinocerus beetle	Ibo: Ebe	Coleoptera	Larvae	Delta State Ekiti State	Ekop *et.al.,* 2010
Anaphe venata	Caterpillar	Yoruba: Ekuku	Lepidoptera	Larvae	Ekiti State Lagos State Ogun State Ondo State Osun State Oyo State	Banjo, *et. al.,* 2006
Heteroligus meles Billberger	Yam beetle	-	Coleoptera	Adults	Ogun State Edo State Enugu State	
Zonocerus	Grasshopper	Yoruba:	Orthoptera	Adults	Kwara State	
Variegatus,		Tata Ibo: abuzu, Ukpana			Delta State Ogun State	
Cytacantharis naeruginosus unicolor	Grasshopper	Yoruba: Tata	Orthoptera	Adults	Nasarawa State Cross River State Oyo State	

		Ibo: abuzu, Ukpana				
Apis mellifera	Honeybee	Yoruba: Oyin	Hymenoptera	All through Eggs, Larvae and Pupae	All States of the Federation	
Macrotermes belliscosus *Macrotermes notalensis*Haviland	Termites	Yoruba: Esunsun Ibo-Aku	Isoptera	Winged adult, queen	Kogi State, Adamawa State Taraba State Ondo State	
*Brachytrupes membranaceus*Drury	Cricket	Yoruba: Ire	Orthoptera	Adults	Plateau State Lagos State	
Gryllotalpa Africana P.de.B.	Mole cricket	Yoruba: Ire	Orthoptera	Adults	Benue State Ekiti State	
*Nezera viridula*L.	Green Stink Bug	-	Hemiptera	Adults	Benue State Kogi State Kwara State Nasarawa State Plateau State	Fasoranti and Ajiboye 1993

3. Edible insects as vehicles toward attaining Sustainable Development Goals (SDGs)

Nigeria is has an average population of 205 million making it the most populous nation on the African continent. With an annual average growth of rate of 2.5%, Nigeria's population is projected to grow by 18.5 million in 2020 and to reach 401 million by the year 2050 (WPR, 2020). Feeding such a growing population means an increase in food production, which comes with adherent consequences placing a heavy pressure on already limited resources like land, energy and the environment. Even if the aforementioned resources are not limited, agricultural production, for instance livestock farming in its present form is implicated for deforestation, environmental degradation, increase in emission of greenhouse gasses (GHG) and conflicts between pastoralist and farmers. The excessive use of fertilizers and pesticides contaminates surface and groundwater, pollute the environment, introduce heavy metals into the soil and affects biodiversity (Tilman *et al.,* 2002; Burkholder *et al.,* 2006).

These ills associated with intensive agricultural practices aimed at feeding an ever-increasing population calls for alternative food production practices that are more sustainable with as little carbon footprints as possible (Dobermann *et al.,* 2017). An alternative healthier and more sustainable production means resorting to other greener sources of protein, such as fungi and insects. In other words, climate smart and nutrition sensitive agricultural practices. Eating insects comes in as the ideal alternative because they offer a number of advantages which among others include high feed-conversion efficiency (animal's capacity to convert feed mass into increased body mass, which is represented as kg of feed per kg of weight gain as explained by Herrero *et. al.*, 2011), can be easily reared on organic side streams thus reducing environmental contamination at the same time adding value to waste (waste to wealth).

Insects can contribute to food security and be a part of the solution to protein shortages, given their high nutritional value, low requirements for land and the high efficiency at which they can convert feed into food (Halloran *et al.,* 2015). In addition, the production of insect biomass as feedstock for animals and fish can be combined with the biodegradation of manure and the composting and sanitizing of waste (Wong, et. al 2018). Insects can partly replace the increasingly expensive protein ingredients of compound feeds in the livestock, poultry and aquaculture

industries. Grains now used as livestock feed, which often comprise half the cost of meat production, could then be used for human consumption (Huis *et al.,* 2013).

Similarly, as mini-livestock edible insects emits less GHGs, require significantly less water than conventional or traditional livestock production and has a low risk of transmitting zoonotic diseases (Premalatha *et al.,* 2011). According to Food and Agriculture Organization of the United Nations (FAO), livestock production accounts for 70 percent of all agricultural land use. Premalatha *et al.* (2011) believes that global demand for livestock products is expected to double from 229 million tonnes to 465 million tonnes by 2050, and meeting this demand will require innovative solutions. Livestock rearing is responsible for 18 percent of GHG emissions (CO_2 equivalent), a higher share than the transport sector (Glatzle, 2014). Methane (CH_4) and nitrous oxide (N_2O) have greater global warming potential (GWP) than CO_2. According to the Intergovernmental Panel on Climate Change (IPCC) - a body of experts saddled with the responsibility of providing independent scientific advice regarding human-induced climate change to the United Nations Framework Convention on Climate Change, if CO_2 has a value of 1 GWP, CH_4 has a GWP of 23 and N_2O has a GWP of 289 (IPCC, 2007; Herrero *et. al,* 2011).

The use of insects as food and feed offers natural sources of nutrients to humans and animals (FAO, 2013). Insects have been cited as one answer to growing food demand as well as to achieving improved environmental sustainability in the production of animal-source foods (Ball, 2014). These unique potentials offered by edible insects make them an ideal accelerator towards achieving the UN's Sustainable Development Goals (SDG) (Pascual *et al.,* 2020). Of the 17 SDGs, the use of insects for food and feed and its associated value addition chain can be used towards achieving 13 of the 17 SDGs.

Participation of women in production and marketing of edible insects aligns with the following SGDs; no poverty, zero hunger, good health and well-being, gender equity, decent work and economic growth and reduced inequalities. Mini livestock farming of edible insects aligns well with SDG nos. 11, 12, 13, 15 and 16 that is; sustainable cities and communities, responsible consumption and production, climate action, life on land, peace justice and strong institutions as well as partnerships for the goals. The use of insect as alternative source of protein in poultry and

aquaculture fits with SDG 14 (life below water) as it has the potential to reduce the use of fishmeal-based protein.

4. Sustainable use of edible insects in Nigeria

Nigeria's year on year, gross domestic product (GDP) is growing marginally around the 2% mark with oil being the key foreign exchange earner. This resulting in an unemployment rate of 23% (NBS, 2020), which is high given its youthful population. Considering the current economic situation in Nigeria with its associated high cost of living, which also results in the raise in prices of conventional animal proteins, insects may well become a cheaper source of protein used in food and feed production (Odebode and Odebode, 2005). Projections shows that, with increase and raising awareness, the edible insect market will account for about 1.5 billion USD by 2026 (GMI, 2020). Nigeria with its teaming youths and shift to agro base economy is better placed to tap into this lucrative and prospective market. For this to happen, there will be a need for significant changes in the edible insect value chain starting from processes of making them available, packaging, safety, consumer awareness through advocacy, standardization and legislation on the use of insect for food and feed on a larger scale (Halloran *et al.,* 2015).

5. Policy consideration and legal challenges

In Nigeria, as far back as 1958, various laws and regulations had been promulgated to ensure the safety and fitness for purpose of the nation's food supply (Omojokun, 2013). Prominent among these laws is the National Agency for Food and Drugs Administration and Control Decree No 15 of 1993 (now NAFDAC Act CAP N1 Laws of the Federal Republic of Nigeria, 2004). As a regulatory body, NAFDAC is responsible for the regulation and control of the importation, exportation, manufacture, advertisement, distribution, sale and use of food, drug, cosmetics, medical devices, chemicals, packaged water and detergent at Federal and State levels in Nigeria. Appropriate tests are conducted and compliance with standard specifications for the effective control of the quality of food, bottled water and the raw materials as well as their production processes in factories and other establishments is ensured. Part of NAFDAC's responsibilities include undertaking investigations into production premises and raw materials for food and establishment of relevant quality assurance systems including certification of the production sites and the regulated products

and pronouncement on the quality and safety of food. The functions of NAFDAC is further complemented by the Standard Organization of Nigeria (SON), which ensure standards for packaging materials etc.

Established by virtue of Act No. 14, 2015, Cap 59 laws of Federal Republic of Nigeria, 2004, SON is among others, saddled with the responsibility of preparing standards relating to products, certification of industrial products as well as the improvement of measurement accuracy and circulation of information relating to standards, which ensures that products and services are fit for their purpose and are comparable and compatible (SON Act, 2015). The role of SON is seemingly important with regards to the sustainable use of edible insects in Nigeria, because a Nigerian standard is required for setting rules and guidelines for common and repeated use of edible insects (Irefin and Ilori, 1996). Similarly, the role of SON is indispensable for the optimum achievement of services and related processes in the packaging, marking or labeling and industrial preservation of edible insects (Omojokun, 2013).

In spite the existence of the aforementioned agencies and the laws that established them, specifics on consumption of insects are generally missing in Nigeria's legislation. This more so that these agencies and the legislation that established them can cover edible insects and their consumption with ease (Wilderspin and Halloran, 2018).

Elsewhere on the continent, the situation in terms of legislation and regulation governing the use of insects as food and feed is similar to those in Nigeria with few exceptions. This is despite the fact that entomophagy is enshrined in the cultures of most Africans. In South Africa despite the popularity and use of edible insects as food and feed, there are no national legislative framework governing their use (Niassy *et al.,* 2018). Unlike in Nigeria, oversights for food and food related products are nested under different government Departments and Agencies; that include the Department of Agriculture Fisheries and Forestry under Agricultural products standards act (Act 119 of 1990) and marketing and agricultural products act (Act 47 of 1996), Department of Health under the foodstuff cosmetics and disinfectant act (Act 54 of 1972), Department of Trade and Industry, South African Bureau of Standards under the standard act (Act 8 of 2008), the consumer protection act (Act 68 of 2008), the National Regulator for Compulsory Specifications act (Act 5 of 2008) and the Consumer protection act 68 of 2008. Similarly, in Kenya, different government

ministries and agencies within the agriculture, trade, industry, and health clusters (Halloran *et al.,* 2015) manage safety of food and related products. Legal policies and legislations under which these agencies operate are mostly drawn from the FAO and World Health Organization (FAO/WHO 2005). Prior to 2017, when the first specifications and standards for the use of dried insects for compounding animal feed (KS 2711: 2017, ICS 65.120) was approved, the Kenyan Bureau of Standards considered insects as contaminants in food following the Codex Alimentarius Commission (CAC) and Sanitary and Phytosanitary standards of the World Trade Organization (World Bank, 2005).

In other jurisdictions such as the European Union (EU) there are legislation governing the future production and consumption of edible insects. For example, Directive 2002/32/EC of the European Parliament and of the Council of 7 May 2002 on undesirable substances in animal feed (Directive 2002/32/EC) prohibits the use of undesirable substances in animal feed. By extension, insects used as feed may not be contaminated by unwanted substances such as heavy metals, lead and zinc. In addition, the European Novel Food Regulation (Regulation (EC) No.258/97), which regulates food and ingredients that were not used for human consumption to a significant degree prior to 15 May 1997, regulates the trade of insects, specifically meant for export (Lähteenmäki-Uutela *et al.,* 2018). Equally, other EU Member States such as Belgium, the Netherlands, France, and the UK allow some insects to be used as food, and have enacted legislations in support of this Macombe *et. al.,* 2019). In Belgium, the Federal Agency for the Safety of the Food Chain (FASFC) has produced a specific regulation for edible insects, which makes Belgium one of the leading nations in terms of edible insect legislation. In the UK, the Food Safety Agency has shown a favourable position on the sale, consumption, and use as feed in aquaculture as well as import of edible insects (Payne *et. al*., 2019).

Enacting specific laws on the use of insects for food and feed production in Nigeria would serve to control and regulate the use of insects by industry processors and would guarantee consumer access to information. However, there are challenges associated with this. Some of these challenges lies in lack of research, information regarding processing and quality of edible insects, absence of networking among producers of edible insects.

6. Proposition for developing integrated policies and laws on edible insects and their sustainable use in Nigeria

To develop a clear and comprehensive legal framework that can pave the way for harnessing the edible insect value chain towards sustainable use and development in Nigeria, an encompassing top to bottom approach involving all stake holders (communities, researchers, government, consumers) is needed. Such an approach will bridge the gaps in knowledge (indigenous and scientific), standards, legislation, marketing, upscaling and commercialization whilst taking into account concerns relating to sustainability and economic development (Fig. 1). We will briefly described the approach we propose as outlined on Fig 1 with a description of roles of the stakeholders at each level. It is however, worth noting that, these roles are not exclusive, and are often multidirectional as depicted by the red arrows on Fig 1.

Fig. 1 Proposed pathway for the development of legislation and policies towards an integrated and sustainable use of edible insects in Nigeria.

The starting point should be at the community level engaging both people who use insects as food and feed and those who serve as sources or harvesters of these insects (Fig. 1). Here engaging local farmers and cooperatives would be worthwhile. Amongst this group, indigenous knowledge can be collated on insect use, harvesting techniques, preservation strategies, marketing and demand at the local level. Such valuable information can then be linked into research and development (RD) programs aimed at enhancing indigenous knowledge (mass rearing and harvesting) to provide insects all year round and in enough quantities for upscaling. Mass rearing can also protect and enhance biodiversity through preventing species from overharvesting and exploitation. Key role players at this stage include universities, research institutes, independent researchers, citizen scientists and non-governmental organizations (Fig. 1). Developing and integrating RDs in a framework for edible insects is a very important component if not the most important as all other components including legislation has to be guided by facts. As such, a solid and robust RD system need to be in place since it can mar or make the whole process. It also can boost consumer preferences, acceptability, marketing and economic viability of venturing into edible insects value chain.

Outcome and inputs from RD efforts should be passed down to the community for their feedback and first hand trails. Thereafter, relevant standardization, certification and monitoring agencies should be involved to ensure compliance. In this instance, NAFDAC needs to ensure adherence to local food specifications in terms of sanitary and phytosanitary hygiene. In addition, SON should ensure compliance with packaging regulations. Environmentalists and relevant NGOs (Fig. 1) with independence can serve an oversight function to ensure that the practices do not pose threats to environment and biodiversity. The next stage is formulation of policy and legislation (Fig. 1). Policies should be formulated by taking into account the culture of the people and potential consumers. A departure point here can be an amendment to the NAFDAC Act CAP N1 of 2004 to include insect-based products in the range of items it regulates. It will be much easier and practical to nest edible insect products under this act than to enact another act or establish a new agency. The latter will complicate matters through introduction of duplicate functions and end up being an expensive venture. Entrusting edible insects certification within NAFDAC will be more acceptable to most Nigerians as they are familiar with the general workings of NAFDAC against a new agency,

which has to build consumer confidence from scratch. Proposal to amend the NAFDAC act should be forwarded to the National Assembly by all stakeholders (communities, NAFDAC, farmer associations, researchers etc.).

With legislation in place comes the legitimization for the use of insects as food and feed and increase demand. This ushers in the next step marketing and upscaling (Fig. 1). This is the stage which, should involve massive awareness campaigns on the value of edible insects with the aim to lure consumers, producers and investors who will tap into the potentials abound in the act of sustainable rearing and consumption of edible insects and economic opportunities within the sector. Marketing strategies such as e-marketing can be used to effectively achieve this. Successful upscaling through the establishment of large-scale insect farms to meet demand and possibly export will be required at this stage. With such farms, unemployment rates can be reduced, and Nigeria can tap into the edible insect market share and join the league of countries such as the Netherlands and attain the last stage, export (Fig. 1). If that is attained, the export market should not be left for only large scale insect farmers, but also open to producers at the community level (see dotted lines in Fig. 1) and should be supported by government agencies in charge of exports like the Nigerian Export Promotion Council (NEPC) with support from the Nigerian Export-Import Bank (NEXIM).

7. Discussion

Eating insects is a common practice among ethnic groups in Nigeria as it forms part of their traditions. Insects are used differently, as snacks or delicacies prepared in special ways for special occasions. Nigeria's edible insect value chain remained largely untapped in its potential as a sustainable source of food security, nutrition and economic activity. This is so because, the sector is not fully integrated formally with regulatory oversights that will see it developed into a vehicle for achieving sustainability and economic growth. In order to achieve this, we propose an integrated multi-stakeholder, multi-directional approach that builds on and feed back to indigenous knowledge systems at the community level.

There are about 20 species of edible insects commonly consumed in Nigeria (Table 1). This represents only about 4.25% of species reportedly eaten in Africa (Kelemu *et al.,* 2015) and about

half the number species reportedly eaten in South Africa (Niassy *et al.,* 2018 and references therein). Of the 20 species of edible insects consumed in Nigeria, 11 seem to be commonly shared across cultures and regions with the palm weevil *Rhynchophorus phoenicis* been the popular edible insect in the South and the stink grasshopper *Zonocerus variegatus* and termites *Macrotermes* spp. in the North. This low diversity of edible insects reported from Nigeria does represents lack of research studies from all the regions of Nigeria. Studies presently found in the literature are mostly from the southwest and southeast whereas Nigeria's ethnic, diversity is mainly found in the northeast, northcentral and northwestern. This paucity of research calls for an increase in research and surveys to determine diversity of insects used by the different ethnic groups in these regions. Aside from commonly reported edible insects, there is the report of the consumption of house fly larva from the Niger Delta region (Okore *et al.,* 2010).

Integrating edible insects into mainstream economic development policies aimed at alleviating poverty, green economy and achieving SDGs will fit well with Nigeria's current vision of diversification from an economy and GDP that is solely dependent on hydrocarbons. With the dwindling oil prices, promoting an edible insects' value chain will be an alternative in filling budget deficits and tapping in the prospective edible insect market economy.

Farmer-herder conflicts are a resultant of migration by herders in search of pasture for their animals. These migrations are caused by worsening weather conditions (desertification), historical reasons, loss of grazing reserves, insecurity in the north and erratic rainfall (Olaniyan and Okeke-Uzodike 2015; ICG 2017). As the herders migrate southwards, conflicts arise with their hosts communities and farmers along the routes due to damages to crops and farms. This conflict is one of Nigeria's security challenges leading to loss of lives with an estimated death toll of 2500 in 2016 alone (ICG 2017). Mini livestock using edible insects has the potential to reduce farmer herder conflicts, as it does not require much land, and resources like traditional livestock production.

Nigeria like most African countries, have no legal framework that covers the use of edible insects despite the fact that insects has been part of tradition. The pathway for legislation we proposed here, takes into account Nigeria's peculiarities as well as streamlining of oversights functions such as certification to few government agencies with similar mandates such as NAFDAC. This is to avoid bureaucratic complexities that could arise when different government agencies are involved

as seen in proposals for countries like South Africa (Niassy *et al.,* 2018) or Kenya where regulations are nested in different government agencies (Halloran *et al.,* 2015). In as much as, the involvement of several government agencies has its advantages, we are of the opinion that such should be avoided as much as possible in Nigeria. We also proposed an amendment to the NAFDAC Act instead of proposing or sponsoring a new Act or establishing another standards or certification agency to ensure fast and quick legislation on edible insects. One key point to consider in drafting standards is to take into account indigenous knowledge and the uses of insects instead of adopting international standards formulated for regions with no history of traditional use of insects (Halloran *et al.,* 2015)

As standards are established and legislation enacted, consumer confidence will be built, upscaling and marketing strategies then need to be put in place for the success of the sector. We proposed the use of both modern and traditional marketing strategies that will be inclusive in a way that unnecessary competition is avoided. Market opportunities have to be made available to the communities as well under a level playing ground to avoid exploitation.

8. Conclusion and recommendations

Regulatory frameworks for edible insects in Nigeria need to be developed. In order to succeed in this regard, there is need for close collaboration among all stakeholders; government, industry and the academia. This would oblige regulators to pay attention to a broad range of regulatory areas, including phytosanitary legislation, biodiversity, disease control and the environment. The collaboration will result in promoting private and public standardization at the national and international levels for insects as food and feed, accompanied by a premarket safety evaluation. The establishment of appropriate international and national standards and legal frameworks to facilitate the use of insects as food and feed and the development and formalization of the sector taking into consideration the potential effects of insect production and rearing on the environment.

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Authors' contribution

AAY conceptualized the idea; AAY, HSU designed, conducted the research and wrote the manuscript.

References

A. van Huis, "Edible insects contributing to food security?" Agriculture and Food Security (2015), 4:20.

Adeoye OT, Oyelowo OJ, Adebisi-Fagbohungbe TA, Akinyemi OD (2014) Eco-diversity of edible insects of Nigeria and its impact on food security. J Biol L Sci, 5(2):175-187.

Agbidye FS, Ofuya TI, Akindele SO (2009) Some edible insect species consumed by the people of Benue state, Nigeria. Pakistan Journal of Nutrition 8(7):945-950.

Alamu OT, Amao AO, Nwokedi CI, Oke OA, Lawa IO (2013) Diversity and nutritional status of edible insects in Nigeria: a review. Int J Biodiver Conserv, 5(4): 215-222.

Ashiru MO (1988) The food value of the larvae of *Anaphe venata* Butler (Lepidoptera: Notodontidae). Ecol Food Nutr 22: 313-320.

Ball J (2014) Edible insects: future prospects for food and feed security. Int For Rev, 16(1): 112-114.

Banjo AD, Lawal OA, Songonuga EA (2006) The nutritional value of fourteen species of edible insects in Southwestern Nigeria. Afr J Biotec 5(3): 298-301.

Burkholder J, Libra B, Weyer P, Heathcote S, Kolpin D, Thorne PS, Wichman M (2007) Impacts of waste from concentrated animal feeding operations on water quality. Envi Health Perspec, 115(2): 308-312.

Caparros Megido R., Sablon L, Geuens M, Brostaux Y, Alabi T, Blecker C, Francis F (2014). Edible Insects Acceptance by Belgian Consumers: Promising Attitude for Entomophagy Development. J Sen Stud, 29(1):14-20.

DeFoliart GR (1999) Insects as Food: Why the Western Attitude Is Important, Ann Rev Entomol, 44: 21-50.

Dobermann D, Swift J, Field L (2017) Opportunities and hurdles of edible insects for food and feed. Nutr Bul 42: 293-308.

Fasoranti JO, Ajiboye DO (1993) Some edible insects of Kwara State, Nigeria. Am Entomol 39(2): 113-116.

FAO (2013) Edible insects. Future prospects for food and feed security, FAO Forestry Paper 171, Rome.

FAO/WHO (2005). Practical Actions to Promote Food Safety: Regional conference on food safety for Africa, Final Report. Harare, Zimbabwe. 3 – 6 October 2005.

Glatzle A (2014) Questioning key conclusions of FAO publications 'Livestock's Long Shadow' appearing again in 'Tackling Climate Change through Livestock' Pastoralism, 4(1), 1.

GMI (2020) Global Market Insights, Edible insects market size, https://www.gminsights.com/industry-analysis/edible-insects-market accessed on 14th May, 2020.

Halloran A, Flore R, Vantomme P, Roos N. (Eds.). (2018). Edible insects in sustainable food systems. Cham: Springer.

Halloran A, Vantomme P, Hanboonsong Y, Ekesi S (2015) Regulating edible insects: the challenge of addressing food security, nature conservation, and the erosion of traditional food culture. Food Sec, 7(3): 739-746.

Herrero M, Gerber P, Vellinga T, Garnett T, Leip A, Opio C, Montgomery H. (2011) Livestock and greenhouse gas emissions: The importance of getting the numbers right. Animal Feed Sci Tech, 166: 779-782.

House J (2018) Insects as food in the Netherlands: Production networks and the geographies of edibility. Geoforum, 94: 82-93.

Huis A V *et al.,* (2013) Edible insects: future prospects for food and feed security. FAO Forestry paper, (171).

ICG (2017) Herders against farmers: Nigeria's expanding deadly conflict. International Crisis Group, Africa report no. 252.

Irefin IA, Ilori MO (1996) Food standardization policies in Nigeria. Food Rev Int, 12(2): 251-270.

Jansen W, Grabowski NT (2019) Insects as Novel Food. The Belgian pioneer experience with insects for human consumption placed on the domestic market. Berliner und Munchener Tierarztliche wochenscrift, 132(5-6): 312-316.

Kelemu S, Niassy S, Torto B, Fiaboe K, Affognon H, Tonnang H, Maniania K, Ekesi S (2015) African edible insects for food and feed: inventory, diversity, commonalities and contribution to food security. J Ins Food Feed, 1(2):103-119.

Lähteenmäki-Uutela A, Hénault-Ethier L, Marimuthu SB, Talibov S, Allen RN, Nemane V, Józefiak D (2018) The impact of the insect regulatory system on the insect marketing system. J Ins Food Feed, 4(3): 187-198.

Macombe C, Le Feon S, Aubin J, Maillard F (2019) Marketing and social effects of industrial scale insect value chains in Europe: case of mealworm for feed in France. J Ins Food and Feed, 5(3): 215-224.

Momodu MS (1999) Development of food irradiation regulations in Nigeria (No. IAEA-CN--76).

NBS (2020) National Bureau of Statistics of Nigeria Fiscal statistics, https://nigerianstat.gov.ng/ accessed on 14th May, 2020

Niassy S, Ekesi S, Hendriks SL, Haller-Barker A (2018) Legislation for the Use of Insects as Food and Feed in the South African Context. In: Halloran A, Flore R., Vantomme P, Roos N (eds) *Edible Insects in Sustainable Food Systems*. Springer, Cham.

Odebode TO, Odebode SO (2005) Protein energy malnutrition and the nervous system: the impact of socioeconomic condition, weaning practice, infection and food intake, an experience in Nigeria. P J N, 4(5): 304-309.

Okore O, Avaoja D, Nwana I (2014) Edible Insects of the Niger Delta area in Nigeria, J Nat Sci Res, 4(5).

Olaniyan A, Okeke-Uzodike U, (2015) Desperate guests, unwilling hosts: Climate change induced migration and farmer-herder conflicts in Southwestern Nigeria, Conflict studies quarterly, 10: 23-40.

Omojokun J (2013) Regulation and enforcement of legislation on food safety in Nigeria. Mycotoxin and Food Safety in Developing Countries, 251-268.

Oonincx DG, De Boer IJ (2012) Environmental impact of the production of mealworms as a protein source for humans–a life cycle assessment. PloS one, 7(12).

Paoletti MG (2005) Ecological Implications of Minilivestock: Potential of Insects, Rodents, Frogs and Snails, Taylor and Francis, New York.

Pascual J, Wyber S, Yildirim E (2020) An accelerator under-used? New report explores the place of culture in SDG implementation. SDG knowledge hub http://sdg.iisd.org/commentary/guest-articles/an-accelerator-under-used-new-report-explores-the-place-of-culture-in-sdg-implementation accessed 20th March, 2020.

Payne C, Megido RC, Dobermann D, Frédéric F, Shockley M., Sogari G (2019) Insects as food in the global north–the evolution of the entomophagy movement. In Edible insects in the food sector (pp. 11-26). Springer, Cham.

Ponzetta MT, Paoletti MG (1997) Insects as food of the Irian Jaya populations. Ecol F Nutr, 36(2-4): 321-346.

Premalatha M, Abbasi T, Abbasi T., Abbasi SA (2011) Energy-efficient food production to reduce global warming and ecodegradation: The use of edible insects. Ren Sust En Rev, 15(9): 4357-4360.

Standard Organization of Nigeria, Act 2015 http://son.gov.ng/wp-content/uploads/2016/11/SON-ACT-2015.pdf accessed 20th May, 2020.

Tilman D, Cassman KG, Matson PA, Naylor R, Polasky S (2002) Agricultural sustainability and intensive production practices. Nature, 418(6898): 671.

Van Huis A (2003) Insects as food in sub-Saharan Africa. Int J Trop Ins Sci 23(3): 163-185.

Van Huis A. (2013) Potential of insects as food and feed in assuring food security. Ann Rev Entomol 58: 563-583.

Van Huis A (2015) Edible insects contributing to food security? Agriculture and Food Security, 4:20.

World Bank (2005) The Role of Standards under Kenya's Export Strategy Contribution to the Kenya Diagnostic Trade and Integration Study. World Bank.

Wilderspin DE, Halloran A (2018) The Effects of Regulation, Legislation and Policy on Consumption of Edible Insects in the Global South. In Edible Insects in Sustainable Food Systems, Springer, Cham.

Wong CY, Lim JW, Uemura Y, Chong FK, Yeong YF, Mohamad M, Hermansyah H (2018). Insect-based lipid for biodiesel production. In AIP Conference Proceedings (Vol. 2016, No. 1, p. 020150). AIP Publishing.

WPR (2020) World Population Review, Nigeria Population 2020. https://worldpopulationreview.com/countries/nigeria-population/ accessed on 13th May, 2020.

Xiaoming C, Ying F, Hong Z, Zhiyong C (2010) Review of the nutritive value of edible insects. Forest insects as food: humans bite back, 85.