Toxicology Reports 4 (2017) 474–483

Contents lists available at ScienceDirect

Toxicology Reports

journal homepage: www.elsevier.com/locate/toxrep

Elements of kitchen toxicology to exploit the value of traditional (African) recipes: The case of *Egusi Okra* meal in the diet of HIV+/AIDS subjects

Chiara Frazzoli[a,b,*], Francesca Mazzanti[b], Mercy Bih Achu[b,c], Guy Bertrand Pouokam[b,d], Elie Fokou[b,c]

[a] *Dept. of Cardiovascular, Dysmetabolic and Aging-Associated Diseases, Istituto Superiore di Sanità, Rome, Italy*
[b] *Nutrition, Food Safety and Wholesomeness. Prevention, Education and Research Network*[1]
[c] *Laboratoire des Sciences Alimentaires et Métabolisme, Département de Biochimie, Faculté des Sciences, Université de Yaoundé I, Yaoundé, Cameroon*
[d] *Laboratory of Food Safety, Biotechnology Center, University of Yaoundé I, Yaoundé, Cameroon*

ARTICLE INFO

Chemical compounds studied in this article:
Deoxynivalenol (PubChem CID: 16212213)
Hexachlorobenzene (PubChem CID: 8370)
Aluminium (PubChem CID: 5359268)
Arsenic (PubChem CID: 5359596)
Benzo(a)pyrene (PubChem CID: 2336)
Perfluoro-octanoic acid (PubChem CID: 9554)
Bis(2-ethylhexyl) phthalate (PubChem CID: 8343)
Bisphenol A (PubChem CID: 6623)
Selenium (PubChem CID: 6326970)
Zinc (PubChem CID: 23994)

Keywords:
Traditional diet
Malnutrition
Food safety
Weight loss
Immune system
Dysmetabolic diseases
Clinical toxicology
Nutrition security

ABSTRACT

The *Egusi Okra* soup is a traditional African meal that is considered of high nutritional value and protective against weight loss. We introduce the concept of "kitchen toxicology" to analyse the recipe of the *Egusi Okra* soup and highlight possible mitigation measures for toxic and/or antinutritional effects in the wide spectrum of health and nutritional needs of HIV+/AIDS subjects. In particular, we focus on toxicants (environmental contaminants, process contaminants, substances leaching from food contact materials) dysregulating the immune status, as well as on interactions between nutrients, contaminants, and/or antinutrients which may lead to secondary/conditioned nutritional deficiencies or imbalances; in their turn, these can modulate the ability to cope with toxicants, and increase nutritional requirements. Recommendations are given for practices preserving the *Egusi Okra* soup from such risk factors, identifying points of particular attention during meal preparation, from purchase of raw ingredients through to food handling, cooking, storage, and consumption. The *Egusi Okra* soup is discussed in the context of a diet that is asked to mitigate complications (weight loss, opportunistic infections) and support antiretroviral therapy in African countries with high HIV/AIDS prevalence. The paper discusses how nutritional interventions benefit of the integration of kitchen toxicology practices in everyday life. Toxicological risk assessment is crucial to understand the history and status of the person exposed to or affected by infectious diseases.

1. Introduction

According to the World Health Organization [1], a proper diet is one of the solutions to maintain a good health status in individuals affected by HIV and AIDS, as it helps to prevent nutritional deficiencies and maintain proper body weight during antiretroviral drug treatments (ART). Weight loss and body mass index $< 17\ kg/m^2$ are independent predictors of illness and mortality in HIV+ patients [2]. Diet and nutrition should be considered as an integral part of the overall strategies of fighting against HIV/AIDS [3]. The simultaneous presence of malnutrition, HIV/AIDS and ART related problems generates a vicious circle in which complications are amplified (including a worse state of malnutrition) and consequent immune-suppression facilitates both opportunistic infections and HIV progression. To maintain the immune status, and therefore to limit the onset of an infectious disease or the progression of HIV infection in HIV subjects, an adequate diet balanced in macronutrients (proteins, carbohydrates, lipids) [4] and micronutrients is required [5–7]. Within the framework of Food Security (i.e. when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life), nutrition security depends on the transfer of sufficient nutrients from soils to edible plants to people, and from soils to plants/feeds to food producing animals to people [8]. Nutrition security may in some circumstances require

* Corresponding author at: Istituto Superiore di Sanità, Via Giano della Bella 34, 00162 Rome, Italy.
E-mail address: chiara.frazzoli@iss.it (C. Frazzoli).
[1] www.noodlesonlus.org.

http://dx.doi.org/10.1016/j.toxrep.2017.06.008
Received 31 December 2016; Received in revised form 18 April 2017; Accepted 22 June 2017
Available online 01 July 2017
2214-7500/ © 2017 Published by Elsevier Ireland Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/BY-NC-ND/4.0/).

nutritional interventions like soil enrichment, feed fortification, food fortification, human supplementation specifically (benefits vs. risks) assessed based on the geological and agro-farming characteristics of the productive system as well as on the dietary habits and nutritional status and needs of the targeted community/group/population [9]. On the other side, the wealth of traditional recipes should be exploited: indeed, besides their high acceptability within the population, the ecological nature of food culture combines crucial features linking geomedical aspects, nutritional needs, tastes (e.g. sea, inland, savanna), as well as availability, accessibility and affordability of ingredients [10]. Systematic analysis of scientific «evidence» by public-health experts has already proved to converge with diets evolved by all the populations of the world after millennia of human food expérimentation [11]. The basic African diets for secure nutrition include indigenous foods as cereals (such as corn, wheat and rice), tubers and roots (such as potatoes, sweet potatoes and cassava), vegetables and fruits, and are expected to become higher in animal-derived proteins and fats. Chronic and repeated (e.g. dietary) exposure to immunotoxicants/immunomodulating chemicals and substances with antinutritional effect can facilitate infectious diseases through the suppressed immune processes and increased nutritional requirements. This can result in increased risk for adverse immune outcomes [12,13]. Also, chemical-induced damage to the immune system might be associated with non-communicable diseases (NCDs) [14]: indeed, environmental factors may contribute to chronic immune-related (including cancer) diseases at relevant exposure levels [15]. Exposure to immunotoxicants can present additional risk to individuals with immune systems that are already fragile, for example, because of primary immunodeficiency, infancy, or old age [14].

In this work we have introduced the meaningful and innovative concept of "kitchen toxicology" and explored how good practices in the kitchen can exploit the value of traditional recipes through the mitigation of dietary toxic exposure. To this purpose, we designed and adopted the following procedure:

a) Identify the target community or population (sub)group
b) Define their general and specific vulnerability at organ/tissue, system and organism level
c) Select a recipe, preferably a traditional one, with specific beneficial effect (direct, indirect) on such targets
d) Identify risk factors/substances with possible (direct, indirect) adverse effects on vulnerable organs/tissues or systems
e) Examine the steps of the recipe, from purchase of raw ingredients through to food handling, cooking, storage, and consumption, and identify those more vulnerable to risk factors and those where such risk factors are manageable
f) Describe good practices that preserve the recipe from risk factors while maintaining its nutritional value.

As case study, we selected an African traditional recipe, the Egusi Okra soup: this recipe combines cereals, roots and leafy vegetables and is known as a meal able to sustain both nutritional status and body weight during ART. We discuss the *Egusi Okra* meal as case study for mitigating dietary toxic exposure through good practices recommended by a science-based "kitchen toxicology". Here, good practices focus on immunotoxicants, antinutritional factors, and toxicants possibly presenting additional risk (communicable and non-communicable diseases) to individuals living with a compromised/fragile immune system.

2. The *Egusi Okra* meal

The *Egusi Okra* soup, generally including meat or fish, is a nutritional recipe able to stimulate appetite by its pleasant taste and scent, to slow down weight loss [16], and to boost the immune system through its essential amino acids and fatty acids, minerals, vitamins (A, E, and folate). The soup is mostly eaten with a staple food named *fufu*. The meal (*Egusi Okra soup* and *fufu*) contains a good combination of indigenous foods (Fig. 1), and also has low levels of anti-nutrients.

Fig. 1. Egusi Okra soup prepared with meat.

The *Egusi Okra* soup recipe is based on locally available and easily affordable ingredients such as egusi, okra and red palm oil (Table 1). Egusi and okra can easily be grown by low income earners and red palm oil is the main cooking oil easily affordable all year round.

Egusi are seeds which, after removal from the fruits, are usually washed, sun-dried, decorticated and ground for cooking. Fokou et al. [17] and Achu et al. [18] found that five main varieties of egusi are commonly consumed across the different climatic zones of Cameroon: *Cucumeropsis mannii* (Fig. 2)*, Cucurbita maxima, Cucurbita moschata, Lagenaria siceraria and Cucumis sativus.* Egusi seeds contain mostly proteins (28–40.5%) and lipids (44–53.5%). The amino acid profile of the proteins of *Cucumeropsis mannii* and *Cucumis sativus* show higher levels of such essential amino acids as histidine (essential for infants), threonine, phenylalanine and tyrosine compared to soybean, and of valine, isoleucine, leucine, phenylalanine and tyrosine compared to casein. The levels of most essential amino acids are also higher than those recommended by the 1985 FAO/WHO for 2–5 years-old children [18,17]. However, egusi seeds have lower protein quality than casein, as their PDCAAS (Protein digestibility-corrected amino acid score) values (0.48–0.67) are lower than casein (1.0) [19,18]. The inclusion of meat or fish in *Egusi Okra* soup increases and completes the essential amino acid values of the soup.

The oils in egusi seeds have 4 main fatty acids: linoleic acid (polyunsaturated fatty acid, or PUFA) (C18:2, 49–69%), oleic acid (C18:1, 9–25%), stearic acid (C18:O, 7–11%), and palmitic acid (C16:O, 10–19%) [20]. An investigation of the anti-atherogenic properties of oils extracted from the egusi seeds of *C. mannii* and *C. sativus* showed that these oils are effective in reducing LDL

Table 1
Egusi Okra soup [16] recipe.

- Boil 1/2 kg of cow meat or smoked game and 4 smoked fish (cod fish or others, e.g. bonga) with salt and onions
- Chop 6 medium okra into thin pieces and put it in a bowl with a bit of water; beat it with a wooden spoon after chopping
- In another pot, heat 4 tablespoon of palm oil and add some sliced onions. Pour in the meat and fish with some broth. Put in the garlic and the ginger. When it boils, put in 1 cup of ground egusi (African Cucurbitaceae seeds)
- Keep the broth boiling for some more minutes and then put in a handful of washed vegetables (bitter leaves) or flutted pumpkin leaves (*okongobong*)
- At last, put in the okra and stir with a wooden spoon. Let it cook for 2 more minutes
- Serve it with any of the fufu type

Alternatives (e.g.): Okra pods can be baked or fried with a few drops of lemon or stewed with vegetables. Crayfish can be added.

Fig. 2. Egusi seeds (*Cucumeropsis mannii*).

cholesterol levels [21]. Egusi is also rich in polyphenols (flavones, isoflavones) whose content may vary according to varieties, environment, growth, and processing [22].

Okra (*Abelmoschus esculentus* L.) is among the most frequently and popularly consumed traditional vegetables in Africa [23]. It is an important multipurpose crop due to various uses of its pods, fresh leaves, buds, flowers, stems and seeds. In West and Central Africa okra is called *gombo* (French), *miyan-gro* (Hausa), *la* (Djerma), *layre* (Fulani), *gan* (Bambara), *kandia* (Manding), *nkruma* (Akan) and *fetri* (Ewe).

Okra can be cooked fresh or dried: the fresh one is preferred and is present for most of the year in the markets, whereas, dried okra is used when the fresh one is scarce during the dry season.

Okra immature fruits/pods (Fig. 3), which are consumed as vegetables, can be used in salads, soups and stews, fresh or dried, fried or boiled. Okra pod accessions are a good source of nutrients including protein, bioavailable calcium (Ca), iron (Fe), zinc (Zn), and fibers [24]. The content of main anti-nutrients (phytate, tannin, and oxalate) is low and is further reduced during traditional processing [24]. Okra is a rich source of fibers, which are essential for digestion and colon health; its mucilage and fibre help controlling sugar absorption. Especially after superfine grinding, okra also helps reabsorb water, traps excess cholesterol, metabolic toxins and surplus bile in its mucilage and slips it out through the stool [25,26]. Okra is also a rich source of folate and minerals (e.g. Ca, Fe, magnesium, or Mg, manganese, or Mn, Zn), thus promoting healthy pregnancy. Its content in vitamin C (antioxidant increasing resistance to infections), folate, and vitamin A covers 30%, 10–20% and 5% of the recommended levels, respectively. In addition, fresh okra is low in

Fig. 3. Okra seeds.

Table 2
Cassava *fufu* [30] recipes.

Fufu* or *nkumkum

Freshly harvested cassava tubers are manually peeled, washed, and cut into pieces, steeped in water (fermented) for 48–72 h. After that, the soft tubers are broken by hand and the fibers taken out. These soft tubers are then hand-squeezed to remove water and dried on porous bags under the sun until it gets dry. Drying can take 2 days to several days depending on the intensity of the heat of the sun and on the quantity of mass dried. The dried paste is hard when touched. It is then ground into powder with a grinding mill and sieved. Some water is boiled in a pot. Some powder is mixed with cold water and poured into the boiling water in the pot to thicken the water, while stirring with a wooden pestle, until it starts boiling. The rest of the sieved powder is added, energetically stirred into a homogenous paste while boiling. This is stirred to the desired consistency for 5 −10 mins with addition of boiled water if need be. The hot elastic *fufu* is made into bundles using a small pan, or wrapped in pre warmed plantain leaves and is ready for consumption.

Water fufu

Freshly harvested cassava tubers are manually peeled, washed, and cut into pieces, steeped in water (fermented) for 48–72 h. After that, the soft tubers are broken by hand or pounded in a wooden mortar and pestle. The fibers are removed by manual sieving with addition of water. The mass is washed through a plastic sieve and the rest of the fibers and hard parts of the tubers are discarded. The filtrate is allowed to sediment for 24 h in a large plastic bowl. After sedimentation, the water is decanted while the sediment is dewatered by putting the mash into a jute bag and pressed by tying with a solid rope and strong sticks and left overnight to remove excess water. If the quantity is much such that it can't get dry over the night, it is refastened with the rope and sticks the following morning and in the evening to drain out the excess water, taking 48 h to get dry. It is then untied, and the dried mass is mixed with a bit of water in a pot until a smooth paste is obtained. This paste is then boiled while stirring until a very thick, sticky and smooth mass (*fufu*) is obtained. It is made into bundles using a plate and is ready for consumption.

calories, with almost no fat [23]. The okra seeds represent 17% of the whole fresh vegetable and are rich in phenolic compounds, mainly oligomeric catechins and flavonol derivatives [27,28].

Red palm oil has high levels of antioxidants, especially vitamin E (tocopherols and tocotrienols, which protect cells' structure and resistance to disease), and provitamin A carotenoids (15 times more than that of carrots and 300 times more than that of tomatoes), making it a valuable resource in the treatment of vitamin A deficiency. Vitamin A enhances the immune system and the red palm oil used in the cooking of *Egusi Okra* soup further reinforces the meal values in supporting immune function of people living with HIV/AIDS. Vitamin A deficiency is also associated with an increased risk of vertical (mother to child) HIV transmission.

The addition of meat or fish enhance the protein, mineral and vitamin quality of the soup. In particular, the addition of saltwater fish will enrich the meal of vitamin D, iodine (I) and PUFAs [29], the latter playing a critical role in the maintenance of immune response.

The soup is generally eaten with *fufu* (Tables 2 and 3), that is a paste prepared from tubers (generally cassava, but also potatoes or cocoyams depending on the region and on the individual taste) or cereals (generally corn, but also millet or rice depending on the region and on the individual taste) which are carbohydrate sources increasing the energy value of the meal, and therefore helping to prevent weight loss [31].

The preparation and cooking procedures vary among countries and among regions within the same country. Cultural values and beliefs greatly influence the eating habits. For instance, to avoid possible diarrhea when egusi is not properly stored, local people add to the traditional recipe a well-known medicinal plant, the *Aframomum melegueta* Schumann (Zingiberaceae) [32,33]. Moreover, two active components isolated from the seed of *A. melegueta*, paradol and shogoal, were found to possess antimycobacterial activity, whereas gingerol, another active compound, inhibits prostaglandin and leukotriene biosynthesis [34]. Despite the variety of *egusi* and *okra* used to cook the soup, as well as preparations and cooking procedures, the nutritional quality of the soup remains high [24]. As for every food, the ingredients of the soup, its preparation and consumption entail different potential risk factors.

Table 3
Corn *fufu* recipe.

Mature dried corn grains are harvested from the farm. Once in the house, they can be tied into small bunches and smoke dried in local kitchens or outside below the ceiling. The grains can also be removed from the cobs and dried under the sun on porous bags. Once dried, the grains are manually selected to remove dirt and bad grains. The healthy grains are then ground in a grinding mill into a powder (corn flour). Before grinding, depending on the taste of the individual, the grains can be dehulled to remove the outer coat before grinding. The powder is then sieved and the chaffs are washed with water and the debris discarded. Much water is boiled in a pot and part of it kept aside to use during cooking. Some powder is added to the washed chaffs and mixed into a homogenous mixture. This mixture is poured into the boiling water in the pot to thicken the water, while stirring with a wooden pestle, until it starts boiling. The rest of the sieved powder is added, energetically stirred into a homogenous paste. Some of the boiled water that had been kept aside is added, the pot covered and allowed to cook with much heat for 10–15 min. The paste is stirred and according to the thickness, hot water can be added again and stirred while cooking, until the desired texture is obtained. The very hot *fufu* is made into bundles using a small pan, or wrapped in plantain leaves or polyethylene papers and is ready for consumption.

Since infectious illness from microbiologically contaminated food are widely recognized (e.g. [35], in this paper we analyse toxicological risk factors particularly relevant to individuals with HIV+/AIDS as they may affect nutritional and/or immune status; our investigation starts from purchased raw materials and ingredients through to food handling, cooking, storage and consumption. The Cameroonian procedure of *Egusi Okra* meal preparation (Tables 1–3) is considered here, with the purpose of highlighting good practices preserving nutrients but protecting food as consumed from i) contaminants directly/indirectly dysregulating the immune system and from ii) antinutritional factors. The proposed approach can support the role of *Egusi okra* soup as a nutritious traditional recipe for the maintenance of health status in HIV/AIDS subjects.

3. Substances worsening nutritional status

Low serum concentration of micronutrients like vitamin A and B vitamins is associated with both lower total counts of CD4 and more rapid disease progression [36]. Malnutrition is a serious and common clinical problem in HIV+ subjects, because both medicine, weariness and disease increase malnutrition status [37]. Aïssi et al. [38] report high frequencies of trace element deficiencies among people living with HIV and under treatment in Cotonou and the Republic of Benin: 31.7% (Zn), 26.37% (Cu) and 46.43% (Fe). People with a CD4 count ≤ 200 cells/uL had the greatest risk of being deficient in Zn and/or Cu. The supplementation of vitamins is associated with reduced mortality in patients with CD4 count less than 100 cells/mL [39]. Although ART is crucial in fighting HIV and AIDS by increasing the patient's life expectancy and contributing to a lower spread of the virus, it shows a set of side effects/complications, in particular impairing digestive tissues and functions, hence nutritional status [39,40,4]. ART alone is not sufficient to recover micronutrient status in settings with deficiencies [41] and mitigation measures could come from appropriate foods and meals [31]. Also for HIV+ subjects without complications and a sufficiently stable weight a nutritious and balanced diet is recommended to satisfy the increased energy and nutritional requirements for supporting the immune system and maintaining weight [31]. In the absence of other diseases, a 10% increase in the daily energy should be considered; in case of opportunistic infections the increase varies from 30 to 50% of the normal caloric intake [4]. Indeed a weight loss of only 5% can be associated to an increased risk of illness and mortality in HIV/AIDS patients [7,42].

Substances present in foods may exacerbate the nutritional impairment in HIV/AIDS subjects and/or increase the body nutritional requirements:

- **Antinutrients.** These (e.g. oxalic and phytic acids and their salts) have a negative/inhibitory effect on the ability of the body to absorb and digest essential minerals (especially Fe and Zn, but also Ca and Mg) and metabolizable energy and amino acids [43]. Antinutrients are able to chelate metal cations, proteins and digestive enzymes (e.g. pepsin, amylase and trypsin) and form insoluble and non-available complexes [43]. The relevance of such action is signified by the use of the [phytate]:[mineral ion] molar ratio as indicator of bioavailability: for instance, phytate begins to lose its inhibitory effect on Fe absorption when [phytate]:[Fe] molar ratios are less than 1.0 [24].
- **Secondary (or conditioned) nutrient-nutrient deficiencies**. Nutrient-nutrient interferences occur in case of unbalanced intakes, via competition in transport mechanisms, e.g. Cu-Zn, Fe-Mn, and Mo-Cu, or metabolism interaction, e.g. Cu-Fe and Fe-Zn [8]. High Ca levels in foods can promote the phytate induced decrease in Zn bioavailability: the [phytate][Ca]/[Zn] millimolar ratio has been suggested as a better index of Zn bioavailability than the [phytate]/[Zn] molar ratio alone [24]. The sub-clinical deficiency of essential cofactors (e.g. Cu, Mn, selenium, or Se, Zn) of antioxidant enzymes may decrease the ability to cope with pro-oxidants and increase the vulnerability to infectious diseases [44]. Altered levels of micronutrients, e.g. Se, have been reported also in relation with HIV infection and/or ART [45,46].
- **Toxicant-induced higher nutritional requirements**. Toxicants may increase nutritional requirements by affecting nutrients metabolism, e.g. decreasing absorption or increasing excretion of micronutrients [8]. For instance, a prolonged intake of toxic TE may interfere with antioxidant micronutrients (e.g. Se-Cd, Se-Hg and Zn-Cd) [47].
- **Toxicants body burden and nutritional imbalances**. Nutritional imbalances may improve internal accumulation of toxicants. For instance, deficiency in macronutrients (e.g. dietary Ca) may increase the absorption of immunotoxic Al [48].
- **Toxicants-gut microbiota interactions**. The importance of gut microbiota in modulating environmental effects on human health is emerging, especially in early life [49]: indeed, microbiome (e.g. the gut microbiome) responses to xenobiotics may modulate immune protection [50].

4. Food contaminants dysregulating the immune system

Several contaminants directly affect the immune system, thus increasing the vulnerability to infections [15]. Examples include trichothecene mycotoxins, such as deoxynivalenol (DON), polyaromatic hydrocarbons (PAHs), dioxins and dioxin-like compounds [51], organochlorines and organophosphorous insecticides [52] and several substances identified as persistent environmental pollutants due to their past or current industrial use: polychlorinated biphenyls [53], hexachlorobenzene, perfluorinated compounds (PFC) [54] and tributyltin. Contribution to the HIV epidemic by aflatoxin is postulated but not yet established [13]. Among inorganic compounds, immunotoxicity has been reported for aluminium (Al) [55], and inorganic arsenic (As) [56]. Cadmium (Cd), mercury (Hg), lead (Pb), vanadium (V), platinum (Pt) and palladium (Pd) are non-essential trace elements (TE) whose potential to impair immune functioning and the response to oxidative stress has been recognized [57]. Many of the above chemicals (e.g. PFC) especially affect the programming of the developing immune system [58], thus emphasizing the role of prenatal and early postnatal transgenerational diet (through placenta and breast milk) in the risks of adverse immune outcomes in the offspring and subsequent generations (transgenerational predisposition, from grand-mother to grand-son) through epigenetic changes [59,60].

4.1. Toxic contaminants in the Egusi Okra soup

Environmental toxic contamination of foods may occur though the environment, cooking methods generating process contaminants, and migration/leaching from food contact materials during cooking and storage [61]. The following paragraphs detail these aspects:

4.1.1. Ingredients of Egusi Okra soup at purchase

The origin of raw materials and ingredients represents a major vulnerable aspect, due to possibility of i) untraceable illegal treatments with veterinary drugs or plant protection products or ii) bad production practices e.g. causing contamination by mycotoxin-producing fungi or by nitrates, perchlorate, and Cd in fertilizers. For instance, several African farmers are used to spreading the harvested egusi to dry under the sun for about 6 days, with a mean value of 4.3 h of sunshine per day. From July to September, during the period of the first harvest, due to high atmospheric relative humidity the quality of the product is affected by extended drying times [62]. There is the possibility of contamination by mycotoxin-producing fungi due to inadequate storing conditions of the dried seeds. The use of a powder or essential oil from dried ground leaves of *Cymbopogon citratus* (lemon grass) has been suggested to control storage deterioration and aflatoxin contamination [63]. Meat inspection and control is insufficient in Africa: for instance, in Cameroon, only two modern slaughterhouses exist in Douala and Yaoundé, while others are traditional. Raw materials and ingredients should not come from areas exposed to pollution sources, including mining sites (i.e. contaminated by inorganic toxicants like Cd and Pb) and e-waste disposal sites, where dioxin contamination may be very high [64].

The *fufu* should also not come from flour contaminated with mycotoxins (e.g. during harvest or storage) and with atmospheric pollutants (e.g. during fermentation) [65]. Vegetables should not have received heavy treatments with pesticides. It is important indeed to know the sources of raw materials and ingredients and purchase them from recognized traders: these should certify that the presence of residues and contaminants is in compliance with safety standards. Finally, water is a main dietary source of toxic elements such as Mn [66] and As [67], as well as of herbicides [68]: use of unsafe water (e.g., from old, worn water pipes or from areas polluted by mining sites or pesticide treatments) during cooking may significantly increase food contamination (e.g., [67]). The frequent inadequate supply of clean water in Africa [107] may mean re-use of water from cleaning of ingredients and raw materials, equipment and utensils, for cooking.

4.1.2. Process contaminants in the recipe of the Egusi Okra soup

Cooking methods and devices of *Egusi Okra* soup recipe may increase the content of high-concern process contaminants such as:

- benzo(a)pyrene formed through smoking of fish [69].
- PAHs as products of combustion and high temperature pyrolysis in smoked fish, and crude vegetable oils [70].
- heterocyclic aromatic amines formed from amino acid pyrolysates at temperatures over 150 °C and found in wood smoke in certain circumstances [71].

4.1.3. Kitchen environment

The kitchen environment should be cleaned through extensive washing of boards, dishes, utensils, and tops to remove residues of soap, disinfectants (e.g., the carcinogen formaldehyde), biocides (hexachlorobenzene), pesticides (e.g. organochlorines), insecticides (e.g. organophosphates, pyrethroids), and anticoagulant rodenticides possibly used to defend food from dirty, pest or insects and possibly directly/indirectly impacting on physiological functions of the immune system. Food is often left not covered with appropriate clean material, thus remaining exposed to airborne chemicals (e.g. Pb, dioxins, PAHs) in dusts, automotive exhaust fumes, and (e)waste burning fumes [64,72,73].

4.1.4. Materials in contact with food during cooking and storage

The combination of poor quality and easy to deteriorate pots, pans, and utensils and improper practices during cooking may lead to the leaching of a number of toxic compounds, including metals (e.g. Al, Cd, Cu, Hg, Ni, Pb). Pots, pans, and utensils in developing areas where incidence of HIV/AIDS is high often come from informal manufacturers/retailers using materials not suitable for foods [74], and from derelict cars and industrial machinery; for instance, worn-out car tyres and plastics are used to smoke fish. Further to Al flexible sheets or pans used to preserve food, Al pots from informal recycling market are used for cooking: this implies the possibility that also other metals like As, Cd, and Pb are leached, especially in the presence of acidic foods, during normal food processing [75,76]. Indeed, dietary exposure to Al due to artisanal cookware, increased by corrosion during cooking, in countries where the geophagic practice exposes people [77] is emerging as a significant and largely unrecognized public health risk deserving urgent attention [76].

In addition to metals, organic endocrine disrupters may also be leached in food, such as [78]:

- Perfluorinated compounds (PFCs) such as perfluoro-octanoic acid (PFOA) may be released by outdated Teflon pans or non-stick cookware coatings for cookware made with polytetrafluoroethylene, if deteriorated or used at temperatures above 230 °C;
- Bis(2-ethylhexyl)phthalate (DEHP) or other phthalates may migrate from soft polyvinylchloride (PVC) plastics upon prolonged contact with fat containing foods (e.g. meat) [79];
- Bisphenol A, an additive of polycarbonate plastic containers, can leach into food from worn surfaces and/or when in contact with hot liquids [74].

Common types of available low cost materials used to package food include discarded plastic and metal bottles and jars, earthenware vessels, glass-sided boxes, old stock of paper prints, rushes, reeds, leaves, vegetable fibers, maize-sheath, wood, animal skins, jute sacks, poly sacks, polyethylene bags, and no standard of regulatory bodies has been effective in ensuring the food safety [80–83]. Packaging materials such as newspaper may release PFCs [84] and substances (e.g. BPA) from the printing inks [85]. Also in the storage phase it is important to keep foods in adequate containers and protect them with covers. In countries where proper regulations do exist, only products approved for use in food facilities should be used. The quality of storage equipment is important, e.g. avoiding use of Al containers for acidic foods or phthalate-releasing PVC wrappings for foods of animal origin. When good practices are not taken, inappropriate storing may determine mycotoxins formation whereas the attempts to increase hygiene may expose to noxious cleansing agents and insecticides. For instance, the use of fumigants and sanitizers against insects and pests should be avoided when foods are stored to prevent deposition of chemicals directly on the foodstuffs' surface. Instead, prior to fumigation and sanitization, all foods and utensils should be removed from the storage area. Melamine, which has miscellaneous toxicity [86,87], can be released by food contact materials, including articles made of melamine-formaldehyde plastics, can coatings, paper, boards and adhesives [88]. When subjected to excessive heat (higher than 70 °C), plates, dishes and other kitchen utensils made from melamine resin can release melamine and formaldehyde into food and exceed threshold values [89].

5. In the kitchen: recommendation to mitigate toxic exposure while preserving nutritional value in consumed food

Natural undesirable substances may naturally occur in foods, including high levels of nitrate in green-leaf vegetables [90,91], mycotoxins, and antinutritional factors (ANF). Several studies have shown reduction of nitrate levels when vegetables are washed, peeled and cooked in water [91]. ANF (e.g. phytate) are endogenous substances occurring in several vegetable products, which elicit adverse health effects by impairing absorption of nutrients and/or affecting bioavailability of essential minerals like Ca, Fe, Mg, and Zn. Adequate storage may decrease e.g. mycotoxin contamination of *fufu*, whereas food processing may reduce ANF and, consequently, increase the bioavailability of nutrients. For instance, improved bioavailability of Fe and Zn is observed with traditional household food technologies including dehulling, peeling, soaking, germination, fermentation, and drying [92,93]. Appropriate processing (Table 2) can reduce cyanogenic glucoside in cassava tubers: high dietary cyanide exposure occurs when high cyanogenic cassava and insufficient processing combine, with possible disruption of the iodide uptake [94]. In general, cooking processes (boiling, stir-frying, steaming, roasting, grilling, frying, baking, broiling, barbecuing, microwaving, smoking, or sun drying) may change the concentrations of various metals and organic contaminants in food as consumed [95].

Interestingly, the Total diet Study (TDS) conducted in Yaoundé, Cameroon, showed that boiled dried and smoked fish was among the major contributing food to Al exposure [96]. Removal of parts particularly vulnerable to contamination is in some case convenient from the benefit-to-risk viewpoint. For instance, except arsenate, or As(V), among different arsenic (As) species, okra accumulates arsenite, or As(III), and dimethylarsinic acid (DMA) mainly in its roots with limited transport to the shoots. The removal of As by boiling vegetables with excess water has been shown to be unsuccessful [97]. In general, cooking procedures that release or remove fat from the product tend to reduce the total concentrations of the organic contaminants (e.g. total DDT, PCBs, phthalates) [98–100]. However, the influence of cooking on the levels of these contaminants depends not only on the particular cooking process, but even more on the specific food item (e.g. fish, meat, vegetables) and its characteristics (e.g. species, size, oil uptake, water loss), whereas cooking seems generally not an effective approach to reduce dietary exposure to perfluoroalkyl and polyfluoroalkyl substances (PFAS), especially PFOS [101,102]. Modifications of cooking practice, e.g. oven cooking or cooking with a heat source above the food, or segregation of the food from the smoke greatly reduce exposure [103].

Cooking methods as boiling and steaming preserve food wholesomeness: based on the *Egusi Okra* soup recipe, some recommendations emerge on how to mitigate toxicant exposure:

- Protect the kitchen from airborne chemicals (prefer an indoor space)
- Use a water source that meets the international standards for drinking water
- Purchase raw materials and ingredients from recognized traders and producers, and from areas not subjected to high toxic exposure
- Keep raw materials and ingredients stored or covered in proper containers at proper temperature. Use only food contact materials (utensils, cookware and packaging materials) approved for use in food facilities, purchased from formal retailers and in good state, undamaged and not deteriorated. Follow the instructions for the use of utensils, cookware and packaging materials with respect to the foodstuff and the cooking method; low-risk materials such as glass or stainless steel are preferable. If the use of Al pans is unavoidable (they are present in traditional markets, Fig. 5), it is recommended to boil the cookware in water prior to cooking to decrease Al leaching into food [104]
- Apply only fumigants and sanitizers approved for use in food facilities, and remove all food and utensils from the structure prior to fumigation and sanitization. Remove residues of fumigants and sanitizers in the kitchen
- Extensively and thoroughly wash vegetables with fresh and clean water to remove traces of insecticides and pesticides
- Prepare cassava properly according to instructions before consumption
- Adopt practices downing the level of lipophylic contaminants in fish: remove adipose tissues and bioaccumulating organs (e.g. liver) by peeling fish, removing entrails, cutting away fat. In the case of fish fat from the belly, the line along the sides, the fat along the back and finally that under the skin should be removed
- When smoking (or drying), charcoal (or alternatively firewood if you are cooking in the kitchen) should be piled around the drip pan and filled with water to maintain a moist environment. The drip pan catches any rendered fat or juice from the food and prevents it from flaming up on the hot coals and pyrolize; alternatively, to avoid that pyrolysis compounds rose with the smoke to deposit on the food, a covered grill should be used. Alternatively, facilitate dripping of rendered fat on a grid, to avoid its carbonization due to direct contact with the flame (Fig. 4). To ensure food is smoked safely and at a safe minimal internal temperature, use two thermometers: one for the food and one for the smoker. Do not use rendered fat and cooking juices to prepare sauces or in the served soup. Consider to marinate (e.g. with oil, lemon, or rosemary), or partially cook in the stove prior to smoking to reduce smoking time. In any case, keep cooking temperature low and constant for a limited time, avoid direct contact between food and flame and avoid overcooking

Fig. 4. A traditional food dryer @2016 courtesy of NOODLES (www.noodlesonlus.org).

Fig. 5. Aluminium pots on sale at the Mokolo market (Yaoundé, Cameroon) @2016 courtesy of NOODLES (www.noodlesonlus.org).

6. Discussion

The National Research Council (United States) states that "*There is no definitive evidence, as yet, that persons who live near contaminated sites or chemical-manufacturing plants have been immunologically compromised to the extent that they are at increased risk of disease. Nonetheless, there is* *reason to believe that chemical-induced damage to the immune system might be associated with pathologic conditions, some of which could become detectable only after a long latency. Likewise, exposure to immunotoxic xenobiotics can present additional risk to individuals with immune systems that are already fragile, for example, because of primary immunodeficiency, infancy, or old age*" [14]. "*Infectious diseases can increase human susceptibility to adverse effects of metal exposure (at suboptimal or toxic levels), and metal excess or deficiency can increase the incidence or severity of infectious diseases*" [105]. Africa, where common infectious diseases are endemic, also has the highest prevalence of essential chemical element deficiencies and rising high (and uncontrolled) rates of toxic contaminations, especially in urban, industrial, (e)waste, mining sites [106–108]. This complex web of interactions has severe but poorly understood impact: toxicovigilance today is more reactive than preventive in Africa [109].

The repeated and prolonged dietary intake of contaminants stemming from wrong practices in the kitchen (from selection of raw foods and ingredients to cooking practices and environment, food contact materials, and utensils) elicits toxic and/or antinutritional effects possibly increasing patients' nutritional requirements while decreasing the absorption of nutrients and therefore the nutritional power of suggested meals. Science-based evidence in scientific literature can put together sets of simple practices for mitigating toxicological risk factors during food consumption and protecting the nutritional benefits of foods, meals and diet. The following aspects deserve attention:

- The **empowerment of consumers**, especially individuals living with a compromised/fragile immune system, is an emerging aspect of prevention strategies in public health. Indeed, public health interventions for proper diet and nutrition should benefit of the integration of proper practices during common kitchen procedures that repeatedly and daily expose people through the diet [61]. Proactiveness (i.e. awareness, participation, motivation) by food operators and consumers is crucial.
- In particular, **maternal nutrition** is reported as a critical factor in the occurrence of HIV vertical transmission by possibly determining a state of compromised, insufficient and/or unbalanced nutritional status of the fetus. Secondary deficiencies are important risk factors that can be reduced by improving maternal nutritional status through a) the education of women to a balanced and safe diet even before conception (during the whole fertile age, as boosted by sustainable food safety paradigm), and dietary supplementation of individuals at risk [60]; b) the reduction of the intake of contaminants that may interact with metabolism or transport of transplacental micronutrients [60]; c) the management of risks of non controlled self dietary supplementations, e.g. by geophagic practice [77]. Epigenetic mechanisms call for the implementation of sustainable food safety policies, i.e. policies protecting the health of the generations to come by ensuring the safety of foods today [10,60].
- **Geomedicine and food safety** (including standards and regulations) within the interdisciplinary umbrella of the One Health approach are necessary at raw food production level to improve consumers' dietary micronutrients intake and abate the carry over of toxic substances impacting on the immune system [110]. Direct evaluation of actual food items is recommended to determine risk-benefit ratios of local ingredients, traditional meals, and diets based on local nutritional needs and local food varieties and species [111]. Human and animal biomonitoring programmes should include those analytes that are known to give interferences such as secondary deficiencies and imbalances [8]. Moreover, the scenario depicted through biomonitoring should be integrated with the understanding of dietary exposure: the recent Total Diet Studies (TDSs) conducted in Yaoundé, Cameroon, on food "as consumed" [96,112] could provide useful information towards risk management and mitigation in the area. For instance, substantial scientific evidence supports the protective action of a balanced Se intake [113] as well as the negative effect of Se deficiency on the immune system [114]. Both prevalence of inadequate intake of other essential elements (e.g. Zn) and excess exposure to toxic elements (e.g. Al, Cd, and Pb) should be considered when assessing both Se requirements of the population and intervention strategies [110]. The Cameroonian scenario depicted by the TDS presents an elevated prevalence of inadequate intake for Ca, Fe, Mg, Zn and Se [112], with a fraction of the study population estimated at excess exposure to, e.g., Al and Cd [96]. Considering the interference mechanisms impairing nutrition (e.g. Zn-Se) and modulating negative effect of toxic exposure (e.g. Se-Al, Se-Cd, Zn-Cd) we can consider that besides possible One Health interventions (e.g. pasture fortification, feed enrichment) or dietary supplements, measures as substitution of Al pots and pans should be urgently considered.
- Besides pathogen-toxicant (e.g. metal) interactions, emerging scientific research on pathogenesis of (chronic and) infectious diseases investigates effect of multiple **interactions between toxicants and gut microbial diversity**, in terms of both toxicokinetics/gastro-intestinal exposure [115] and vulnerability or susceptibility of the immune system [116].

7. Conclusion

Nutrients and contaminants in meals are determinants of health. Following the proposed methodology, we found how, based on available and corroborated scientific knowledge, the nutritional value of recipes can be exploited through good practices in the kitchen. In particular, a series of good practices has emerged on how to reduce adverse dietary exposure during the preparation of a traditional African recipe, such as the *Egusi Okra* soup. Such a recipe can be used to mitigate complications caused by HIV/AIDS and ART, such as weight loss and opportunistic infections. The paper suggests how interventions for secure and safe diet and nutrition would also benefit of the analysis of common kitchen practices that repeatedly and daily expose the population. "Kitchen toxicology" is closely interrelated with nutrition: indeed, the prevention/mitigation of dietary contaminants is warranted to protect immunity and wholesome meals for people living with disease, to both reduce the disease impact, contain its progress, and improve as much as possible the quality of life and life expectancy. This paper fosters the new emerging paradigm for studying and preventing many infectious diseases, in which the assessment of toxicological risk factors *from farm to fork* (and *mother-to-child*) is crucial to understand the history and status of the person exposed to or affected by an infectious disease. Nutritionists and toxicologists should dialogue to improve the impact of diet and nutritional interventions on the treatment outcome in everyday life. The manuscript contributes to the translational aspect of scientific know how, from environmental health (science) to society.

Acknowledgements

The paper stems from the *narrative prevention* activities of the ISS in collaboration with the North-South and South–South Network NOODLES (Nutrition & food safety and wholesomeness. Prevention, education and research Network, www.noodlesonlus.org) and the Centre Pasteur du Cameroon, Yaoundé (ALERT project, funded by the Italian Ministry of Economic Development). In memory of Marie Madeleine Gimou.

References

[1] WHO, Nutrient requirements for people living with HIV/AIDS, Report of a technical consultation, Geneva, (2003).
[2] E. Liu, D. Spiegelman, H. Semu, C. Hawkins, G. Chalamilla, A. Aveika, S. Nyamsangia, S. Mehta, D. Mtasiwa, W. Fawz, Nutritional status and mortality among HIV infected patients receiving antiretroviral therapy in Tanzania, J. Infect. Dis. 204 (2) (2011) 282–290.

[3] J.H. Irlam, N. Siegfried, M.E. Visser, N.C. Rollins, Micronutrient supplementation for children with HIV infection, Cochrane Database Syst. Rev. 10 (2013) CD010666.
[4] J.W.C. Hsu, P.B. Penchars, D. Macallan, A. Tomkins, Macronutrients and HIV/AIDS: a Review of Current Evidence. Consultation on Nutrition and HIV/AIDS in Africa: Evidence, Lessons and Recommendations for Action, Department of Nutrition for Health and Development WHO, Durban, South Africa, 2005.
[5] H.C. Anyabolu, E.A. Adejuyigbe, O.O. Adeodu, 2014 serum micronutrient status of haart-naïve, HIV infected children in south western Nigeria: a case controlled study, AIDS Res. Treat. 35104 (2014) 3, http://dx.doi.org/10.1155/2014/351043.
[6] M.K. Baum, A. Campa, S. Lai, S. Sales Martinez, L. Tsalaile, P. Burns, M. Farahani, Y. Li, E. van Widenfelt, J.B. Page, H. Bussmann, W.W. Fawzi, S. Moyo, J. Makhema, I. Thior, M. Essex, R. Marlink, Effect of micronutrient supplementation on disease progression in asymptomatic, antiretroviral-naive, HIV-infected adults in Botswana: a randomized clinical trial, JAMA 310 (20) (2013) 2154–2163.
[7] V. Pribram, Decreased nutritional status and nutritional interventions for people living with HIV, in: V. Pribram (Ed.), Nutrition and HIV, first edition, Wiley-Blackwell, Oxford United Kingdom, 2011.
[8] C. Frazzoli, B. Bocca, A. Mantovani, The one health perspective in trace elements biomonitoring, J. Toxicol. Environ. Health B Crit. Rev. 18 (7–8) (2015) 344–370.
[9] M.A. Wirakartakusumah, P. Hariyadi, Technical aspects of food fortification, Food Nutr. Bull. 19 (2) (1998) 101–108.
[10] C. Frazzoli, Health as natural transgenerational capital (sustainable food safety): the ecology of eating in Senegal, with a focus on savanna areas, pastoral systems, Frontiers in Public health (2017) (in press).
[11] F. Berrino, Prevention and tao, Epidemiol. Prev. 34 (5–6) (2010) 83–86.
[12] J.M. Kreitinger, C.A. Beamer, D.M. Shepherd, Environmental immunology: lessons learned from exposure to a select panel of immunotoxicants, J. Immunol. 196 (8) (2016) 3217–3225.
[13] J.H. Williams, J.A. Grubb, J.W. Davis, J.S. Wang, P.E. Jolly, N.A. Ankrah, W.O. Ellis, E. Afriyie-Gyawu, N.M. Johnson, A.G. Robinson, T.D. Phillips, HIV and hepatocellular and esophageal carcinomas related to consumption of mycotoxin-prone foods in sub-Saharan Africa, Am. J. Clin. Nutr. 92 (1) (2010) 154–160.
[14] US National Research Council, Subcommittee on Immunotoxicology. Biologic Markers in Immunotoxicology, National Academies Press (US), Washington (DC), 1992 5, The Capacity of Toxic Agents to Compromise the Immune System. Biologic Markers of Immunosuppression.
[15] R.R. Dietert, M.S. Piepenbrink, Lead and immune function, Crit. Rev. Toxicol. 36 (4) (2006) 359–385.
[16] E. Polle, R. Sama, A. Bame, E. Philippe, A. Tchana, Nourishing the Ailing Body. A Positive Living Nutrition Handbook for People Living with HIV/AIDS Based on Traditional Recipes from Cameroon, Fobang Foundation, Yaoundé, Cameroon, 2010.
[17] E. Fokou, M.B. Achu, M.F. Tchouanguep, Preliminary nutritional evaluation of five species of egusi seeds in Cameroon, Afr. J. Food Nutr. Dev. 4 (1) (2004) 1–11.
[18] M.B. Achu, E. Fokou, C. Tchiégang, M. Fotso, M.F. Tchouanguep, Nutritive value of some cucurbitaceae oilseeds from different regions in Cameroon, Afr. J. Biotechnol. 4 (10) (2005) 1329–1334.
[19] M.B. Achu, E. Fokou, G. Kansci, M. Fotso, Chemical evaluation of protein quality and phenolic compound levels of some Cucurbitaceae oilseeds from Cameroon, Afr. J. Biotechnol. 12 (7) (2013) 735–743.
[20] E. Fokou, M.B. Achu, G. Kansci, R. Ponka, M. Fotso, C. Tchiégang, M.F. Tchouanguep, Chemical properties of some cucurbitaceae oils from Cameroon, Pak. J. Nutr. 8 (9) (2009) 1325–1334.
[21] M.B. Achu, E. Fokou, C. Tchiégang, M. Fotso, M.F. Tchouanguep, Atherogenicity of cucumeropsis mannii and cucumis sativus oils from Cameroon, Afr. J. Food. Sci. 2 (2008) 021–025.
[22] M.I. Alarcón-Flores, F. Hernández-Sánchez, R. Romero-González, P. Plaza-Bolaños, J.L. Martínez Vidal, A. Garrido Frenich, Determination of several families of phytochemicals in different pre-cooked convenience vegetables: effect of lifetime and cooking, Int. J. Food Sci. Nutr. 65 (7) (2014) 791–796.
[23] S. Kumar, S. Dagnoko, A. Haougui, A. Ratnadass, D. Pasternak, C. Kouame, Okra (Abelmoschus spp.) in West and Central Africa: potential and progress on its improvement, Afr. J. Agric. Res. 5 (25) (2010) 3590–3598.
[24] H.F. Gemede, G.D. Haki, F. Beyene, A.Z. Woldegiorgis, S.K. Rakshit, Proximate, mineral and antinutrient compositions of indigenous Okra (Abelmoschus esculentus) pod accessions: implications for mineral bioavailability, J. Nutr. Food Sci. S3 (003) (2015), http://dx.doi.org/10.4172/2155-9600.s3-003.
[25] A. Bangana, N. Dossou, S. Wade, A.T. Guireo, D. Lemonnier, Cholesterol lowering effects of Okra (Hibiscus esculentus) in Senegalese adult men, Ann. Nutr. Metab. 18 (1) (2005) 199–200.
[26] Y. Chen, B.C. Zhang, Y.H. Sun, J.G. Zhang, H.J. Sun, Z.J. Wei, Physicochemical properties and adsorption of cholesterol by okra (Abelmoschus esculentus) powder, Food Funct. 6 (12) (2015) 3728–3736.
[27] P. Arapitsas, Identification and quantification of polyphenolic compounds from okra seeds and skins, Food Chem. 110 (2008) 1041–1045.
[28] F. Xia, Y. Zhong, M. Li, Q. Chang, Y. Liao, X. Liu, R. Pan, Antioxidant and anti-fatigue constituents of okra, Nutrients 7 (10) (2015) 8846–8858.
[29] A. Mantovani, D. Ferrari, C. Frazzoli, Sustainability, security and safety in the feed-to-fish chain: focus on toxic contamination, Int. J. Food Sci. Nutr. 4 (2–2) (2015) 6–24.
[30] O.P. Bamidele, M.B. Fasogbon, D.A. Oladiran, E.O. Akande, Nutritional composition of fufu analog flour produced from Cassava root (Manihot esculenta) and Cocoyam (Colocasia esculenta) tuber, Food Sci. Nutr. 3 (6) (2015) 597–603.
[31] FAO, Living Well with HIV/AIDS. A Manual on Nutritional Care and Support for People Living with HIV/AIDS, Joint publication with World Health Organization, Rome, Italy, 2002.
[32] T. Jiofack, C. Fokunang, N. Guedje, V. Kemeuze, E. Fongnzossie, B.A. Nkongmeneck, P.M. Mapongmetsem, N. Tsabang, Ethnobotanical uses of medicinal plants of two ethnoecological regions of Cameroon, Int. J. Med. Med. Sci. 2 (3) (2010) 60–79.
[33] C. Lans, Comparison of plants used for skin and stomach problems in Trinidad and Tobago with Asian ethnomedicine, J. Ethnobiol. Ethnomed. 3 (2007) 3, http://dx.doi.org/10.1186/1746-4269-3-3.
[34] S. Umukoro, B. Rasaq Ashorobi, Further pharmacological studies on aqueous seed extract of Aframomum melegueta in rats, J. Ethnopharmacol. 115 (3) (2008) 489–493.
[35] USDA, Food safety for People With HIV/AIDS: A need to know guide for those who have been diagnosed with HIV/AIDS, (2011) Washington, U.S..
[36] P.K. Drain, R. Kupka, F. Mugusi, W. Fawzi, Micronutrients in HIV-positive persons receiving highly active antiretroviral therapy, Am. J. Clin. Nutr. 85 (2) (2007) 333–345.
[37] L. Kessler, H. Daley, G. Melanga, S. Graham, The impact of the human immunodeficiency virus type 1 on the management of severe malnutrition in Malawi, Ann. Trop. Paediatr. 20 (1) (2000) 50–56.
[38] A.K. Aïssi, A. Hounto-Ogouyemi, E. Lozes, C.R. Johnson, S. Kplakatcha, V. Dougnon, E. Tchiakpe, J.R. Klotoe, Y. Barogui, P. Guedenon, P.A. Edorh, F. Loko, Frequency of deficiencies in trace elements and correlations with the degree of immunosuppression in people living with HIV in Cotonou (Benin), Int. J. Biosci. 3 (4) (2013) 58–67.
[39] W.D. Dudgeon, K.D. Phillips, J.A. Carson, R.B. Brewer, J.L. Durstine, G.A. Hand, Counteracting muscle wasting in HIV-infected individuals, HIV Med. 7 (5) (2006) 299–310.
[40] A. Duncan, K. Klassen, The nutritional management of complications associated with HIV and antiretroviral therapy, in: V. Pribram (Ed.), Nutrition and HIV, first edition, Wiley-Blackwell, 2011.
[41] R. Shivakoti, P. Christian, W.T. Yang, N. Gupte, N. Mwelase, C. Kanyama, S. Pillay, W. Samaneka, B. Santos, S. Poongulali, S. Tripathy, C. Riviere, S. Berendes, J.R. Lama, S.W. Cardoso, P. Sugandhavesa, A.M. Tang, R.D. Semba, T.B. Campbell, A. Gupta, NWCS 319 and PEARLS Study Team, Prevalence and risk factors of micronutrient deficiencies pre- and post-antiretroviral therapy (ART) among a diverse multicountry cohort of HIV-infected adults, Clin. Nutr. 35 (1) (2016) 183–189.
[42] M. Sicotte, E.V. Langlois, J. Aho, D. Ziegler, M.V. Zunzunegui, Association between nutritional status and the immune response in HIV + patients under HAART: protocol for a systematic review, Syst. Rev. 3 (2014) 9.
[43] I. Proietti, C. Frazzoli, A. Mantovani, Exploiting nutritional value of staple foods in world's semi-arid areas: risks and benefits, challenges and opportunities of sorghum, Healthcare 3 (2) (2015) 172–193.
[44] I. Lehmann, U. Sack, J. Lehmann, Metal ions affecting the immune system, Met. Ions Life Sci. 8 (2011) 157–185.
[45] V.L. Flax, L.S. Adair, L.H. Allen, S. Shahab-Ferdows, D. Hampel, C.S. Chasela, G. Tegha, E.J. Daza, A. Corbett, N.L. Davis, D. Kamwendo, A.P. Kourtis, C.M. van der Horst, D.J. Jamieson, M.E. BAN Study Team, Plasma micronutrient concentrations are altered by antiretroviral therapy and lipid-based nutrient supplements in lactating HIV-Infected malawian women, J. Nutr. 145 (8) (2015) 1950–1957.
[46] R. Kupka, G.I. Msamanga, D. Spiegelman, N. Rifai, D.J. Hunter, W.W. Fawzi, Selenium levels in relation to morbidity and mortality among children born to HIV-infected mothers, Eur. J. Clin. Nutr. 59 (11) (2005) 1250–1258.
[47] EFSA, European food safety authority. scientific opinion on dietary reference values for selenium, EFSA J. 12 (10) (2014) 3846.
[48] EFSA, European food safety authority. scientific opinion of the panel on food additives, flavourings, processing aids and food contact materials on a request from european commission on safety of aluminium from dietary intake, EFSA J. 754 (2008) 1–34.
[49] T.G. Dinan, J.F. Cryan, Gut Instincts: microbiota as a key regulator of brain development, ageing and neurodegeneration, J. Physiol. (2016), http://dx.doi.org/10.1113/jp273106.
[50] M. Shimizu, Modulation of intestinal functions by dietary substances: an effective approach to health promotion, J. Tradit. Complement. Med. 2 (2) (2012) 81–83.
[51] A. Baccarelli, P. Mocarelli, D.G. Patterson Jr., M. Bonzini, A.C. Pesatori, N. Caporaso, M.T. Landi, Immunologic effects of dioxin: new results from seveso and comparison with other studies, Environ. Health Perspect. 110 (12) (2002) 1169–1173.
[52] E. Corsini, M. Sokooti, C.L. Galli, A. Moretto, C. Colosio, Pesticide induced immunotoxicity in humans: a comprehensive review of the existing evidence, Toxicology 307 (10) (2013) 123–135.
[53] EFSA, European Food Safety Authority, Opinion of the Scientific Panel on contaminants in the food chain [CONTAM] related to the presence of non dioxin-like polychlorinated biphenyls (PCB) in feed and food, EFSA J. 284 (2005) 1–137.
[54] P. Grandjean, E.W. Andersen, E. Budtz-Jørgensen, F. Nielsen, K. Mølbak, P. Weihe, C. Heilmann, Serum vaccine antibody concentrations in children exposed to perfluorinated compounds, JAMA 307 (4) (2012) 391–397.
[55] H. Celik, N. Celik, A. Kocyigit, M. Dikilitas, The relationship between plasma aluminum content, lymphocyte DNA damage, and oxidative status in persons using aluminum containers and utensils daily, Clin. Biochem. 45 (18) (2012) 1629–1633.
[56] N.L. Dangleben, C.F. Skibola, M.T. Smith, Arsenic immunotoxicity: a review, Environ. Health. 12 (1) (2013) 73, http://dx.doi.org/10.1186/1476-069X-12-73.

[57] A.J. Theron, G.R. Tintinger, R. Anderson, Harmful interactions of non-Essential heavy metals with cells of the innate immune system, J. Clinic Toxicol. 3 (2012).
[58] J. Kovarik, C.A. Siegrist, Immunity in early life, Immunol. Today 19 (4) (1998) 150–152.
[59] R.R. Dietert, Developmental immunotoxicity, perinatal programming, and non-communicable diseases: focus on human studies, Adv. Med. (2014).
[60] C. Frazzoli, C. Petrini, A. Mantovani, Sustainable development and next generation's health: a long-term perspective about the consequences of today's activities for food safety, Ann. Ist. Super. Sanità 45 (1) (2009) 65–75.
[61] I. Proietti, C. Frazzoli, A. Mantovani, Identification and management of toxicological hazards of street foods in developing countries, Food Chem. Toxicol. 63 (2014) 143–152.
[62] S.A. Bankole, A. Osho, A.O. Joda, O.A. Enikuomehin, Effect of drying method on the quality and storability of egusi melon seeds (Colocynthis citrullus L.), Afr. J. Biotechnol. 4 (8) (2005) 799–803.
[63] S.A. Bankole, A.O. Joda, J.S. Ashidi, The use of powder and essential oil of Cymbopogon citratus against mould deterioration and aflatoxin contamination of egusi melon seeds, J. Basic Microbiol. 45 (1) (2005) 20–30.
[64] C. Frazzoli, A. Mantovani, Toxicants exposures as novel zoonoses: reflections on sustainable development, food safety and veterinary public health, Zoonoses Public Health 57 (2010) e136–e142.
[65] J.N. Ugwu, C.O.B. Okoye, C.N. Ibeto, Impacts of vehicle emissions and ambient atmospheric deposition in Nigeria on the Pb, Cd, and Ni content of fermented cassava flour processed by sun-drying, Hum. Ecol. Risk Assess. 17 (2011) 478–488.
[66] Agency for Toxic Substancesand Disease Registry, Toxicological Profile for Manganese, ATSDR, Atlanta, 2012.
[67] EFSA, European food safety authority. Scientific opinion on arsenic in food, EFSA J. 7 (10) (2009) 1351.
[68] C. Muruka, J. Njuguna, A. Muruka, K. Otuto, M.M. Atieno, Food poisoning investigation in an under-resourced environment: a case report, Food Public Health 1 (2011) 6–10.
[69] K. Schütte, H. Boeing, A. Hart, W. Heeschen, E.H. Reimerdes, D. Santare, K. Skog, A. Chiodini, Application of the BRAFO tiered approach for benefit-risk assessment to case studies on heat processing contaminants, Food Chem. Toxicol. 50 (4) (2012) S724–35.
[70] EFSA, European Food Safety Authority. Polycyclic Aromatic Hydrocarbons in Food. Scientific opinion of the panel on contaminants in the food chain, EFSA J. 724 (2008) 1–114.
[71] A. Stołyhwo, Z.E. Sikorski, Polycyclic aromatic hydrocarbons in smoked fish −a critical review, Food Chem. 91 (2005) 303–311.
[72] A. Singh, K. Chandrasekharan Nair, R. Kamal, V. Bihari, M.K. Gupta, M.K. Mudiam, G.N. Satyanarayana, A. Raj, I. Haq, N.K. Shukla, A.H. Khan, A.K. Srivastava, Assessing hazardous risks of indoor airborne polycyclic aromatic hydrocarbons in the kitchen and its association with lung functions and urinary PAH metabolites in kitchen workers, Clin. Chim. Acta 452 (2016) 204–213.
[73] P. Smichowski, D. Gómez, C. Frazzoli, S. Caroli, Traffic-related elements in airborne particulate matter, App. Spectrosc. Rev. 43 (1) (2008) 23–49.
[74] G.B. Pouokam, G.C. Ajaezi, A. Mantovani, O.E. Orisakwe, C. Frazzoli, Use of Bisphenol A-containing baby bottles in Cameroon and Nigeria and possible risk management and mitigation measures: community as milestone for prevention, Sci. Total Environ. 481 (2014) 296–302.
[75] F. Tateo, M. Bononi, Identification of organic contaminants in disposable aluminium foil containers, Food Add. Contam. 23 (10) (2006) 1030–1037.
[76] J.D. Weidenhamer, M.P. Fitzpatrick, A.M. Birom, P.A. Kobunskim, M.R. Hudson, R.W. Corbin, P. Gottesfeld, Metal exposures from aluminum cookware: an unrecognized public health risk in developing countries, Sci. Total Environ. 579 (2017) 805–813.
[77] C. Frazzoli, G.B. Pouokam, A. Mantovani, O.E. Orisakwe, Health risks from lost awareness of cultural behaviours rooted in traditional medicine: an insight in geophagy and mineral intake, Sci. Total Environ. 566–567 (2016) 1465-147.
[78] I. Skjevrak, C. Brede, I.L. Steffensen, A. Mikalsen, J. Alexander, P. Fjeldal, H. Herikstad, Non-targeted multi-component analytical surveillance of plastic food contact materials: identification of substances not included in EU positive lists and their risk assessment, Food Add. Contam. 22 (10) (2005) 1012–1022.
[79] H. Takano, R. Yanagisawa, K.-I. Inoue, T. Ichinose, K. Sadakano, T. Yoshikawa, Di-(2-ehylhexyl) phthalate enhances atopic dermatitis-Like skin lesions in mice, Environ. Health Perspect. 114 (8) (2006) 1266–1269.
[80] B.A. Adejumo, F.A. Ola, The appraisal of local food packaging materials in Nigeria, CJ Eng. Sci. 3 (2008) 13–20.
[81] N.M. Manalili, M.A. Dorado, R. van Otterdijk, Appropriate Food Packaging Solutions for Developing Countries, FAO, Rome, Italy, 2014.
[82] J.K. Mensah, E. Adai, D. Adei, M.D. Ashie, Perceptions of the use of indigenous leaves as packaging materials in theready-to-eat cornmeals, Int. J. Biol. Chem. Sci. 6 (3) (2012) 1051–1068.
[83] C.F. Onzo, P. Aazokpota, P. Agbani, F. Gbaguidi, J.D. Hounhouigan, D. Kossou, Caractéristiques physico-chimiques, phytochimiques et toxicité des espèces végétales utilisées comme emballages alimentaires en Afrique de l'Ouest, Int. J. Biol. Chem. Sci. 8 (4) (2014) 1504–1516.
[84] T.H. Begley, K. White, P. Honigfort, M.L. Twaroski, R. Neches, R.A. Walker, Perfluorochemicals: potential sources of and migration from food packaging, Food Addit. Contam. 22 (10) (2005) 1023–1031.
[85] M.L. Lopez Espinosa, A. Granada, P. Araque, J.M. Molina-Molina, M.C. Puertollano, A. Rivas, M. Fernandez, I. Cerrillo, M.F. Olea Serrano, C. Lopez, N. Olea, Oestrogenicity of paper and cardboard extracts used as food containers, Food Addit. Contam. 4 (1) (2007) 95–102.
[86] J. Yang, L. An, Y. Yao, Z. Yang, T. Zhang, Melamine impairs spatial cognition and hippocampal synaptic plasticity by presynaptic inhibition of glutamatergic transmission in infant rats, Toxicol 289 (2–3) (2011) 167–174.
[87] W. Zhou, Y. Jiang, H. Shi, J. Dai Qingkai Liu, C. Shen, H. Yang, The characteristics of immune system changes in children who ingested melamine-contaminated powdered formula in China, Int. J. Environ. Health Res. 20 (4) (2010) 289–297.
[88] EFSA, European Food Safety Authority. Scientific Opinion on Melamine in Food and Feed. EFSA panel on contaminants in the food chain (CONTAM) and EFSA panel on food contact materials, enzymes, flavourings and processing aids (CEF), EFSA J. 8 (4) (2010) 1573.
[89] Bundesinstitut für Risikobewertung (Federal Institute for Risk Assessment), 2011. Release of melamine and formaldehyde from dishes and kitchen utensils. Opinion Nr. 012/2011, 09 March 2011.
[90] EFSA, European Food Safety Authority. Statement on possible public health risks for infants and young children from the presence of nitrates in leafy vegetables, EFSA J. 8 (12) (2010) 1935.
[91] EFSA, European Food Safety Authority. Nitrate in vegetables. Scientific opinion of the panel on contaminants in the food chain, EFSA J. 689 (2008) 1–79.
[92] H.N. Ene-obong, I.C. Obizoba, Effect of domestic processing on the cooking time, nutrients, antinutrients and in vitro protein digestibility of the African yam bean (Sphenostylis stenocarpa), Plant Foods Hum. Nutr. 49 (1) (1996) 43–52.
[93] I.C. Obizoba, J.V. Atii, Evaluation of the effect of processing techniques on the nutrient and antinutrient contents of pearl millet (Pennisetum glaucum) seeds, Plant Foods Hum. Nutr. 45 (1) (1994) 23–34.
[94] A.K. Chandra, S. Mukhopadhyay, D. Lahari, S. Tripathy, Goitrogenic content of Indian cyanogenic plant foods & their in vitro anti-thyroidal activity, Indian J. Med. Res. 119 (5) (2004) 180–185.
[95] F.I. Bassey, F.C. Oguntunde, C.M.A. Iwegbue, V.N. Osabor, C.A. Edem, Effects of processing on the proximate and metal contents in three fish species from Nigerian coastal waters, Food Sci. Nutr. 2 (3) (2014) 272–281.
[96] M.M. Gimou, R. Pouillot, U.R. Charrondiere, L. Noël, T. Guérin, J.C. Leblanc, Dietary exposure and health risk assessment for 14 toxic and essential trace elements in Yaoundé: the Cameroonian total diet study, Food Addit. Contam. Part A Chem. Anal. Control Expo Risk Assess. 31 (6) (2014) 1064–1080.
[97] S. Chandra, R. Saha, P. Pal, Arsenic uptake and accumulation in Okra (Abelmoschus esculentus) as affected by different arsenical speciation, Bull. Environ. Contam. Toxicol. 96 (3) (2016) 395–400.
[98] J.L. Domingo, Influence of cooking processes on the concentrations of toxic metals and various organic environmental pollutants in food: a review of the published literature, Crit. Rev. Food Sci. Nutr. 51 (1) (2011) 29–37.
[99] T. Fierens, G. Vanermen, M. Van Holderbeke, S. De Henauw, I. Sioen, Effect of cooking at home on the levels of eight phthalates in foods, Food Chem. Toxicol. 50 (2012) 4428–4435.
[100] N.D. Wilson, N.M. Shear, D.J. Paustenbach, P.S. Price, The effect of cooking practices on the concentration of DDT and PCB compounds in the edible tissue of fish, J. Expo Anal. Environ. Epidemiol. 8 (3) (1998) 423–440.
[101] S.P. Bhavsar, X. Zhang, R. Guo, E. Braekevelt, S. Petro, N. Gandhi, E.J. Reiner, H. Lee, R. Bronson, S.A. Tittlemier, Cooking fish is not effective in reducing exposure to perfluoroalkyl and polyfluoroalkyl substances, Food Chem. Toxicol. 66 (2013) 277–285.
[102] S. Costa, C. Afonso, N.M. Bandarra, S. Gueifão, I. Castanheira, M.L. Carvalho, C. Cardoso, M.L. Nunes, The emerging farmed fish species meagre (Argyrosomus regius): how culinary treatment affects nutrients and contaminants concentration and associated benefit-risk balance, Food Chem. Toxicol. 60 (2013) 277–285.
[103] W. Lijinsky, The formation and occurrence of polynuclear aromatic hydrocarbons associated with food, Mutat. Res. 259 (3–4) (1991) 251–261.
[104] R. Karbouj, P. Nortier, I. Desloges, A simple pre-treatment of aluminium cookware to minimize aluminium transfer to food, Food Chem. Toxicol. 47 (3) (2008) 571–577.
[105] M.L. Ackland, J. Bornhorst, G. Dedoussis, R.R. Dietert, J. Nriagu, J. Pacyna, J. Pettifer, Metals in the environment as risk factors for infectious diseases: gaps and opportunities, in: J.O. Nriagu, E.P. Skaar (Eds.), Trace Metals and Infectious Diseases, MIT Press, Cambridge, Mass, 2015, pp. 270–307.
[106] C. Frazzoli, A. Mantovani, R. Esposito, Sustainable food safety and toxicant zoonoses: new prevention challenges in global health governance, Quaderni della Società Italiana di Medicina Tropicale e Salute Globale 1 (2016) 117–127.
[107] O.E. Orisakwe, C. Frazzoli, Water Supply in Niger Delta of Nigeria: from Public Protests to Scientific Discourse, NOVA Science Pub Inc., NY, U.S, 2010.
[108] C. Frazzoli, O.E. Orisakwe, R. Dragone, A. Mantovani, Diagnostic health risk assessment of e-waste on the general population in developing countries' scenarios, Environ. Impact Assess. Rev. 30 (6) (2010) 388–399.
[109] G.B. Pouokam, H. Hamed, R. Ngwafor, C. Frazzoli, Toxicovigilance systems and practices in Africa, Toxics 4 (2016) 13, http://dx.doi.org/10.3390/toxics4030013.
[110] C. Frazzoli, A. Mantovani, R. Esposito, Sustainable food safety and toxicant zoonoses: new prevention challenges in global health governance, Quaderni della Società Italiana di Medicina Tropicale e Salute Globale 1 (2015) 117–127.
[111] A. Mantovani, F. Baldi, C. Frazzoli, S. Lorenzetti, F. Maranghi, Modelli per la valutazione rischio-beneficio in sicurezza alimentare. Rapporti ISTISAN 12/50, (2012).
[112] M.M. Gimou, U.R. Charrondière, J.C. Leblanc, L. Noël, T. Guérin, R. Pouillot, Dietary exposure and health risk assessment for 11 minerals and trace elements in Yaoundé: the Cameroonian Total Diet Study, Food Addit. Contam. Part A 30 (9) (2013) 1556–1572.
[113] J. Kamwesiga, V. Mutabazi, J. Kayumba, J.C. Tayari, J.C. Uwimbabazi, G. Batanage, G. Uwera, M. Baziruwiha, C. Ntizimira, A. Murebwayire, J.P. Haguma, J. Nyiransabimana, J.B. Nzabandora, P. Nzamwita, E. Mukazayire,

Effect of selenium supplementation on CD4+ T-cell recovery, viral suppression and morbidity of HIV-infected patients in Rwanda: a randomized controlled trial, AIDS 29 (9) (2015) 1045–1052.

[114] H. Steinbrenner, S. Al-Quraishy, M.A. Dkhil, F. Wunderlich, H. Sies, Dietary selenium in adjuvant therapy of viral and bacterial infections, Adv Nutr. 6 (1) (2015) 73–82.

[115] P. Akbari, S. Braber, S. Varasteh, A. Alizadeh, J. Garssen, J. Fink-Gremmels, The intestinal barrier as an emerging target in the toxicological assessment of mycotoxins, Arch. Toxicol. (2016) (in press).

[116] R.R. Dietert, E.K. Silbergeld, Biomarkers for the 21st century: listening to the microbiome, Toxicol. Sci. 144 (2) (2015) 208–216.

Further reading

EFSA, European Food Safety Authority, Opinion of the Scientific Panel on contaminants in the food chain [CONTAM] related to Hexachlorobenzene as undesirable substance in animal feed, EFSA J. (2006) 402, 1–49.

EFSA, European Food Safety Authority, Opinion of the Scientific Panel on Contaminants in the Food Chain on a request from the Commission to assess the health risks to consumers associated with exposure to organotins in foodstuffs. EFSA J. (2004) 102, 1–119.

Guy B. Pouokam, B.U. Saha Foudjo, Chi Samuel, Philomina Fankam Yamgai, A. Kamda Silapeux, Joel Taguemkam Sando, G. Fankam Atonde, Chiara Frazzoli. Contaminants in Foods of Animal Origin in Cameroon: A One Health Vision for Risk Management "from Farm to Fork". Front. Public Health, doi: https://doi.org/10.3389/fpubh.2017.00197 .

C. Frazzoli, E.A. Asongalem, O.E. Orisakwe, Cameroon-Nigeria-Italy scientific cooperation: veterinary public health and sustainable food safety to promote one health/one prevention, Rapporti ISTISAN, 12/49 (2012).

A. Mangili, D.H. Murman, A.M. Zampini, C.A. Wanke, Nutrition and HIV Infection: review of weight loss and wasting in the era of highly active antiretroviral therapy from the nutrition for healthy living cohort, Clinic Infect. Dis. 42(6) (2006) 836–842.

P. Mensah, A. Tomkins, Household-level technologies to improve the availability and preparation of adequate and safe complementary foods, Food Nutr. Bull. 24(1) (2003) 104–125.

MINSANTE, WFP, Final report on Etude du profil de vulnérabilité alimentaire des ménages des PVVIH sous ARV au Cameroun" (2011).

UNAIDS (Joint United Nations Programme on HIV/AIDS), report on the global AIDS epidemic UNAIDS 2013.

J.M. Wagacha, J.W. Muthomi, Mycotoxin problem in Africa: current status, implications to food safety and health and possible management strategies, Int. J. Food Microbiol. 124(1) (2008) 1–12.