



Typical edible non-dairy animal products in Africa from local animal resources

Silvana Mattiello , Mariangela Caroprese , Gianni Matteo Crovetto , Riccardo Fortina , Andrea Martini , Mina Martini , Giuliana Parisi , Claudia Russo , Carla Severini , Massimo Zecchini & (ASPA Commission 'Animal productions in development cooperation projects')

To cite this article: Silvana Mattiello , Mariangela Caroprese , Gianni Matteo Crovetto , Riccardo Fortina , Andrea Martini , Mina Martini , Giuliana Parisi , Claudia Russo , Carla Severini , Massimo Zecchini & (ASPA Commission 'Animal productions in development cooperation projects') (2017): Typical edible non-dairy animal products in Africa from local animal resources, Italian Journal of Animal Science, DOI: [10.1080/1828051X.2017.1348915](https://doi.org/10.1080/1828051X.2017.1348915)

To link to this article: <http://dx.doi.org/10.1080/1828051X.2017.1348915>



© 2017 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group.



Published online: 12 Jul 2017.



[Submit your article to this journal](#)



Article views: 79













[View related articles](#)



[View Crossmark data](#)

Typical edible non-dairy animal products in Africa from local animal resources

Silvana Mattiello^a , Mariangela Caroprese^b , Gianni Matteo Crovetto^c , Riccardo Fortina^d , Andrea Martini^e , Mina Martini^f , Giuliana Parisi^e , Claudia Russo^f , Carla Severini^b , and Massimo Zecchini^a  (ASPA Commission 'Animal productions in development cooperation projects')

^aDipartimento di Medicina Veterinaria–Laboratorio di Benessere animale, Etologia applicata e Produzioni sostenibili, University of Milano, Milano, Italy; ^bDipartimento di Scienze Agrarie, degli Alimenti e dell'Ambiente, University of Foggia, Foggia, Italy; ^cDipartimento di Scienze Agrarie e Ambientali, University of Milano, Milano, Italy; ^dDipartimento di Scienze Agrarie, Forestali e Alimentari and CISA–Centro Interdipartimentale di Ricerca e Cooperazione Tecnico-Scientifica con l'Africa, University of Torino, Torino, Italy; ^eDipartimento di Scienze delle Produzioni Agroalimentari e dell'Ambiente, University of Firenze, Firenze, Italy; ^fDipartimento di Scienze Veterinarie, University of Pisa, Pisa, Italy

ABSTRACT

This review aims to identify the main typical non-dairy edible products of animal origin available in Africa, describing their production processes and their strengths and constraints. Farm animals are mainly raised in an extensive, family-run system; there is, however, a significant development of intensive poultry production. Meat products are usually obtained by drying, but meat and/or offal can also be stored as stuffed products and can be additionally treated by smoking and/or curing. The increasing poultry production provides eggs and meat at low price. The small-scale/family farms are managed mainly by women and children, with a positive social impact. The assets and limits of local breeds and of extensive versus semi-extensive or intensive production systems are discussed. Seafood are an essential source of proteins, minerals and micronutrients. Due its high perishability, the proportion of cured fish in this continent is higher than the world average. Wildlife can supply high-quality meat, but attention must be paid to the vulnerable/endangered species and to the sanitary aspects of this food chain. Insects are traditionally consumed in Africa, supplying very cheap highly nutritive food, with low environmental impact. Finally, a variety of honey and other bee products, including some Slow Food praesidia, are described. From the point of view of the respect of biodiversity and ecosystems, local culture, accessibility and nutritional requirements, animal productions in Africa are usually carried out in a sustainable way; however, the low efficiency of most traditional production systems represents an important limit, also in relation to export opportunities.

ARTICLE HISTORY

Received 28 February 2017
Revised 22 May 2017
Accepted 12 June 2017

KEYWORDS

Meat; bushmeat;
invertebrates; honey; Africa



Introduction

With approximately 1 billion inhabitants, Africa has about 15% of world's population. The African continent accounts for around 4% of world production of animal products. In this continent, livestock breeding is an important economic activity from which food (meat, milk) and non-food commodities and services (manure, traction, hides and skins, wool, etc.), and cash income are derived. However, its share of world trade in animal products is less than 1% and its consumption of animal products is among the lowest in the world (Mankor 2013).

The main animal species farmed in Africa are cattle (estimated population in 2014: 312 million), sheep

(341 million), goats (374 million), swine (35 million), poultry (1.9 billion), equids (donkeys, horses and mules; 2.6 million) and camelids (23 million) (FAOSTAT 2016). In addition to farmed terrestrial animals, there are remarkable resources deriving from local wildlife and invertebrates. Fish and seafood also contribute to animal production, although the African role in fish global and intra-regional trade is currently negligible and irrelevant due to many reasons, such as inadequate market and trade infrastructure, the lack of proper packaging material and storage conditions, both at processing sites and markets (The WorldFish Center 2009).

Consequently, animal products include meat, milk and dairy products, eggs, fish and seafood products.

CONTACT Prof. Silvana Mattiello  silvana.mattiello@unimi.it  Dipartimento di Medicina Veterinaria–Laboratorio di Benessere animale, Etologia applicata e Produzioni sostenibili, Università degli Studi di Milano, Via Celoria no. 10, 20133, Milano, Italy

© 2017 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group.

This is an Open Access article distributed under the terms of the Creative Commons Attribution-NonCommercial License (<http://creativecommons.org/licenses/by-nc/4.0/>), which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

According to FAOSTAT (2016), in 2014 the African meat production from ruminants was 10.1 million tons, of which 64% from cattle and buffaloes, 30% from small ruminants and 6% from camelids. Poultry meat production was 5.7 million tons, whereas pig meat production was only 1.3 million tons. Meat production from equids and rabbits is negligible (37.5 and 94.7 tons, respectively). Annual milk production is around 31 million tons. Eggs, hides and skins are produced in significant quantities, too. Additionally, in 2015 the total fishery production in Africa accounted for 10.8 million tons (FAO-GLOBEFISH 2017).

An increase in demand for animal products is now underway in Africa, mainly due to the urbanisation process, that has a considerable impact on patterns of food consumption in general, and in particular on the demand for livestock products. Besides milk and dairy products, that certainly play a major role in African animal production, meat and other non-dairy products are gaining increasing importance. For example, in Sub-Saharan Africa, beef and poultry meat consumption in 2015 was 4.3 and 1.9 million tons, respectively, but by 2050 the consumption of these meats is estimated to reach 13.5 million and 11.8 million tons, respectively. Chicken meat production expanded by almost 5% per year between 2000 and 2011, in spite of the highly pathogenic avian influenza (HPAI) H5N1 detected since 2006, and Africa increased its contribution to the total world production from 4.7 to 5.1% (The Poultry Site 2013; Hagag et al. 2015). Aquaculture production has also been significantly increasing in the past decade in some African countries like in Egypt, where it has grown 10-fold since the 1990s, and in Uganda, Mozambique, Malawi and Nigeria. A relevant increase of fishery production is expected by the year 2020. The World Fish Centre (Delgado et al. 2003) has predicted that in sub-Saharan Africa, we will assist to a 2% increase of production derived from capture fisheries and to a 6% of production derived from aquaculture, with Egypt, Morocco and South Africa as main producers.

In terms of live animals, Africa is indeed a net exporter (in recent years, exports are 6.4 million heads, of which 1% camelids, 14% cattle, 33% goats and 52% sheep), due to economic reasons. However, the internal demand of animal products is not fully satisfied. Therefore, about 3.3 million heads of live animals (of which 30% are cattle, 31% goats, 37% sheep and 2% camelids) are annually imported (Thornton 2010), and Africa remains a net importer of animal products, while at the same time the opportunities for intra-African trade are not fully exploited. For example, despite the high quantity of poultry meat produced and

the rapid development of this sector, the very high demand for this product (about 40 kg *pro capite* per year) must be covered by the import. The import of relatively low-priced frozen chicken meat increased from around 191,000 tons in 2008 to nearly 371,000 tons in 2012, corresponding to about 20% of the national broiler consumption.

Domestic production is therefore not able to meet the steady growth in demand yet, mainly because the level of intensification of production systems is low and animal products are insufficiently exploited. This has the effect of making African producers uncompetitive on markets; therefore, extra-African exporting countries are a constant threat to the development of the trade of African animal products. The demand for food products of animal origin could be met, in a long term, by the continent's own production only by an effective promotion of intra-African trade. Before this can be done, however, there are an additional number of obstacles that need to be overcome. These constraints fall into two categories: non-sanitary constraints and sanitary constraints (Mankor 2013).

Scope of this review is to identify the main typical edible products of animal origin that are nowadays available in Africa, focussing on meat and other non-dairy products, with the aim to describe their production processes and their strengths and constraints, in order to highlight possible future development strategies.

Meat products

The top five African meat-producing countries in terms of meat volume are South Africa, Egypt, Nigeria, Morocco and Sudan that produce about 50% of total African meat (Table 1; FAOSTAT 2016). In Sub-Saharan Africa, beef and ovine were the most consumed meats in 2015, followed by poultry and pork. Beef meat is mainly produced in large farms, mostly in Southern Africa, using extensive ranching systems.

Small ruminants are an important meat source in the arid and semiarid zones of the Sahel and East Africa, where small herds are kept by smallholders who rely mainly on crops, but keep small ruminants as a subsidiary source of income and meat, and a safeguard against crop failure and low crop prices. They are comparatively more numerous than cattle: sheep and goats outnumber cattle by 2.1:1 as a whole, 3.7:1 in Western Africa, 1.3:1 in Eastern Africa and 2.1:1 in Southern Africa (FAOSTAT 2016). This high concentration of small ruminants probably reflects environmental (drought, feed availability, disease) and socioeconomic (land scarcity, management system,

Table 1. Meat (thousand tons) and honey production (tons) in African countries (FAOSTAT 2016).

| Country | Meat (2015) | Honey (2013) |
|--------------------------|-------------|--------------|
| Algeria | 740 | 6147 |
| Angola | 261 | 23,300 |
| Benin | 77 | – |
| Botswana | 88 | – |
| Burkina Faso | 198 | – |
| Burundi | 24 | 747 |
| Cameroon | 334 | 4300 |
| Central African Republic | 169 | 16,200 |
| Chad | 154 | 1050 |
| Congo | 58 | – |
| Cote d'Ivoire | 272 | 650 |
| DRC | 261 | – |
| Egypt | 2068 | 5100 |
| Eritrea | 41 | – |
| Ethiopia | 679 | 45,000 |
| Gabon | 38 | – |
| Gambia | 8 | – |
| Ghana | 255 | – |
| Guinea | 87 | 900 |
| Guinea Bissau | 26 | 130 |
| Kenya | 641 | 12,000 |
| Lesotho | 30 | – |
| Liberia | 33 | – |
| Libya | 184 | 815 |
| Madagascar | 324 | 4400 |
| Malawi | 184 | – |
| Mali | 390 | 190 |
| Mauritania | 108 | – |
| Morocco | 1124 | 5300 |
| Mozambique | 205 | 545 |
| Namibia | 77 | – |
| Niger | 299 | – |
| Nigeria | 1464 | – |
| Rwanda | 73 | 50 |
| Senegal | 196 | 3150 |
| Sierra Leone | 44 | 840 |
| South Africa | 2798 | 1080 |
| Somalia | 195 | – |
| Sudan | 1078 | 740 |
| Swaziland | 27 | – |
| Tanzania | 489 | 30,000 |
| Togo | 68 | – |
| Tunisia | 331 | 5100 |
| Uganda | 458 | 712 |
| Zambia | 327 | 750 |
| Zimbabwe | 249 | – |
| Total | 17,236 | 169,306 |

profitability of small ruminant production, consumer preferences) conditions. Goats are more numerous than sheep in sub-Saharan Africa and goat production tends to be subsistence-oriented and to cater to the needs of a larger number of rural and low-income consumers.

Attention has recently been drawn towards local ruminant breeds, some of which have been included in the Ark of Taste, the international catalogue of typical endangered foods promoted by the Slow Food movement. The inclusion in the Ark represents an added value to qualify typical edible African animal products deriving from sustainable production processes. In few cases, breeds are also valued by promoting their products as Slow Food praesidia, as in the case of the *Ankole* Long-Horned cattle reared in

Uganda and Rwanda and used for both meat and milk production, or of the *Molo* sheep from Kenya, which produces high-quality meat and wool (Slow Food Foundation for Biodiversity 2016).

Pigs are raised in a low number (35 million heads; FAOSTAT 2016), mainly due to religious beliefs. The main pig producing countries are Nigeria, Angola, Malawi, Uganda and Burkina Faso. Most of the pigs raised in Africa are crosses or local breeds raised under the traditional sector. The broad genetic variability of indigenous livestock breeds enables them to have valuable traits; these include disease resistance, high fertility and low protein requirement. Animals are usually raised in a traditional way (free range, fed mostly on grass, brewery, cereal by-products or waste products/food remnants). A commercial small-scale system is also found, and it is characterised by improved breeds fed concentrates and having relatively good performance.

As mentioned above, pork meat only represents a small share of total meat consumption in Africa. In some countries (Kenya, Tanzania), the pig market is dependent on tourism, so factors that affect the performance of the tourist industry also affect the market for pork and pork products. Lard provides additional income to small-scale pig breeders. FAO estimates on lard production show that South Africa reaches nearly 10,000 tons, followed by Mozambique (6373 tons), Angola (3126 tons), Kenya (823 tons) and Zimbabwe (272 tons) (FAOSTAT 2016).

Besides being consumed fresh, meat can be transformed to be stored for a longer time and to increase its safety. To this aim, the most common method is drying, but meat and/or offal can also be stored as stuffed products and, in both cases, the products can be additionally treated by smoking. For the aim of this review, we divided meat products into three main categories: dry meat products (<15% moisture), intermediate products (from 15% to 20% moisture) and fresh meat products (>20% moisture) (Table 2). In some cases, the border among these three typologies is not well marked, because intermediate or fresh products can also be dried to improve their characteristics, as described below (Benkerroum 2013).

Dry meat products

The oldest methods to preserve meat are probably by salting and sun drying. Given the lack of adequate storage facilities, the original purpose of drying meat was its preservation to last as long as possible, although this method is not always effective to prevent oxidative rancidity (Timón et al. 2014). There are

Table 2. Meat products in African countries, classified according to product type.

| Product type | Local name | Country/Region | Type of meat | Reference |
|---|------------------|--|---|--|
| Dry products (<15% moisture) | <i>Ban-shems</i> | Libya | Beef (fifth quarter) | Benkerroum (2013) |
| | <i>Banda</i> | Nigeria | Donkey, horse, camel, buffalo and game | Ajiboye et al. (2011) |
| | <i>Biltong</i> | Nigeria, South Africa, Namibia | Beef, game, ostrich and others | Attwell (2003); Burnham et al. (2008) |
| | <i>Bubanita</i> | Morocco | Lamb | Benkerroum (2013) |
| | <i>Droewors</i> | South Africa, Namibia | Beef, sheep, game | Burnham et al. (2008); D'Amato et al. (2013) |
| | <i>Gueddid</i> | Maghreb | Lamb or beef (also goat or camel in subarid areas) | Benkerroum (2013) |
| | <i>Jiorge</i> | Nigeria | Donkey, horse, camel, buffalo and game | Ajiboye et al. (2011) |
| | <i>Khlii</i> | Morocco | Camel (most traditional) and lamb or beef (most common) | Benkerroum (2013) |
| | <i>Kilishi</i> | Cameroun, Nigeria | Beef | Benkerroum (2013) |
| | <i>Kourdass</i> | Morocco | Lamb (fifth quarter) | Benkerroum (2013) |
| Intermediate products (from 15% to 20% moisture) | <i>Kundi</i> | Sahel | Beef, camel and horse | Collignan et al. (2008) |
| | <i>Ndariko</i> | Nigeria | Beef, sheep, goat, camel, buffalo and game | El Sheikha and Montet (2014) |
| | <i>Tinko</i> | Nigeria | Beef | Ajiboye et al. (2011) |
| Fresh meat products (>20% moisture) | <i>Naqaneq</i> | North Africa | Beef, lamb, buffalo or poultry | Benkerroum (2013) |
| | <i>Pastrima</i> | Egypt (and other North African countries) | Beef, lamb, goat, buffalo and camel | Kadim et al. (2008); Benkerroum (2013) |
| Fresh meat products (>20% moisture) | <i>Merguez</i> | Morocco, Tunisia, Algeria, Libya, Mauritania | Poultry, beef | Benkerroum et al. (2003) |
| | <i>Theal</i> | North Africa | Beef | Benkerroum (2013) |

many typical meat products of the Maghreb countries (Morocco, Algeria and Tunisia) obtained by such a basic technology, and that can be stored at room temperature for more than one year. One of the most famous is the *gueddid*, primarily prepared from lamb or beef meat; in the subarid zones of the Maghreb, camel and goat meats are mostly used. At consumption, *gueddid* is softened and desalted by immersion in water. *Gueddid* is now regarded as a prestigious and highly prized cultural heritage food in North African countries (Benkerroum 2013).

Khlii, or *khlii* (and related products), is a typical Moroccan cured meat product obtained from salted-dried meat. Although genuine *khlii* is believed to be made from camel meat, beef is the most widely used species in practice. Properly made and conditioned *khlii* can be preserved for more than two years at room temperature (Benkerroum 2013).

There are also many products made with dry stomach, liver, lung and kidney. Among these, we find the Moroccan *kourdass*, made with stomach pieces used to wrap pieces of liver, lung and fat into rolls; each roll is diametrically rolled up in the intestine to be sealed and sun-dried for seven days (Benkerroum 2013). Another traditional meat product made with offal is the Libyan *ban-shems*, prepared from bovine stomach stuffed with pieces of kidney, liver and lung (Benkerroum 2013). The stomach and the other offal pieces are sun-dried separately, and the pieces of kidney, liver and lung are packed into the stomach, and

then cooked and conditioned in animal fat in a similar manner as for *khlii*.

The *kilishi* from Cameroun is a traditional dried meat prepared cutting beef lean meat into thin sheets (1–2 mm thickness). The sheets are sun-dried for about 4 hours and then immersed in a slurry of groundnut caked and seasonings; after the immersion, the sheets are dried again in the sun for further 5–12 hours and finally roasted briefly over fire. There are many variations of this method (Jones et al. 2001).

In Nigeria, the most common names for dried meat are *tinko*, *kilishi* and *kundi*, majorly prepared by the Northerners. Others include *ndariko*, *jiorge* and *banda*, which are prepared from meats of donkey, horse, camel, buffalo and game (Ajiboye et al. 2011). In this country, meat preservation is achieved through the combination of drying and smoking; smoking may be done at a temperature of 29 °C (cold smoking) or at a higher temperature of about 80 °C (hot smoking).

Jerky (from the South American term *ch'arki*, which means 'dried meat') is a common type of meat obtained by a combination of drying and deposition of naturally produced chemicals resulting from the thermal breakdown of wood (Ajiboye et al. 2011).

Biltong is a well-known uncooked dried meat product widely consumed in South Africa, but similar products can be found also in other African countries, such as Botswana and Nigeria, where many different types of meat are used to produce it: beef, ostrich and game meat. It is typically made from raw fillets of

meat cut into strips following the grain of the muscle, or flat pieces sliced across the grain (Attwell 2003; Burnham et al. 2008; Matsheka et al. 2014).

Intermediate moisture meat products

Intermediate moisture meat products (15–20% moisture or a water activity of 0.65–0.90) are typically represented by *pastirma* and certain types of *naqaneq*. The *pastirma* (or *basterma*, *basturma*, *pastrami*) is the most popular traditional meat product in Egypt and consists of cured and dried meat strips encased in a mixture of garlic, fenugreek and various spices. Although *pastirma* is preferably made from beef, various other meat types are also used, including lamb, goat, buffalo and camel. The finished product has a pH of 4.5–5.8, a salt content of 6.0%, water activity of 0.85–0.90 and moisture of 35–52% (Kadim et al. 2008; Benkerroum 2013).

Naqaneq is a generic Arabic term used to designate any sausage, either raw or cooked, obtained from ground meat (beef, lamb, buffalo or poultry), seasoned and pushed into a natural casing (bovine or ovine intestine) previously soaked in boiling water. The composition, taste and flavour of these sausages are highly variable from one country to another, and even among regions of the same country, depending on the seasoning, the specific casing used, as well as the maturation and drying conditions (Benkerroum 2013).

Fresh meat products

Fresh meat products (>20% moisture) include *merguez*, *mkila*, *tehal* and some types of *sujuk* where no or partial drying is applied during processing. *Merguez* is a typical Maghreb raw sausage with a small diameter (18–22 mm). At present, *merguez* is mainly produced at a semi-industrial scale using modern machines to chop the meat and push the batter into the casing, in addition to the use of nitrites, functioning as colouring and preservative agents. Natural casing is being gradually replaced by synthetic collagen casing. *Merguez* is a highly perishable product and should therefore be consumed within 2 d after preparation; in some countries, such as Tunisia and Algeria, it is commonly added as an ingredient in *couscous*.

Tehal (or *tehane*) is bovine spleen stuffed with ground beef that is seasoned with various spices and cooked in an oven. *Bubanita* (*boubanita*) is a typical Moroccan specialty prepared from lamb meat cut into small cubic pieces, seasoned and stuffed into previously cleaned lamb rumen, which is then tied at its

openings with a rope and hung to a roof, where it is left to slowly dry and ferment.

Poultry

Birds are raised mainly for meat and egg production. In addition, it is worth remembering that poultry can also have an important role in rituals, since in some countries (like Uganda) birds are often used in ceremonies, rituals, gifts and sacrifices (Akinola and Essien 2011).

In poultry production, the role of chickens is widely predominant, but other species, such as turkeys, ducks, geese, pigeons and guinea fowl, are also produced in Africa. The seven biggest producers are South Africa, Egypt, Morocco, Nigeria, Algeria, Libya and Tunisia. With a combined output of 3.64 million tons, these countries account for almost 80% of the regional total.

In most African countries, the small-scale poultry production utilises available household labour and surplus on-farm resources. In some countries, the chicken to human population ratio of a village can be as much as 1.5:1. Family poultry production significantly contributes to generate cash income for families: it is carried out in extensive (free-range and/or backyard village systems), semi-extensive or small-scale intensive husbandry systems, and it is generally carried out by women and children (Sambo et al. 2015). Poultry are usually raised together with other domestic animals (e.g. other monogastric species, such as pigs and rabbits, small and large ruminants) and, in some cases, also with fish (Guèye 2001). In these family-run systems, the low level of literacy among farmers is one of the main obstacles for the evolution of the sector and for improving the economical output of this activity that is often characterised by poor reproductive performance and growth rates, high mortality, losses due to predation, disease and lack of access to feed and drugs.

Although about 80% of the poultry population in Africa is reared in traditional systems (Guèye 1998), it is important to remember that in South Africa the panorama of poultry production is completely different. In this country, the poultry sector has completely changed its organisation and structure during the last century, evolving from a backyard activity into a complex and highly integrated industry, similar to what happened in many western countries (Maia 2015).

Birds of indigenous or local types, exotic breeds and crosses between two or more types of poultry breeds are often kept. According to DAGRIS (2007), in Africa there are 90 local chicken breeds, characterised by a wide phenotypic variability (Hans 2012).

Indigenous breeds are robust, highly resistant to diseases, have low nutritional requirements and a multipurpose attitude, a pivotal aspect that is strategic in that specific geographic context. On the other hand, they take long time to reach sexual maturity and have a small mature carcass weight and the hens produce only few eggs per year (about 2–4 clutches, each of about 10–12 eggs) (Hans 2012). Among the many local breeds, it is worth mentioning the *Molo Mushunu* chicken from Kenya and the *Bigawi* chicken from Egypt, which are Slow Food praesidia since 2009 and 2014, respectively (Slow Food Foundation for Biodiversity 2016).

Unfortunately, the birds reared are very often currently a mixture of different genotypes. For instance, the South African *Boschveld* chicken is in reality a cross between three indigenous local breeds, i.e., *Venda*, *Matabele* and *Ovambo* (Hans 2012).

As to the exotic breeds, they show a poor tolerance to the local, often harsh, conditions, and are therefore rarely farmed in favour of local breeds. However, the preference given by local people to indigenous breeds sometimes clashes with the need to have more efficient animal productions, particularly considering the increasing demand for food of animal origin and the need to be more environmentally sustainable. In fact, according to some authors, the different pollutants should be quantified not in absolute values, but per unit of food (chicken meat or eggs) (Crovetto 2015). In this view, intensive or at least semi-intensive poultry production should be encouraged, not instead, but in addition to the extensive, free-roaming and scavenging traditional systems.

The marketing of live birds involves mainly men and children (boys), since women are normally excluded, particularly when the market is far from the village. Instead, both women and men are involved in chicken slaughter and cleaning activities (USAID 2010). When the products (live birds and eggs) are destined for urban consumers, in most countries they are not directly sold by the family poultry producers, since various intermediaries are involved, creating a more complex chain (Guèye 2001).

The marketing system is quite informal and poorly developed. Surplus males, pullets, non-productive hens, large-sized birds, old hens and even sick birds are usually found in the public markets, where they are slaughtered on demand under very poor hygienic conditions, in environments very often congested with people and animals. This contributes to the risk of disease transmission from poultry to humans (USAID 2010).

In rural areas, birds are often sold alive. This modality simplifies the chain, as it does not require processing and/or refrigeration (Hans 2012), because the birds can be slaughtered when needed, and the slaughtering method can be chosen by the consumers according to their religious beliefs (e.g. according to the Islamic requirements to be considered as '*halal*').

Local chicken meat achieves interesting market prices, as it is considered tastier and stronger flavoured than commercial broiler meat. In many African countries, meat and eggs from exotic chicken breeds are perceived to have a poorer taste compared to that of local breeds (Dana et al. 2010). In Africa, poultry meat is largely utilised in traditional dishes and sometimes can be processed to obtain *naqaneq* and *merguez* (Table 2) (Benkerroum et al. 2003; Benkerroum 2013).

Fishery and seafood products

Even if Africa has a great availability of fish and shellfish resources in the water of oceans, rivers and lakes, its contribution to the global fish production is very low, although it is rapidly growing (from 5.9% in 1950 to 8.1% in 2011), thanks to the extension of national EEZs (Exclusive Economic Zones) to 200 miles, the improving fishing capacity due to the technological progress, the creation of national industrial fleets, the diffusion of motorisation of artisanal canoes and the fishing agreements signed over time between African countries and others countries, especially the EU (FAO-GLOBEFISH 2017). The production comes for 1/3 from inland fisheries (mainly in East Africa) and for 58% from marine capture fisheries (mainly in West Africa, where there is one of the most important fishing zone of the World), whereas the contribution of aquaculture is currently very marginal (FAO 2016a).

In Africa, over 5.5 million people are involved in fishery and fish farming (with only 284,000 people involved in this last activity), and a higher number is represented by full-time and part-time people involved in trading and processing. In the processing activities, the role of women is relevant, representing about 58% of the total number of employees (FAO 2016a).

Even though Africa has extensive marine fisheries, they are exploited mainly by foreign commercial fleets, only marginally contributing to the continent's food needs. These last are satisfied almost exclusively by the small-scale coastal inshore and by the inland freshwater fisheries, that involve the coasts of West and Southern Africa and the continental (lacustrine and riverine) basins of Senegal, Niger, Volta, Congo, Lake Chad, Nile and Zambezi river systems.

Although fish consumption in sub-Saharan Africa is very low, seafood are an essential source of proteins, minerals and micronutrients for the diet of over 400 million of Africans (The WorldFish Center 2009).

In case of very perishable food, like fishery products, the lack of basic facilities (running water, sanitation, electricity, ice, storage or refrigeration devices) at the processing sites, together with the unhygienic processing and preservation methods, is responsible for the loss of a large amount of seafood and seafood products (estimated between 20 and 40% of product harvested), as a consequence of spoilage.

It is recognised that improving fish processing and marketing technologies could markedly reduce the post-harvest losses (more than 50%), at the same time increasing the economic and nutritional value of the fishery products (The WorldFish Center 2009). Africa's proportion of cured fish is higher than the world average (FAO 2016a). Among the methods for fish processing, the more common are hot smoking (mainly in West Africa), salting, fermentation, sun drying and the treatment of fish by frying (in West, Southern or Central Africa). Fermented products are usually hand-crafted, according to processing methods that differ from one country to another, including, for example, fermentation with salting and drying, fermentation and drying without salting, and fermentation with salting but no drying. Fermented fishery products may be whole or in cut pieces and are usually consumed as they are or may be utilised as a condiment (Essuman 1992).

Wildlife (bushmeat)

The consumption of the so-called bushmeat is quite common all over Africa, representing up to 50% of the animal protein intake in some tropical forest regions (Nasi et al. 2011). Most of this meat derives from wild species that are hunted, either legally or illegally (Abernethy et al. 2013). A large proportion of hunted species in Africa are terrestrial mammals (Fa and Peres 2001). Among large herbivore species, consumers' preferences may differ, depending on the ethnic group or on the local habits (Fa et al. 2002), and the consumption of a certain species is driven also by its availability and hunting vulnerability (Ndibalema and Songorwa 2007; Vega et al. 2013). Therefore, the consumption of common species, such as wildebeest (*Connochaetes taurinus*) and buffalo (*Syncerus caffer*) in the Serengeti National Park (Tanzania), is often more frequent than that of rare species, although eland (*Taurotragus oryx*) seems to be the preferred meat in terms of sensorial attributes (Ndibalema and

Songorwa 2007). Although the consumption of wild meat is concentrated mainly on common species, the list of hunted species includes also ungulate and bird species classified by IUCN as 'Vulnerable', such as the zebra duiker (*Cephalophus zebra*) and the Congo peafowl (*Afropavo congensis*), and several primate species (e.g. *Colobus satanas*, *Cercopithecus solatus*, *Mandrillus sphinx*), some of which are even classified as 'Critically endangered' (e.g. *Procolobus pennantii*, *Procolobus preussi*, *Cercopithecus dryas*) (Taylor et al. 2015). Bushmeat hunting is considered one of the major threats for the conservation of these species and also for the conservation of other species, such as predators, due to the reduction of their preys (Abernethy et al. 2013). For these reasons, this activity is not considered sustainable for certain species in some geographic areas. However, in some regions, local populations rely on wild meat as one of the main protein sources (e.g. São Tomé) (Carvalho et al. 2015). In these situations, solutions should be identified in order to preserve local biodiversity. Some authors suggest that the only solution to this problem would be a considerable reduction of meat consumption (Machovina et al. 2015). However, given the appreciation of consumers for bushmeat, other authors (Skinner 1989; van Schalkwyk et al. 2010) consider that game ranching of wild species for meat production could be a valid alternative to hunting in the wild, in order to satisfy the market demand and, at the same time, safeguarding biodiversity but, in any cases, a serious regulation of hunting activity is always required (Carvalho et al. 2015). Additionally, game ranching may represent a valid alternative for the use of abandoned and degraded farmlands that are no more suitable for traditional agricultural activities (Chomba and Nyirenda 2014), in order to generate an income both from meat production and trophy hunting (Skinner 1989). Additionally to game ranching, farming has been proposed for species other than large mammals. For example, meat from the genus *Thryonomys* (e.g. greater cane rat, also called grasscutter) or *Cricetomys* (e.g. African giant rat) are widely consumed in Central and Sub-Saharan African countries. Meat from these species is very appreciated, due to its organoleptic characteristics (colour, flavour, tenderness and juiciness; Ladele et al. 1996). However, the availability on the market of hunted specimens can be limited, and their high retail price is another constraint that may limit the consumption of these typical meat products. For these reasons, Ladele et al. (1996) highlighted the importance of carrying out a domestication process on these species and of implementing breeding and management procedures. However, after the first promising

Table 3. Most consumed species of edible insects in African countries, classified according to taxonomic order (van Huis et al. 2013).

| Order | Species | Geographic area |
|-------------|---|---|
| Coleoptera | <i>Augosoma centaurus</i> (scarab beetle) | All Africa |
| | <i>Rhynchophorus phoenicis</i> (palm weevil) | Democratic Republic of Congo, Republic of Central Africa |
| Hemiptera | <i>Agonoscelis pubescens</i> (sorghum bug) | Republic of Sudan |
| | <i>Coridius viduatus</i> (melon bug) | Republic of Sudan, Namibia |
| | <i>Ecosternum delegorguei</i> (stink bugs) | South Africa, Malawi, Zimbabwe |
| Hymenoptera | <i>Macrotermes subhyalinus</i> (termites) | Uganda, Democratic Republic of Congo, Zambia, Republic of Central Africa, Kenya, Zimbabwe |
| Lepidoptera | <i>Oecophylla longinoda</i> (weaver ant) | Democratic Republic of Congo, Cameroon |
| Orthoptera | Caterpillar, mopane caterpillar | Central Africa |
| | <i>Locustana pardalina</i> (locust) | South Africa |
| | <i>Ruspolia nitidula</i> , <i>Ruspolia differens</i> (edible grasshopper) | Eastern and Southern Africa |

attempts to farm these species, there has been a progressive abandonment of this farming activity, probably due to a poor technical support deriving from an insufficient knowledge and research on their management requirements (Adu et al. 1999).

Meat from wild animals can be consumed either fresh or processed, in order to obtain typical products, such as *biltong* and *droëwors*, which are largely consumed especially in South African countries (Table 2; D'Amato et al. 2013). Several studies on the chemical and sensorial characteristics of bushmeat (Ladele et al. 1996; Hoffman 2000a, 2000b; Hoffman and Ferreira 2004; Van Zyl and Ferreira 2004; Hoffman et al. 2007a, 2007b; Petit et al. 2014) are available to support the appreciation of consumers for this kind of meats, because of their low fat content and pleasant taste.

In addition to the risk of reducing biodiversity by threatening some of the most vulnerable or even endangered species, the consumption of wild meat can lead to high sanitary and health problems for humans. For example, although there are currently no clear indicators regarding the source of Ebola virus, fruit bats of the *Pteropodidae* family (frequently hunted and consumed in several countries of central Africa) are considered the natural host of the virus, which is also believed to transmit through wild primates (monkeys, chimpanzees, gorillas) and antelopes (Asaad 2015).

Invertebrates

The term 'entomophagy' means the consumption of insects by humans. Entomophagy is still part of the eating habits of about 2 billion people in the world, including Asia, Africa and Latin America. Currently, about 2163 species of edible insects have been identified, and these are mainly concentrated in tropical and subtropical areas (Jongema 2012), where they represent an important traditional food source. In some

African communities, they account for 5–10% of protein intake (Ayieko and Oriamo 2008) and Vantomme et al. (2004) estimated that 70% of Kinshasa's 8 million inhabitants eat caterpillars.

The most commonly consumed insects are as follows: beetles (Coleoptera, 31%), caterpillars (Lepidoptera, 18%), bees, wasps and ants (Hymenoptera, 14%), locusts and crickets (Orthoptera, 13%), cicadas, leafhoppers, planthoppers, scale insects and true bugs (Hemiptera, 10%), termites (Isoptera, 3%), dragonflies (Odonata, 3%), flies (Diptera, 2%) and other orders (5%) (Table 3; van Huis et al. 2013).

Up today most edible insects are harvested in the wild. However, in recent times, the concept of farming insects for food has been growing, in particular among Eastern peoples (Laos, Thailand and Vietnam). The insect harvesting/rearing is a low-tech, low-capital investment option that offers entry even to the poorest sections of society (landless for instance) and can offer livelihood opportunities for both urban and rural people (van Huis et al. 2013).

Insects can be found in abundance throughout the African continent and they become important sources of food, when other resources are scarce. Their availability mainly depends on local climatic conditions, being higher during the rainy season (Pagezy 1975; Bahuchet and Garine 1990; Vantomme et al. 2004; van Huis et al. 2013). During the rest of the year, insects are also available, either dried or smoked.

The nutritional value of edible insects is highly variable. Even within the same group of species, the nutritional value may differ depending on both intrinsic (e.g. metamorphic stage of the insect) and extrinsic factors (e.g. the habitat in which the species lives and its diet) (Xiaoming et al. 2010), as well as on the preparation process (boiling, frying, drying). In general, insects are an important source of fat (with a high content of polyunsaturated and essential fatty acids; Womeni et al. 2009), protein (often rich of essential

amino acids, as in some termite species; Bukkens 2005; Sogbesan and Ugwumba 2008), vitamin (mainly B1, B2, B12 and E; Bukkens 2005), fibre (chitin derived from the exoskeleton; Finke 2007) and mineral content (mainly iron and zinc; Bukkens 2005; van Huis et al. 2013), although their composition is highly variable across species and orders and also depending on the parts of the plant on which they feed (Bukkens 2005).

Insects are often consumed as a whole, fried, sun-dried smoked, steamed in banana leaves (Uganda) or roasted in hot ash and sand (winged termites *Hodotermes mossambicus* in Botswana; Nonaka 1996), but they can also be processed into granular or paste forms. In East Africa, sun-dried termites can be grounded into powder and mixed with other food ingredients by baking, boiling, steaming or processing them into crackers, muffins, sausages or meatballs (Kinyuru et al. 2009; Ayieko et al. 2010).

Recently, the food industry has promoted the production of new products based on insects and the commercialisation of pre-cooked food, in order to reduce the 'visibility' of insects into food preparations (Schösler et al. 2012; Verbeke 2014; Tan et al. 2015).

The recent global interest in the (re)discovery of entomophagy, also by the western countries, stimulated their food industry to find alternative presentations of this kind of food, in order to give insects an 'unrecognisable' appearance, similar to other western food (hot dogs, sticks of fish, etc.) (Sogari and Vantomme 2014; Azzollini et al. 2016). This may lead to a future collaboration among developing countries (mainly producers of raw material) and developed countries (mainly industrial producers) for the introduction of new products on the market and for improving the extraction of proteins, fats, chitin, minerals and vitamins, which is presently too costly and needs to be further developed to become profitable and applicable for industrial use in the food and feed sectors. Insects are also used as feed, mainly for poultry (Farina et al. 1991; van Huis 1996).

Besides their taste and nutritional value, insect consumption has several additional advantages. First of all, it is environmentally friendly, because insects have a high nutritional conversion efficiency (about 50% compared to chicken (45%), pork (35%) and beef (15%)) and do not have inedible wastes like bones, tendons and skin, although their exoskeleton (10–20% of total body weight) is indigestible for humans. The most interesting aspect, however, is the high efficiency of nitrogen utilisation in insects, higher than poultry and much higher than other farm species (Oonincx et al. 2015). This is particularly important in view of the increasing demand for protein in the next decades

and of the need to make the dietary protein supply environmentally sustainable.

Furthermore, insects produce a quantity of CO₂ emission per kg of mass gain averagely lower than pigs (–16%) and ruminants (–67%) (Oonincx et al. 2010). This suggests higher feed conversion efficiencies for insects than for mammalian livestock. Also in terms of total GHG emissions (g CO₂ eq./kg body mass/day), insects are less environmentally impacting in comparison with pigs (–88%) and ruminants (–72%) (Oonincx et al. 2010).

Moreover, insects require much less water than conventional livestock, and their production does not require large amounts of soy, corn and wheat (that are instead widely used for conventional livestock) and can be fed on organic waste streams (Oonincx et al. 2010; Oonincx and de Boer 2012). Finally, for insect rearing, only a limited ground surface is needed and land clearing to expand production is not required.

From a sanitary point of view, insects show a low risk of spread of disease and infection, including zoonosis, provided that they are treated with the same sanitary devices of any other food product (Rumpold and Schlüter 2013; van Huis et al. 2013) and, due to their nutritional value, may have positive effects on human health, such as helping to prevent anaemia. Evidence of allergies induced through the ingestion of insects is scarce, but some allergic reactions have been reported (Phillips and Burkholder 1995).

However, several issues should be considered, such as microbial safety, toxicity and the presence of inorganic compounds. Specific health implications should be considered especially when insects for feed are reared on waste products, such as manure or slaughterhouse waste.

Other products from insects

Besides being used directly as a food source, insects can provide also other indirect food products. In this field, the most important insects are bees.

Beekeeping can be started up with few resources, even by landless households, and is not a labour-intensive activity; therefore, it can be easily managed by women and combined with the other daily activities. Furthermore, it contributes to the well-being of the whole community, for example, by helping the pollination of flowering plants (Gebru et al. 2016).

The more common bees in Africa are the European honey bee (*Apis mellifera ligustica*; mainly in North Africa), the more aggressive African honey bee (*Apis mellifera scutellata*) and the Cape honey bee (*Apis mellifera capensis*; mainly in the southern extreme)

(Ruttner 1988). African bees seem to be more apt to store pollen, while European bees store more honey. Stingless bees, which are present in all tropical parts of the world, are also food-producing animals in Africa.

The best known primary products of beekeeping are honey and wax, but pollen, propolis, royal jelly, venom, queens, bees and their larvae are also marketable primary bee products. While most of these products can be consumed or used as they are, they can also be transformed or used as ingredients of other products (Krell 1996).

In this chapter, we will deal only with the most important African food products from bees: honey, fermented beverages, pollen and stingless bee honey (Table 4).

Honey

In the year 2013, total honey production in Africa was 169,306 tons, corresponding to about 10% of the world average production (FAOSTAT 2016). Ethiopia is the most important African honey producer (Robert 2010; Gebru et al. 2016), followed by Tanzania (Table 1).

Honey has value as a food that can be used as it is, or in traditional food and drink preparations, also at times of food shortage. It also has a value as a medicine, as a cash crop for both domestic and export markets and as an important part of some cultural traditions, being used on special occasions such as birth, marriage and funeral ceremonies (FAO 2016b).

The more ancient method to harvest honey consists of collecting honey from wild swarms, and it is still adopted by the hunter-gatherer people of *Hadza* in Tanzania, and by the nomadic *Mbenga* pygmy people of *Bayaka*, in Central African Republic. The next step in the technological evolution of beekeeping is the keeping of bees in 'traditional' hives, made of locally available material. A further evolutionary step is represented by the use of hives with moveable combs, but without frames or foundation sheets, like the top-bar hives of Africa, also used worldwide in 'natural beekeeping'. The more intensive and now widespread beekeeping practices of the last century are based on the moveable frame hives, that allow centrifugal extraction and quick processing of large amounts of uniform honey with high-quality standards, with minimum contamination by other hive materials (Krell 1996).

Most African honeys are multifloral, and we often have scarce information about the nectar sources. The most studied are from Ethiopia, and four of these (*Bore*, *Rira*, *Tigray White* and *Wenchi Volcano*) have

even become Slow Food praesidia (Slow Food Foundation for Biodiversity 2016) (Table 4).

The most famous Ethiopian honey is *Tigray White* honey. This honey can be white, red or yellow, depending on the flowers available. Ninety per cent of the production consists of a bright white-coloured honey, with good consistency and large grains without homogeneity.

Unifloral honeys are produced only in few African countries, like Algeria (Makhloufi et al. 2015) (Table 4). Increasing consumer knowledge and appreciation of honey has been developing a particular market niche for honeys identifiable by specific characteristics in terms of colour and flavour, and originating from one or few sources of flowers. Differential pricing sometimes makes the production from rare floral sources very attractive.

Fermented honey beverages

In many regions, honey is or was the only, or the most accessible, source of fermentable sugars. *Tej*, also called 'honey wine' or 'honey beer', is the main fermented honey beverage in Ethiopia, and in this country, about 2/3 of pure honey production is used for this purpose (Robert 2010). *Berz* is similar to *tej*, but it is sweeter and has a lower alcoholic content (Debebe et al. 2016). The fermentation process is spontaneous and depends on several factors (e.g. microflora, the physical and chemical environment, duration of fermentation, etc.), that affect the chemical and physical properties of the final products (Bahiru et al. 2001). The same occurs to *mead*, another beverage typical of Kenya and South Africa, made of water and fermented honey, frequently added with various herbs, apple juice, grape juice, mulberry, malt, vinegar and spices, either infused or co-fermented or blended after fermentation (Mendes-Ferreira et al. 2010; Katoh et al. 2011).

In some parts of non-Islamic Africa, the traditional brewing and consumption of honey beer is very common. The base is crudely pressed or drained honey, often with added brood or pollen. An additional nutrient base is generally provided for the yeasts, which may add characteristic flavours as well. The beverage is always consumed before fermentation is finished. Preparation by a skilled brewer (in East Africa most commonly women) can be as fast as 5–6 hours (Krell 1996).

Pollen

In some African countries, like Egypt, pollen production is becoming increasingly interesting. Pollen is the

Table 4. Bee products in the most important African honey producer countries, classified according to product type.

| Product type | Local name | Country | Type of flowers | Reference |
|--------------|----------------------|-----------------------------|---|--|
| Honey | No official name | Algeria | Monofloral: <i>Eucalyptus</i> spp., <i>Hedysarum coronarium</i> , <i>Pimpinella anisum</i> and <i>Citrus</i> spp. Multifloral, deducted by honey pollen analysis: <i>Acacia</i> sp., <i>Brassicaceae</i> , <i>Carduus</i> sp., <i>Centaurea</i> sp., <i>Convolvulus arvensis</i> , <i>Eucalyptus</i> spp., <i>Olea europaea</i> , <i>Papaver rhoeas</i> , <i>Pimpinella anisum</i> , <i>Trifolium</i> spp., <i>Rubus</i> sp. and <i>Vicia</i> sp. North-western region: <i>Acacia</i> sp., <i>Brassicaceae</i> , <i>Carduus</i> sp. and <i>Centaurea</i> sp. Central north region: <i>Coriandrum sativum</i> , <i>Echium</i> sp. and <i>Trifolium</i> spp. North-eastern region <i>Aplacaeae</i> . The most important plants for honeybee production are as follows: <i>Eucalyptus</i> spp., <i>Pterocarpus</i> sp., <i>Entada abyssinica</i> , <i>Diospyros mespiliformis</i> , <i>Acacia</i> spp., <i>Isobertlinia baumii</i> , <i>Brakystegia tamarindoides</i> and other <i>B.</i> spp. | Makhloufi et al. (2015) |
| | No official name | Angola | | FAO (2016b) |
| | No official name | Central African Republic | | Debold (1984) |
| | No official name | Egypt | Scarce information. Main nectar sources: Medicinal, aromatic and ornamental plants: <i>Acacia</i> spp., <i>Bauhinia</i> spp., <i>Ocimum</i> sp., <i>Buddleja</i> spp., <i>Carum carvi</i> , <i>Castanea sativa</i> , <i>Ceratonia siliqua</i> , <i>Conyza</i> spp., <i>Dracaena fragrans</i> , <i>Portulaca</i> sp., <i>Convolvulus</i> spp. <i>Nigella sativa</i> , <i>Jacaranda</i> spp., <i>Eucalyptus</i> spp., <i>Mentha</i> spp., <i>Azadirachta indica</i> , <i>Mimosa pudica</i> , <i>Ziziphus</i> spp., <i>Thymus</i> spp., <i>Reseda</i> spp. Vegetables: <i>Erica sativa</i> , <i>Brassica oleracea</i> , <i>Vicia faba</i> , <i>Capsicum frutescens</i> , <i>Capsicum frutescens</i> , <i>Cucumis sativus</i> , <i>Daucus carota</i> , <i>Phaseolus lunatus</i> , <i>Lactuca sativa</i> , <i>Coriandrum sativum</i> , <i>Lupinus</i> sp., <i>Phaseolus lunatus</i> , <i>Lactuca sativa</i> , <i>Cucumis melo</i> , <i>Abelmoschus esculentus</i> , <i>Allium cepa</i> , <i>Solanum lycopersicum</i> , <i>Citrus lanatus</i> Fruit trees: <i>Malus</i> sp., <i>Citrus aurantium</i> , <i>Musa acuminata</i> , <i>Psidium guajava</i> , <i>Citrus paradisi</i> , <i>Citrus limon</i> , <i>Citrus sinensis</i> , <i>Citrus nobilis</i> Field crops: <i>Medicago sativa</i> , <i>Gossypium barbadense</i> , <i>Trifolium alexandrinum</i> , <i>Linum usitatissimum</i> , <i>Helianthus annuus</i> , <i>Sesamum indicum</i> White honey from the flowers of <i>Schefflera abyssinica</i> . Dark honey from several different flowers, primarily from <i>Prunus africana</i> , <i>Vernonia amygdalina</i> and <i>Hagenia abyssinica</i> | Debold (1984) Abou-Shaara (2015) |
| | Bore | Ethiopia | From the nectar of many different plants (over 20 identified). The flowers that are most popular with the producers are from <i>Hypericum revolutum</i> , <i>Syzygium guineense</i> , <i>Erica arborea</i> and <i>Hagenia abyssinica</i> | Slow Food Foundation for Biodiversity (2016) |
| | Rira | Ethiopia | Presumably mainly labiates family (like sage), and to a lesser extent prickly pear and <i>Euphorbia</i> spp. <i>Egymia abyssinica</i> and <i>Erica arborea</i> | Slow Food Foundation for Biodiversity (2016) |
| | Tigray White | Ethiopia | Mainly <i>Dombeya goetzeni</i> | Slow Food Foundation for Biodiversity (2016) |
| | Wenchi Volcano Honey | Ethiopia | <i>Callistemon citrinus</i> , <i>Eucalyptus stricklandii</i> , <i>Acacia xanthophloea</i> , <i>Croton megalocarpus</i> , <i>Erythrina abyssinica</i> , <i>Helianthus annuus</i> | Slow Food Foundation for Biodiversity (2016) |
| | Ogtek | Kenya | Hive yield in honey is low for <i>Origanum</i> spp., <i>Thymus</i> spp. and <i>Arbutus unedo</i> , and high for <i>Anthyllis cythoides</i> , <i>Rosmarinus officinalis</i> , <i>Ceratonia siliqua</i> and <i>Ziziphus lotus</i> | Slow Food Foundation for Biodiversity (2016) |
| | No official name | Kenya | <i>Eucalyptus</i> , <i>Kotschyia</i> , <i>Syzygium</i> , <i>Dierivilla</i> , <i>Citrus</i> , <i>Zea mays</i> | Agribusiness information portal (2016) |
| | No official name | Morocco | | Khabbach et al. (2013) |
| | No official name | United Republic of Tanzania | | Prandin et al. (2000); Murray et al. (2001) |

(continued)

Table 4. Continued

| Product type | Local name | Country | Type of flowers | Reference |
|-------------------------------|--|--|--|--|
| Fermented beverages | Berz Honey beer <i>Mead</i> | Ethiopia Central African Republic Mainly Southern African coun- tries and Kenya | Not specified Scarce information Not specified | Bahiru et al. (2001) Debold (1984) Katcho et al. (2011); Mendes- Ferreira et al. (2010) |
| | Tej No official name <i>Arusha</i> | Ethiopia Mainly Egypt Tanzania | Not specified Sesame, maize, clover, sunflower, wild mustard Not specified | Bahiru et al. (2001) Ismail et al. (2013) Slow Food Foundation for Biodiversity (2016) |
| Pollen Stingless bee honey | No official name. Mainly from <i>Trigona spp. stingless bee</i> | Ethiopia | Not specified | Garedew et al. (2004) |
| | No official name | Tanzania | Not specified | Kihwele (1997) |

sole protein food harvested by bee foragers in their natural environment (Ismail et al. 2013). Bees usually mix pollen grains with nectar or regurgitated honey, in order to make it stick together and adhere to their hind legs. The resulting pollen pellets, harvested using pollen traps, are therefore usually sweet in taste (Krell 1996).

Fresh pollen stored at room temperature loses its quality within a few days, but if it is dried to less than 10% (preferably 5%) moisture content, or frozen, it can last for months or even for years (Dietz and Stevenson 1980).

Stingless bee honey

Stingless bees are closely related to the honey bees, bumble bees and orchid bees. Work with stingless bees is called meliponiculture. Stingless bees are present in all tropical parts of the world and are amongst the longest evolved bees. About 400–500 different species of stingless bees are known (50 of which in Africa), but new species are identified every year.

In Africa, meliponiculture is practised mainly in Tanzania and Ethiopia (Kihwele 1997; Garedew et al. 2004). The honey harvested yearly from a stingless bee colony is most often between 200 g and 5 kg, depending on the bee species, vegetation and handling. Today, there are farmers in Tanzania keeping stingless bees in log hives as they traditionally keep honey bees, but new rational rearing systems are also being developed. The honeys, often very different from species to species, have a much higher water content, are more acid, have a stronger bacteriostatic (inhibitory) effect than *A. mellifera* honey and contain no diastase (Cortopassi-Laurino and Gelli 1991). Among stingless bee honeys, we can also find a Slow Food praesidium, the *Arusha* stingless bee honey produced in Tanzania, which is a sweet liquid multiflower honey, with citrusy and floral notes (Slow Food Foundation for Biodiversity 2016).

Conclusions

The present review highlights the important role that animal productions play in African countries, mainly as a food source that provides high-value nutritional food to local people, but also for their traditional role in religious ceremonies and special occasions. Their importance is witnessed by the wide variety of products available and by the many different preparation processes, which have been developed depending on the local resources and on the social, economic and climatic conditions, that obviously affect the

processing and storage methods. Unfortunately, in spite of the great variety of local breeds and products, only few cattle and poultry breeds have received special attention in terms of biodiversity conservation. However, the increasing interest towards these breeds is shown by the inclusion of some of them in the Slow Food Ark of Taste or as Slow Food praesidia (Slow Food Foundation for Biodiversity 2016).

Few examples of large-scale production chains can be found, and therefore the possibility of exporting local animal products is low, except for honey. Furthermore, small-scale and family owned farms are not always able to guarantee safe hygienic procedures; as a consequence, some risks for human health may arise and this certainly contributes to limit the possibilities to export these products.

Possible future development strategies to promote animal production may include the identification of peculiar products related to specific breeds or production processes that could reach a higher value on the market and might also be exported in order to generate additional income, although attention should be paid to avoid that this exportation results in a further economic and nutritional depletion of population and in a disappearance of biodiversity.

Other possible improvements to the system, also related to the possibility of exporting animal products, may derive from cooperation projects, aiming to a training on hygienic and sanitary aspects of the whole production chain.

According to Burlingame and Dernini (2012), 'Sustainable diets are those diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally accepted, accessible, economically fair and affordable; nutritionally adequate, safe and healthy, while optimising natural and human resources'. In the light of this definition, we can consider that animal productions in Africa are usually carried out in a sustainable way, although the low efficiency of most traditional production systems hampers the possibility to make food security effective, considering the population growth and the increasing demand for food of animal origin. Invertebrates offer excellent opportunities for providing high nutritional food with low environmental impact. However, biodiversity can be threatened by the consumption of bushmeat deriving from hunting of endangered species. In this respect, it might be advisable to encourage the breeding of wild species, in order to satisfy the demand for highly appreciated and traditional meat types, without securing them


from the wild. Furthermore, some local breeds of traditional domestic species are at risk, and a careful management is required to protect them.

Disclosure statement

No potential conflict of interest was reported by the authors.


ORCID

Silvana Mattiello  <http://orcid.org/0000-0003-1885-949X>

Mariangela Caroprese  <http://orcid.org/0000-0002-5292-3291>

Gianni Matteo Crovetto  <http://orcid.org/0000-0003-1156-2087>

Riccardo Fortina  <http://orcid.org/0000-0002-3949-4402>


Andrea Martini  <http://orcid.org/0000-0003-1011-7352>

Mina Martini  <http://orcid.org/0000-0002-0847-2841>

Giuliana Parisi  <http://orcid.org/0000-0003-4646-6036>

Claudia Russo  <http://orcid.org/0000-0001-6263-009X>

Carla Severini  <http://orcid.org/0000-0002-4064-8018>

Massimo Zecchini  <http://orcid.org/0000-0003-3161-4411>

References

- Abernethy K, Coad L, Taylor G, Lee M, Maisels F. 2013. Extent and ecological consequences of hunting in Central African rainforests in the 21st century. *Philos Trans Roy Soc B*. 368:20120303.
- Abou-Shaara HF. 2015. Potential honey bee plants of Egypt. *Cercetări Agronomice În Moldova*. 48:99–108.
- Adu EK, Alhassan WS, Nelson FS. 1999. Smallholder farming of the greater cane rat, *Thryonomys swinderianus*, temminck, in Southern Ghana: a baseline survey of management practices. *Trop Anim Health Prod*. 31:223–232.
- Agribusiness Information Portal. 2016. Honey value chain. [accessed 2016 Oct 12]. <http://www.agricoop.info.ke/files/downloads/Honey%20full%20pdf.pdf>.
- Ajiboye AE, Kolawole OM, Oladosu TO, Adedayo MR, Akintunde JK. 2011. Studies on the microorganisms associated with dried meat (Tinko) sold in Ilorin, Nigeria. *Afr J Microbiol Res*. 5:4150–4154.
- Akinola LF, Essien A. 2011. Relevance of rural poultry production in developing countries with special reference to Africa. *Worlds Poult Sci J*. 67:697–705.
- Asaad AM. 2015. Ebola virus disease: the current global health crisis. *J Clin Microbiol Case Rep*. 1:002e.
- Attwell E. 2003. Biltong wakes up. *Food Rev*. 30:11–13.
- Ayieko MA, Oriamo V, Nyambuga IA. 2010. Processed products of termites and lake flies: improving entomophagy for food security within the Lake Victoria region. *Afr J Food Agric Nutr Dev*. 10:2085–2098.
- Ayieko MA, Oriamo V. 2008. Consumption, indigenous knowledge and cultural values of the lake fly species within the Lake Victoria region. *Afr J Environ Sci Technol*. 2:282–286.
- Azzollini D, Derossi A, Severini C. 2016. Understanding the drying kinetic and hygroscopic behaviour of larvae of yellow mealworm (*Tenebrio molitor*) and the effects on their

- quality. *Journal of Insects as Food and Feed*. <http://dx.doi.org/10.3920/JIFF2016.0001>
- Bahiru B, Mehari T, Ashenafi M. 2001. Chemical and nutritional properties of 'tej', an indigenous Ethiopian honey wine: variations within and between production units. *JFTA*. 6:104–108.
- Bahuchet S, Garine LD. 1990. Recipes for a forest menu. In: Hladik CM, Bahuchet S, Garine LD, editors. *Food and nutrition in the African rain forest*. Abingdon; Paris: United Nations Educational, Scientific and Cultural Organization; p. 53–54.
- Benkerroum N, Daoudi A, Kamal M. 2003. Behaviour of *Listeria monocytogenes* in raw sausages (merguez) in presence of a bacteriocin-producing lactococcal strain as a protective culture. *Meat Sci*. 63:479–484.
- Benkerroum N. 2013. Traditional fermented foods of North African countries: technology and food safety challenges with regard to microbiological risks. *Comp Rev Food Sci F*. 12:54–89.
- Bukkens SGF. 2005. Insects in the human diet: nutritional aspects. In: Paoletti MG, editor. *Ecological implications of minilivestock; role of rodents, frogs, snails, and insects for sustainable development*. Abingdon; New Hampshire: Science Publishers; p. 545–577.
- Burlingame B, Dernini S. 2012. *Sustainable diets and biodiversity: directions and solutions for policy, research and action*. Rome: FAO.
- Burnham GM, Hanson DJ, Koshicj CM, Ingham SC. 2008. Death of *Salmonella* serovars, *Escherichia coli* O157:H7, *Staphylococcus aureus* and *Listeria monocytogenes* during the drying of meat: a case study using biltong and droëwors. *J Food Saf*. 28:198–209.
- Carvalho M, Rego F, Palmeirim J, Fa J. 2015. Wild meat consumption on São Tomé Island, West Africa: implications for conservation and local livelihoods. *Ecol Soc*. 20:27.
- Chomba C, Nyirenda V. 2014. Game ranching: a sustainable land use option and economic incentive for biodiversity conservation in Zambia. *Open J Ecol*. 4:571–581.
- Collignan A, Santchurn S, Zachia-Rozis N. 2008. Dehydration of muscle food. In: Huy YH, Clary C, Farid MM, Fasina OO, Noomhorm A, Welti-Chanes J, editors. *Food drying science and technology: microbiology, chemistry, applications*. Lancaster (PA): DEStech Publications Inc.; p. 721–744.
- Cortopassi-Laurino M, Gelli DS. 1991. Analyse pollinique, propriétés physicochimiques et action antibactérienne des miels d'abeilles africanisées *Apis mellifera* et de Meliponine's du Brésil [Pollen analysis, physicochemical properties and antibacterial action of honey from Africanised bees *Apis mellifera* and stingless bees from Brazil]. *Apidologie*. 22:61–73.
- Crovetto GM. 2015. Poultry and pig production systems in developing countries. In: Bertoni G, editor. *World food production facing growing needs and limited resources*. Milano: Vita e Pensiero Università; p. 437–456.
- D'Amato ME, Alechine E, Cloete KW, Davison S, Corach D. 2013. Where is the game? Wild meat products authentication in South Africa: a case study. *Investig Genet*. 4:6.
- DAGRIS. 2007. *Domestic Animal Genetic Resources Information System (DAGRIS)*. Addis Ababa (Ethiopia): ILRI.
- Dana N, van der Waaij LH, Dessie T, van Arendonk JA. 2010. Production objectives and trait preferences of village poultry producers of Ethiopia: implications for designing breeding schemes utilizing indigenous chicken genetic resources. *Trop Anim Health Prod*. 42:1519–1529.
- Debebe A, Chandravanshi BS, Redi-Abshiro M. 2016. Total contents of phenolics, flavonoids, tannins and antioxidant capacity of selected traditional Ethiopian alcoholic beverages. *Bull Chem Soc Ethiop*. 30:27–37.
- Debold KJ. 1984. *Beekeeping development in the Central African Republic*. Rome: FAO; [accessed 2016 Oct 12]. http://agris.fao.org/agris-search/search.do?record_ID=US19850036048
- Delgado CL, Wada N, Rosegrant MW, Meijer S, Ahmed M. 2003. *Fish to 2020: supply and demand in changing global markets*. Washington (DC): International Food Policy Research Institute (IFPRI) WorldFish Center.
- Dietz A, Stevenson HR. 1980. Influence of long-term storage on the nutritional value of frozen pollen for brood rearing of honeybees. *Apidologie*. 11:143–151.
- El Sheikh AF, Montet D. 2014. African fermented foods: historical roots and real benefits. In: Ray RC, Montet D, editors. *Microorganisms and fermentation of traditional foods*. Boca Raton (FL): CRC Press, Taylor and Francis Group; p. 248–282.
- Essuman KM. 1992. *Fermented fish in Africa. A study on processing, marketing and consumption*. FAO Fisheries Technical Paper. No. 329. Rome: FAO.
- Fa JE, Juste J, Burn RW, Broad G. 2002. Bushmeat consumption and preferences of two ethnic groups in Bioko Island, West Africa. *Hum Ecol*. 30:397–416.
- Fa JE, Peres CA. 2001. Game vertebrate extraction in African and Neotropical forests: an intercontinental comparison. In: Reynolds JD, Mace GM, Redford KH, Robinson JG, editors. *Conservation of exploited species*. Cambridge (UK): Cambridge University Press; p. 203–241.
- FAO. 2016a. *The State of World Fisheries and Aquaculture 2016. Contributing to food security and nutrition for all*. Rome.
- FAO. 2016b. Values of honey. [accessed 2016 Oct 12]. <http://www.fao.org/docrep/006/y5110e/y5110e06.htm>
- FAO-GLOBEFISH. 2017. Fish trade in Africa: an update. [accessed 2017 May 10]. <http://www.fao.org/in-action/globefish/fishery-information/resource-detail/en/c/338418/>.
- FAOSTAT. 2016. *Food and Agriculture Organization of the United Nations. Statistics Division*. [accessed 2016 Oct 12]. <http://faostat3.fao.org/home/E>.
- Farina L, Demey F, Hardouin J. 1991. Production de termites pour l'aviculture villageoise au Togo [Termite production for poultry farming in Togo villages]. *Tropicicultura*. 9:181–187.
- Finke MD. 2007. Estimate of chitin in raw whole insects. *Zoo Biol*. 26:105–115.
- Garedew A, Schmolz E, Lamprecht I. 2004. Microcalorimetric investigation on the antimicrobial activity of honey of the stingless bee *Trigona* spp. and comparison of some parameters with those obtained with standard methods. *Thermochim Acta*. 415:99–106.
- Gebre YG, Gebre AE, Beyene G. 2016. Review on the role of honeybee in climate change mitigation and poverty alleviation. *Livestock Res Rural Dev*. 28:48.
- Guèye EF. 1998. Poultry plays an important role in African village life. *World Poultry*. 14:14–17.
- Guèye EF. 2001. Marketing of family poultry products in Africa to be improved. *World Poultry*. 17:12–16.

- Hagag IT, Mansour SMG, Zhang Z, AAAH, Ismaiel El BM, Salama AA, Cardona CJ, Collins J, Xing Z. 2015. Pathogenicity of highly pathogenic avian influenza virus H5N1 in naturally infected poultry in Egypt. *PLoS One*. 10:e0120061.
- Hans L. 2012. Chickens in Africa. *Aviculture Europe*. [accessed 2016 Oct 12]. <http://www.aviculture-europe.nl/nummers/12E04A10.pdf>
- Hoffman LC. 2000a. The yield and carcass chemical composition of impala (*Aepyceros melampus*), a southern African antelope species. *J Sci Food Agric*. 80:752–756.
- Hoffman LC. 2000b. Meat quality attributes of night-cropped mpala (*Aepyceros melampus*). *S Afr J Anim Sci*. 30:133–137.
- Hoffman LC, Ferreira AV. 2004. Chemical composition of two muscles of the common duiker (*Sylvicapra grimmia*). *J Sci Food Agric*. 84:1541–1544.
- Hoffman LC, Kroucamp M, Manley M. 2007a. Meat quality characteristics of springbok (*Antidorcas marsupialis*). 1: Physical meat attributes as influenced by age, gender and production region. *Meat Sci*. 76:755–761.
- Hoffman LC, Kroucamp M, Manley M. 2007b. Meat quality characteristics of springbok (*Antidorcas marsupialis*). 2: Chemical composition of springbok meat as influenced by age, gender and production region. *Meat Sci*. 76:762–767.
- Ismael AHM, Owayss AA, Mohanny KM, Salem RA. 2013. Evaluation of pollen collected by honey bee, *Apis mellifera* L. colonies at Fayoum Governorate, Egypt. Part 1: botanical origin. *J Saudi Soc Agri Sci*. 12:129–135.
- Jones MJ, Tanya VN, Mbofung CMF, Fonkem DN, Silverside DE. 2001. A microbiological and nutritional evaluation of the West African dried meat product, Kilishi. *J Food Technol Africa*. 6:126–129.
- Jongema Y. 2012. List of edible insects of the world. Wageningen University, Wageningen, The Netherlands. [accessed 2016 Oct 12]. <https://www.wur.nl/en/Expertise-Services/Chair-groups/Plant-Sciences/Laboratory-of-Entomology/Edible-insects/Worldwide-species-list.htm>
- Kadim IT, Mahgoub O, Purchas RW. 2008. A review of the growth, and of the carcass and meat quality characteristics of the one-humped camel (*Camelus dromedaries*). *Meat Sci*. 80:555–569.
- Katoh T, Koguchi M, Saigusa N, Teramoto Y. 2011. Production and antioxidative activity of mead made from various types of honey and black rice (*Oryza sativa* var. *indica* cv. *shiu*n). *Food Sci Technol Res*. 17:149–154.
- Khabbach A, Libiad M, Ennabili A. 2013. Melliferous flora and apiculture in the pre-rif of the province of Taza (north of Morocco) [Flora melifera y la apicultura en el pre-rif de la provincia de Taza (norte de Marruecos)]. *Revista Luna Azul*. 36:78–90.
- Kihwele DVN. 1997. Honey production, quality control and marketing in Tanzania. Perspectives for honey production in the tropics. *Proceedings of the NECTAR Symposium*; Dec 18, 1995; Utrecht, The Netherlands; p. 67–88.
- Kinyuru JN, Kenji GM, Njoroge MS. 2009. Process development, nutrition and sensory qualities of wheat buns enriched with edible termites (*Macrotermes subhyalinus*) from Lake Victoria region, Kenya. *Afr J Food Agric Nutr Dev*. 9:1739–1750.
- Krell R. 1996. Value-added products from beekeeping. *FAO Agricultural Services Bulletin* no. 124. [accessed 2016 Oct 12]. <http://www.fao.org/docrep/w0076e/w0076e04.htm>
- Ladele AA, Joseph K, Omotesho OA, Ijaiya TO. 1996. Sensory quality ratings, consumption pattern and preference for some selected meat types in Nigeria. *Int J Food Sci Nutr*. 47:141–145.
- Machovina B, Feeley KJ, Ripple WJ. 2015. Biodiversity conservation: the key is reducing meat consumption. *Sci Total Environ*. 536:419–431.
- Maia J. 2015. Saving SA's poultry industry is worth doing. [accessed 2016 Oct 12]. <http://www.bdlive.co.za/opinion/2015/03/20/saving-sas-poultry-industry-is-worth-doing>
- Makhloufi C, Kerkvliet J, Schweitzer P. 2015. Characterisation of some monofloral Algerian honeys by pollen analysis. *GRANA*. 54:156–166.
- Mankor A. 2013. Promoting intra-Africa trade in animals and animal products. *Proceedings of the 20th Conference of the Oie Regional Commission for Africa*; 2013 Feb 18–22; Lomé, Togo; p. 1–6.
- Matsheka MI, Mpuchane S, Gashe BA, Allotey J, Khonga EB, Coetzee SH, Murindamombe G. 2014. Microbial quality assessment and predominant microorganism of biltong produced in butcheries in Gaborone, Botswana. *Food Nutr Sci*. 5:1668–1678.
- Mendes-Ferreira A, Cosme F, Barbosa C, Falco V, Inês A, Mendes-Faia A. 2010. Optimization of honey-must preparation and alcoholic fermentation by *Saccharomyces cerevisiae* for mead production. *Int J Food Microbiol*. 144:193–198.
- Murray SS, Schoeninger MJ, Bunn HT, Pickering TR, Marlett JA. 2001. Nutritional composition of some wild plant foods and honey used by Hadza foragers of Tanzania. *J Food Compos Anal*. 14:3–13.
- Nasi R, Taber A, Van Vliet N. 2011. Empty forests, empty stomachs? Bushmeat and livelihoods in the Congo and Amazon Basins. *Int for Rev*. 13:355–368.
- Ndibalema VG, Songorwa AN. 2007. Illegal meat hunting in Serengeti: dynamics in consumption and preferences. *Afr J Ecol*. 46:311–319.
- Nonaka K. 1996. Ethnoentomology of the Central Kalahari San. *Afr Stud Monogr*. 22:29–46.
- 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:e51145=
- Oonincx DG, van Itterbeeck J, Heetkamp MJW, van den Brand H, van Loon J, van Huis A. 2010. An exploration on greenhouse gas and ammonia production by insect species suitable for animal or human consumption. *PLoS One*. 5:e14445.
- Oonincx DG, van Broekhoven S, van Huis A, van Loon JJA. 2015. Feed conversion, survival and development, and composition of four insect species on diets composed of food by-products. *PLoS One*. 10:e0144601.
- Pagezy H. 1975. Les interrelations homme faune de la forêt du Zaïre [The relationship between man and wildlife in Zaïre]. In: *L'Homme et l'Animal, Premier Colloque d'Ethnozoologie [The man and the animal, First colloquium of ethnozoology]*. Paris: Institut International d'Ethnoscience; p. 63–68.
- Petit T, Caro Y, Petit AS, Santchurn SJ, Collignan A. 2014. Physicochemical and microbiological characteristics of biltong, a traditional salted dried meat of South Africa. *Meat Sci*. 96:1313–1317.

- Phillips JK, Burkholder WE. 1995. Allergies related to food insect production and consumption. *Food Insects Newslett.* 8:1–4.
- Prandin L, Pedrazzini G, Mutinelli F. 2000. Beekeeping in Tanzania [*Apis mellifera scutellata*, *Eucalyptus*, *Kotschya*, *Syzygium*, *Diervillea*, *Citrus*, *Zea mays*]. *Tropicultura.* 18:94.
- Robert HS. 2010. The 1st International Post-Graduate Course on Commercial Beekeeping in Modern Agriculture. Rehovot: Hebrew University of Jerusalem.
- Rumpold BA, Schlüter OK. 2013. Nutritional composition and safety aspects of edible insects. *Mol Nutr Food Res.* 57:802–823.
- Ruttner F. 1988. Biogeography and taxonomy of honeybees. Berlin: Springer Verlag.
- Sambo E, Bettridge J, Dessie T, Amare A, Habte T, Wigley P, Christley RM. 2015. Participatory evaluation of chicken health and production constraints in Ethiopia. *Prev Vet Med.* 118:117–127.
- Schösler H, de Boer J, Boersema JJ. 2012. Can we cut out the meat of the dish? Constructing consumer-oriented pathways towards meat substitution. *Appetite.* 58:39–47.
- Skinner JD. 1989. Game ranching in southern Africa. In: Hudson RJ, Drew KR, Baskin LM, editors. *Wildlife production systems.* Cambridge: Cambridge University Press; p. 286–306.
- Slow Food Foundation for Biodiversity. 2016. [accessed 2016 Oct 12]. <http://www.fondazioneSlowFood.com/en>
- Sogari G, Vantomme P. 2014. A tavola con gli insetti [At the table with insects]. Fidenza: Mattioli 1885 Editore.
- Sogbesan A, Ugwumba A. 2008. Nutritional evaluation of termite (*Macrotermes subhyalinus*) meal as animal protein supplements in the diets of *Heterobranchus longifilis*. *Turkish J Fish Aquat Sci.* 8:149–157.
- Tan HSG, Fischer ARH, Tinchan P, Stieger M, Steenbekkers LP, van Trijp HCM. 2015. Insects as food: exploring cultural exposure and individual experience as determinants of acceptance. *Food Qual Prefer.* 42:78–89.
- Taylor G, Scharlemann JPW, Rowcliffe M, Kumpel N, Harfoot MBJ, Fa JE, Melisch R, Milner-Gulland EJ, Bhagwat S, Abernethy KA, et al. 2015. Synthesising bushmeat research effort in West and Central Africa: a new regional database. *Biol Conserv.* 181:199–205.
- The Poultry Site. 2013. [accessed 2016 Oct 12]. <http://www.thepoultrysite.com/articles/2971/global-poultry-trends-2013-africas-chicken-growth-exceeds-world-average/>.
- The WorldFish Center. 2009. Fish supply and food security for Africa. [accessed 2017 May 10]. http://pubs.iclarm.net/resource_centre/WF_2466.pdf
- Thornton P. 2010. Livestock production: recent trends, future prospects. *Philos Trans R Soc.* 365:2853–2867.
- Timón ML, Broncano JM, Andrés AI, Petróñ MJ. 2014. Prevention of rancidity and discolouration of Iberian dry cured sausage using proteases. *Food Sci Technol.* 58:293–298.
- USAID. 2010. Partnership for safe poultry in Kenya (PSPK): regional poultry value chain analysis. United States Agency for International Development. [accessed 2016 Oct 12]. pdf.usaid.gov/pdf_docs/Pnadu076.pdf
- van Huis A. 1996. The traditional use of arthropods in Sub-Saharan Africa. *Proceedings of the Section Experimental and Applied Entomology of the Netherlands Entomological Society (N.E.V.).* vol. 7; 1995 Dec 15; Utrecht, The Netherlands p. 3–20.
- van Huis A, van Itterbeeck J, Klunder H, Mertens E, Halloran A, Muir G, Vantomme P. 2013. Edible insects. Future prospects for food and feed security. Vol. 171 of *FAO Forestry Paper.* Rome: Food and Agriculture Organization of the United Nations.
- van Schalkwyk DL, McMillin KW, Witthuhn RC, Hoffman LC. 2010. The contribution of wildlife to sustainable natural resource utilization in Namibia: a review. *Sustainability.* 2:3479–3499.
- Van Zyl L, Ferreira AV. 2004. Physical and chemical carcass composition of springbok (*Antidorcas marsupialis*), blesbok (*Damaliscus dorcas phillipsi*) and impala (*Aepyceros melampus*). *Small Rum Res.* 53 :103–109.
- Vantomme P, Göhler D, N'Deckere-Ziangba F. 2004. Contribution of forest insects to food security and forest conservation: the example of caterpillars in Central Africa. Chicago (IL): McArthur Foundation, ODI Wildlife Policy Briefing; p. 3.
- Vega MG, Carpinetti B, Duarte J, Fa JE. 2013. Contrasts in livelihoods and protein intake between commercial and subsistence bushmeat hunters in two villages on Bioko Island, Equatorial Guinea. *Conserv Biol.* 27: 576–587.
- Verbeke W. 2014. Profiling consumers who are ready to adopt insects as a meat substitute in a Western society. *Food Qual Prefer.* 39:147–155.
- Womeni HM, Linder M, Tiencheu B, Mbiapo FT, Villeneuve P, Fanni J, Parmentier M. 2009. Oils of insects and larvae consumed in Africa: potential sources of polyunsaturated fatty acids. *OCL.* 16:230–235.
- Xiaoming C, Ying F, Hong Z, Zhiyong C. 2010. Review of the nutritive value of edible insects. In: Durst PB, Johnson DV, Leslie RL, Shono K, editors. *Forest insects as food: humans bite back: proceedings of a workshop on Asia-Pacific resources and their potential for development.* Abingdon; Bangkok: FAO Regional Office for Asia and the Pacific; p. 85–92.