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Chapter 13
Exotic Meats: An Alternative Food Source

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13.1 Introduction

It is estimated that by the year 2050 the world population will increase to 8.2–10.5 billion (United Nations Department of Economic and Social Affairs 2017). This fact worries food producers, and especially meat producers, who are aware that the land available for meat production is limited. Therefore, the only real method of increasing meat production is to utilise the available land more efficiently, being the ultimate goal of any livestock industry achieve sustainable livestock production with minimum costs in the shortest possible time (Hoffman 2008; Ojewola and Udom 2005).

In this sense, the use of exotic meats as a complement to traditional meats is becoming more and more meaningful. It is well known that a large number of exotic species, such as reptiles or amphibians have served as protein source for human populations around the world (Černíková et al. 2015; Klein et al. 2007). Many undomesticated, exotic and wild animals are hunted, harvested, and captured by fishing. This type of meat is a very important protein source for those people who do not have access to domesticated animals (Ockerman and Basu 2009). In general, the consumption of these meats is greater in the tropical and subtropical regions (Cawthorn and Hoffman 2016; Klemens and Thorbjarnarson 1995). In these regions

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that have a high rural population, bush meat represents an important food source for multiple reasons such as the lack of alternative sources, financial limitations or cultural preferences (Oduntan et al. 2012).

In contrast, the consumption of these meats in European Union or USA is comparatively much lower than in tropical and subtropical countries. In Europe, there is little tradition of comsumption of reptile meat. However, some examples can be found of consumption of reptile meat such as the consumption of lizard (*Timon lepidus*) in Spain or that of turtle soup in the United Kingdom during the nineteenth and early twentieth centuries (Magnino et al. 2009). Currently, and especially during the last 50 years increased consumption of exotic dishes in developed countries (Černíková et al. 2015). To this regard, there is also an increase for the importation of these exotic species into countries such as the USA and the EU (Hoffman 2008).

This increase in interest and demand for exotic meats has caused the overexploitation of some of these species in certain regions (Klemens and Thorbjarnarson 1995; Hoffman 2008; Magnino et al. 2009). In order to overcome this problem, captive breeding has been proposed as an alternative to the capture of wild animals. This also supposes a new commercial possibility for those farmers of certain zones (Saadoun and Cabrera 2008; Uhart and Milano 2002). In fact, terrapins, snakes, lizards, crocodiles, frogs and iguanas are farmed for human consumption in various parts of the world (Magnino et al. 2009).

The fact of farming these species in captivity has a series of problems, such as different feeding habits. Some of them are vegetarian (land tortoises or iguana), while most reptile and amphibian species have a varied diet includes arthropods, insects, molluscs, amphibians, birds, mammals, fishes, or other reptiles (Klein et al. 2007).

Part of the increase in interest for exotic meats by consumers in developed countries can be related to their health awareness (Hoffman 2008). Thus, therefore, the two main aspects that determine the acceptability of these meats by the consumer are the availability and the nutritional characteristics (Hoffman and Cawthorn 2013). It is therefore of particular importance to control all aspects of captive breeding of these animals. Being a monogastric animals, diet strongly influences the meat composition (Osthoff et al. 2010). Additionally, the composition of tissues of aquatic animals tend to change with species, climate, seasons, sexual maturity, levels and regime of feeding (Cagiltay et al. 2014; Shearer et al. 1994).

Another very important aspect is the risk assessment that involves consuming this type of exotic meats. There are different studies that link the consumption of reptile meats with an increase in the intake of disease agents and/or toxic chemical substances which might be of public health problem. A study of Panel on Biological Hazards from European Food Safety Authority concluded that the consumption of reptile meats may involve the intake of dangerous bacteria (*Salmonella*) and parasites (*Spirometra, pentastomids*) (Klein et al. 2007). Khan and Tansel (2000) also found high levels of mercury in the tissues of alligators from the Everglades, while in turtles were found some cases of *Vibrio cholera* (Huang and Lin 1999).

Part of these problems is related to the fact that the meat of this type of species is normally a by-product (Klemens and Thorbjarnarson 1995; Saadoun and Cabrera

2008). Usually, exotic species are mostly reared by far for their skins that are highly valued by the leather industry. Contamination of the meat is likely because the skin is valuable and must be removed carefully, which provides greater opportunity for contamination of carcass and therefore, the meat (Klein et al. 2007; Madsen et al. 1992). Although meat was seen as only a by-product, it is becoming more important as the industry grows (Hoffman et al. 2000).

For species reared in aquatic environments, the quality of water in which animals are raised is one of the most important aspect. However, hygienic practices during farming, processing and slaughtering reduce the risk to the consumer when consuming meat from farmed exotic species (Magnino et al. 2009). Therefore, it is preferable that animal species destined for human consumption must be slaughtered and processed in specialized slaughterhouses and plants that ensure hygienic conditions and good handling conditions for the meat (Bertolini et al. 2005; Hoffman and Cawthorn 2013).

On the other hand, it is very important that there is information about the quality of the meat and productive yields so that the farmers get to promote this type of exotic meats (Saadoun and Cabrera 2008). However, it is very complicated to obtain information on the composition of the meat, as well as the values of certain nutrients of exotic species, since many times its consumption is limited to very specific areas and this type of meat represents little interest for the global scientific community. Thus, although further studies should continue to characterize the meat of this exotic species, this chapter intends to make a general review of the existing information on the proximal composition and other nutrients such as amino acids, fatty acids and mineral profiles in alternative meats.

13.2 Crocodiles

Taxonomically, “crocodiles” are classified within three families: *Alligatoridae*, *Crocodylidae* and *Gavialidae* (Klein et al. 2007). Figure 13.1 shows the main crocodiles species used for human consumption. Globally, several species of crocodiles are bred on farms (“Nile crocodile” *Crocodylus niloticus*, “freshwater crocodile” *Crocodylus johnstoni*, “siamese crocodile” *Crocodylus siamensis*, *Crocodylus acutus*, “saltwater crocodile” *Crocodylus porosus*, “alligator” *Alligator mississippiensis* and “caiman” *Caiman yacare*) (Černíková et al. 2015).

Figure 13.2 shows the global distribution of crocodiles. The Nile crocodile (*Crocodylus niloticus*) is native to Africa and is reared in many countries including Egypt, Madagascar, Kenya, Zimbabwe, Tanzania, Seychelles, Comoro Islands, South Africa, Israel, Indonesia, France, Japan, United Kindong and Spain. The saltwater crocodile (*Crocodylus porosus*) is farmed in Australia, Papua New Guinea and Thailand, while the freshwater crocodile (*Crocodylus johnstoni*) is also farmed in Australia. The Siamese crocodile (*Crocodylus siamensis*) is farmed in Thailand and Cambodia, while in North America, alligator (*Alligator mississippiensis*) is typically farmed in Southern USA (Georgia, Florida, Texas and Louisiana). In

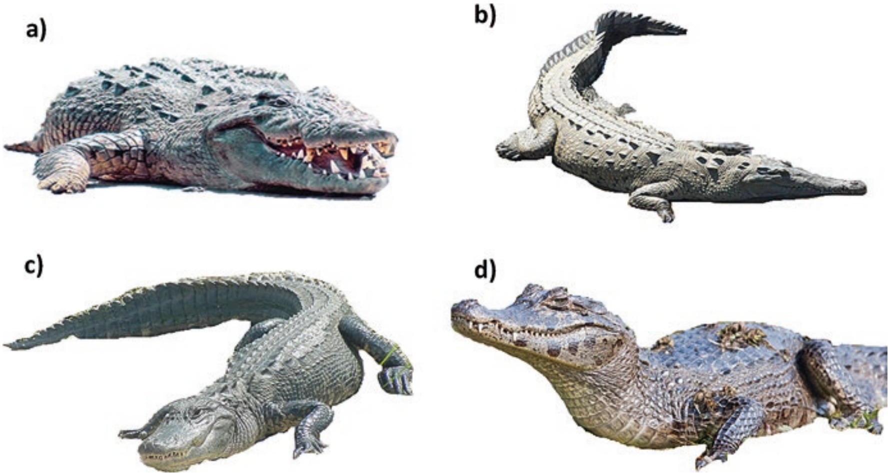

Fig. 13.1 Edible crocodiles: *Crocodylus niloticus* (**a**), *Crocodylus acutus* (**b**), *Alligator mississippiensis* (**c**) and *Caiman yacare* (**d**)

Fig. 13.2 Global distribution (wild and farm-raised) of crocodiles

Central and South America caiman (*Caiman crocodilus*) is established from Mexico to Peru, while (*Caiman yacare*) is observed in Brazil, Argentina, Uruguay, Paraguay and Bolivia (Cawthorn and Hoffman 2016; Magnino et al. 2009; Saadoun and Cabrera 2008).

Consumption of crocodile, caiman and alligator meat occurs mostly in Australia, Thailand, Africa, Brazil and the USA (Alves et al. 2012; Cawthorn and Hoffman 2016; Klein et al. 2007). The main farms and infrastructure for breeding captive crocodiles are located in Africa (Zimbabwe, South Africa) utilising the Nile crocodile, and in Australia and Asia mainly utilising the saltwater crocodile and the saltwater crocodile/Siamese crocodile hybrid (Klein et al. 2007). Of all the crocodile carcass, the tail is considered to be the most valuable part, while there are other edible parts of the crocodile body, such as neck, shoulder and/or legs with less value (Černíková et al. 2015; Gill 2007; Hoffman et al. 2000). In fact, some studies concluded that only tail and dorsal fillets are used for human diets, and the rest of parts may be fed back to the crocodiles (Klein et al. 2007).

In the Table 13.1 are presented the proximate composition, fatty acids, amino acids and minerals of the main species of edible crocodiles. The proximate composition obtained from crocodile's meat indicates protein levels between 14% and 24.4% in *Cocodrilus niloticus*, 16–18% in *Alligator mississippiensis* and 19.4–24.4% in *Caiman yacare*. These values are similar to the other meats and indicate that crocodile meat is a good source of protein. The moisture represented a mean of 74.5% of all species, and range between 66.1% and 80%, while the values of ash were similar in the three cases, and ranged between 0.42% and 1%. With regard to the fat amount, this value had more variation. In *Crocodylus niloticus* varied between 0.47% and 13.3%, in *Alligator mississippiensis* between 0.8% and 1% and in *Caiman yacare* between 0.29% and 4.2%. This variation could be due to different parameters. However, it is well known that the location has a high influence on fat content. In fact, different studies demonstrate that tail presents higher content of fat and lower of moisture than legs and necks (Hoffman et al. 2000; Saadoun and Cabrera 2008).

It is well known that not only the fat content has importance from the nutritional point of view, but the content of certain fatty acids plays a very important role. To this regard, the fat composition of the crocodile's meat is known to contain high levels of monounsaturated fatty acids (MUFA) (between 33.2% and 51.3%) and saturated fatty acids (SFA) (between 26.0% and 41.1%) while the content of polyunsaturated fatty acids (PUFA) present greater variation. The PUFA content in *Alligator mississippiensis* and *Caiman yacare* were similar (17.6–19.6%), while in the *Crocodylus niloticus* meat, the PUFA values ranged between 10.7% (Hoffman et al. 2000) and 38.1% (Osthoff et al. 2010).

From the nutritional point of view, this meat had the advantage of possessing a high essential fatty acids like C18:2*n*-6 (8.4–10.9% *Alligator mississippiensis* and *Caiman yacare* and 9.1–29.6% in *Crocodylus niloticus*) and C18:3*n*-3 (1.4–3.3%). In addition, crocodile meat also presented high contents of several fatty acids with high biological importance such as derived *n*-6 family FA, especially C20:4*n*-6 (about 4.3%) and also *n*-3 family FA in *Alligator mississippiensis*, especially C20:5*n*-3 (EPA; ≈1.7%) and C22:6*n*-3 (DHA; ≈5.6%). These results agree with those other authors (Cossu et al. 2007; Hoffman et al. 2000). The *n*-6/*n*-3 ratio remained within the internationally recommended levels (<4) in *Alligator mississippiensis* and *Caiman yacare*, while in *Cocodrylus niloticus* ranged between 5.35 and 9.02.

On the other hand, the results obtained by different researches showed the high content of essential amino acids and minerals in crocodile meat. Only amino acid composition data of *Crocodylus niloticus* and *Crocodylus acutus* meat have been

Table 13.1 Proximate composition and nutritional characteristics of crocodile meat

	Crocodylus niloticus [1]	*Crocodylus acutus* [2]	*Alligator mississippiensis* [3]	*Caiman yacare* [4]
Proximate Composition	***g/100 g***	***n/a***	***g/100 g***	***g/100 g***
Moisture	66.1–75.9	-	73–80	75.2–77.1
Protein	14.0–22.9	-	16–18	19.4–24.4
Fat	0.47–13.3	-	0.8–1.0	0.29–4.2
Ash	0.42–0.97	-	0.5–1.0	0.58–1.0
Fatty Acids	***%***	***n/a***	***%***	***%***
C16:0	20.2–25.4	-	19.9–21.5	21.9
C16:1*n-7*	3.1–5.9	-	6.5–6.9	2.72
C18:0	7.9–9.9	-	4.4–4.8	15.4
C18:1*n-9*	27.3–43.1	-	40.9–44.4	34.9
C18:2*n-6*	9.1–29.6	-	9.1–10.5	8.4
C18:3*n-3*	1.6	-	1.4–1.5	3.32
C20:4*n-6*	4.2	-	-	4.34
C20:5*n-3*	0.20–0.48	-	1.6–1.8	0.76
C22:6*n-3*	0.90–1.1	-	5.4–5.8	0.57
SFA	28.7–37.7	-	26.0–28.7	41.4
MUFA	33.2–51.1	-	47.4–51.3	39.2
PUFA	10.7–38.1	-	17.6–19.6	19.4
$\sum$ *n-6*	9.1–34.3	-	9.2–10.6	12.9
$\sum$ *n-3*	1.7–3.8	-	8.4–9.0	4.7
n-6/n-3	5.35–9.02	-	1.09–1.17	2.74
P/S	0.29–1.33	-	0.66–0.68	0.47
Amino Acids	***g/kg meat***	***g/100 g protein***	***n/a***	***n/a***
Lysine	6.97–13.8	9.84	-	-
Methionine	2.06–5.72	2.93	-	-
Threonine	3.29–6.95	5.33	-	-
Leucine	6.43–12.6	8.87	-	-
Isoleucine	3.56–8.52	5.24	-	-
Phenylalanine	2.91–6.02	4.45	-	-
Valine	3.47–7.69	4.82	-	-
Histidine	2.15–5.75	2.99	-	-
Serine	2.82–6.08	3.31	-	-
Arginine	6.35–9.65	5.88	-	-
Cysteine	2.07–2.57	-	-	-
Tyrosine	2.60–5.89	5.44	-	-
Alanine	4.53–9.02	6.59	-	-
Aspartic acid	13.6–16.8	8.43	-	-
Glutamic acid	21.7–27.5	16.96	-	-
Glycine	4.06–10.7	5.64	-	-
Proline	5.31–6.48	-	-	-

(continued)

Table 13.1 (continued)

	Crocodylus niloticus [1]	*Crocodylus acutus* [2]	*Alligator mississippiensis* [3]	*Caiman yacare* [4]
Minerals	***mg/kg***	***n/a***	***mg/100 g***	***n/a***
Ca	68	-	9	-
Mg	185	-	27	-
P	1939	-	231	-
Na	282	-	47	-
K	2423	-	367	-
Fe	3	-	0.9	-

[1] (Cerníková et al. 2015; Hoffman et al. 2000; Osthoff et al. 2010)
[2] (Hernández-Hurtado et al. 2018)
[3] (Ockerman and Basu 2009; Peplow et al. 1990)
[4] (Cossu et al. 2007; Rodrígues et al. 2007; Romanelli et al. 2002; Neto et al. 2007). n/a: data not available

found. In these cases, the glutamic acid was the major amino acid, followed by aspartic acid, lysine and leucine. Regard to mineral contents, the major mineral was K with values between 242 and 367 mg/100 g of meat followed by P (194–231 mg/100 g). The Na content is very low (28–47 mg/100 g), as well as the Fe levels (0.3–0.9 mg/100 g).

Therefore, crocodile meat could be marketed as a healthy food owing to its favourable unsaturated fatty acid profile and the high content of protein, minerals and essential amino acids, which indicate that crocodile meat could be appropriate for consumers (Černíková et al. 2015). Additionally, crocodile meat is a very important by-product from the economic point of view that it is already on sale in some "premium" markets (Cossu et al. 2007).

13.3 Frog

Frogs are amphibians that belongs to the family *Ranidae*. They are aquatic species, where it lives in and around permanent lakes, rivers, ponds and swamps (Muhammad and Ajiboye 2010). Figure 13.3 shows the main frog species used for human consumption. Frogs are consumed over the world. Many frog species are edible. In fact, more than 50 different species are used for human consumption, most are extracted from their natural habitat (Neveu 2004). The worldwide exportation of frog meat is centred on Indonesia, Vietnam and Turkey (Altherr et al. 2011; Blé et al. 2016).

Figure 13.4 shows the global distribution of frogs. The American bullfrog (*Rana catesbeiana*) and Indian bullfrog (*Rana tigrina*) are the most consumed frogs of Southern American and Asian countries. These species are captured from wild habitat and bred in captivity. In contrast, the European countries prefers smaller frogs, such as green frog (*Rana esculanta*) and *Rana ridibunda*. These two species are mainly imported from Turkey, Bangladesh, Albania, China, Malaysia and Indonesia

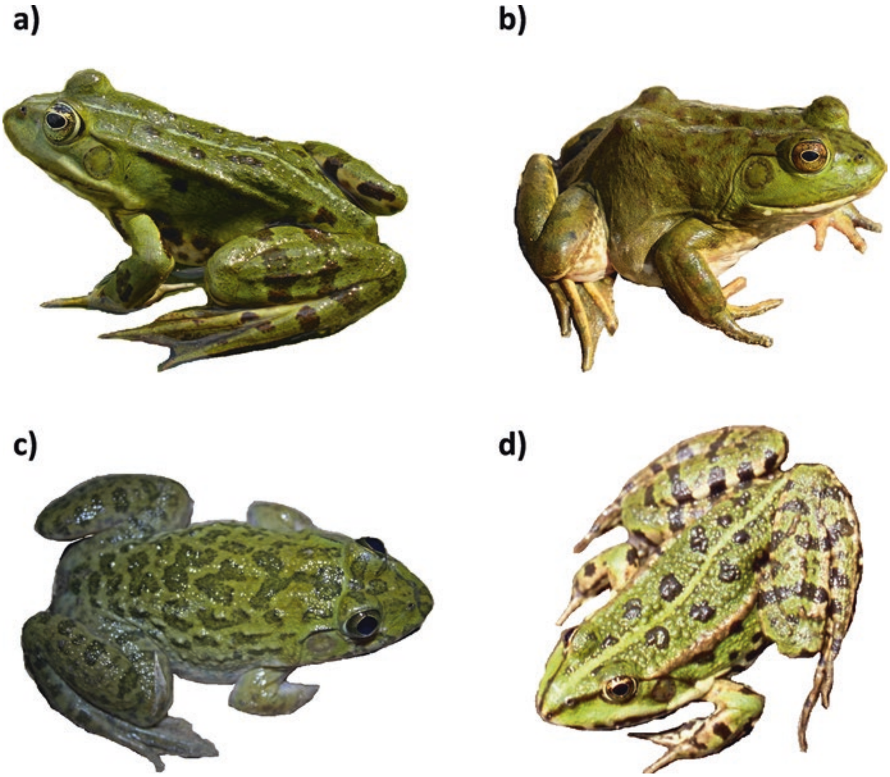

Fig. 13.3 Edible frogs: *Rana esculenta* (**a**), *Rana catesbeiana* (**b**), *Hoplobatrachus occipitalis* (**c**), *Rana ridibunda* (**d**)

Fig. 13.4 Global distribution (wild and farm-raised) and importing countries of frogs

(Cagiltay et al. 2014; Neveu 2004; Neveu 2009). Frogs are also eaten in several countries in Africa. The most consumed species in this case are *Pyxicephalus adspersus*, *P. edulis*, *Hoplobatrachus occipitalis*, *Trichobatrachus robustus*, *Conraua spp*. and *Ptychadena spp*. (Blé et al. 2016; Mohneke et al. 2009). In addition to the aforementioned countries, major frog leg suppliers include Belgium, China, Japan, Mexico, the Netherlands, Brazil, India, Thailand and Taiwan (Çaklı et al. 2009; Tokur et al. 2008).

Nowadays, the frog meat is an attractive food choice in restaurants in Europe (Cagiltay et al., 2014). Consequently, frogs are traded world-wide and the major frogs' legs importing countries include France, the United States, Belgium, and Luxembourg (Ali et al. 2015; Tokur et al. 2008). The frog meat is appreciated for its exquisite flavour, taste and texture and also is a source of protein of high biological value (Çaklı et al. 2009; Bahar et al. 2008; Blé et al. 2016).

As with other types of animals, the high demand for frog meat encouraged its culture and agro-based production across the world. The possibility of growing large numbers of frogs in a limited space and with a small amount of water provides a high yield, and makes their culture profitable (Özogul et al. 2008). The main producers of cultured frogs are Indonesia, Taiwan Province of China and Turkey (Özogul et al. 2008). In this case, the main species used are *Rana catesbeiana, Lithobates catesbeianus* and *Hoplobatrachus tigrinus* (Ali et al. 2015; Daszak et al. 2006). Additionally, a great technological advance has been experimented in the last years in the cultivation of frog. The production of American bullfrog (*Rana catesbeiana*) have been intensified under controlled conditions (Olvera-Novoa et al. 2007). With respect to edible parts, frog meat is marketed in different ways depending on the country. In Brazil, frogs are marketed as whole carcass, while in the international market frog meat is usually commercialized as fresh or frozen legs (Çaklı et al. 2009; Gonçalves and Otta 2008).

In the Table 13.2 are presented the proximate composition, fatty acids, amino acids and minerals of the main species of edible frogs. The proximate composition obtained from frog's meat indicates protein levels between 13 and 22.9 g/100 g of fresh meat and 53.7 g/100 g of dry matter. Due to this values, frog meat is used as protein source in the diet of many consumers (Özogul et al. 2008; Onadeko et al. 2011). The moisture was between 72.8 and 79.7 g/100 g, while the values of ash ranged between 0.20% and 3.1% in fresh meat and 6.1% in dry matter.

The content of fat was about 1% (0.62–1.2%) in *Rana esculenta*, *Hoplobatrachus occipitalis* and *Rana ridibunda*. In *Rana catesiana* meat, the values of fat had more variation and ranged between 0.33% and 7.4%. The content of fatty acids revealed that in *Rana galamensis* and *Rana ridibunda* meat the major fatty acids were PUFA, followed by SFA and finally MUFA. However, in *Rana esculenta*, the values of SFA (26.8–31.7%), MUFA (18.5–42.5%) and PUFA (20.3–30.3%) presented higher variation than the other frog meat studied. Frog meat also contain essential fatty acids; the content of C18:2*n*-6 was between 9.1% and 29.6%, while the content of C18:3*n*-3 was 0.2–3.3%. It is also remarkable the high content of C20:5*n*-3 (1.8–6.1%) and C22:6*n*-3 (0.9–6.7%) that presented frog meat. These fatty acids (*n*-3 and *n*-6 fatty acids) have an important role in human nutrition and nutritional physiology

Table 13.2 Proximate composition and nutritional characteristics of frog meat

	Rana esculenta[1]	*Rana galamensis*[2]	*Rana catesbeiana*[3]	*Hoplobatrachus occipitalis*[4]	*Rana ridibunda*[5]
Proximate Composition	***g/100 g***	***g/100 g DM***	***g/100 g***	***g/100 g***	***g/100 g***
Moisture	78.8–79.7	-	72.8–79.2	77.8	74.8–79.4
Protein	18.8–19.2	53.7	13.6–19.4	19.5	18.5–22.9
Fat	0.62–1.2	9.52	0.33–7.4	1.06	0.74–0.93
Ash	0.56–0.85	6.1	0.20–3.1	1.28	1–1.4
Fatty Acids	***%***	***%***	***n/a***	***n/a***	***mg/100 g frog***
C16:0	19.3–23.3	18.1–18.6	-	-	70.5–125.4
C16:1*n-7*	7.1–13.1	2.1–2.7	-	-	6.27–7.84
C18:0	3.6–6.3	8.4–9.1	-	-	54.8–74.0
C18:1*n-9*	10.8–26	14.5–15.9	-	-	54.2–75.1
C18:2*n-6*	6.4–16.7	17.1–21.3	-	-	38.1–81.5
C18:3*n-3*	0.2–3.3	2.0–2.8	-	-	15.7–18.5
C20:4*n-6*	0.16–0.22	0.24–0.43	-	-	70.6–92.5
C20:5*n-3*	1.8–6.1	2.9–4.6	-	-	31.4–37
C22:6*n-3*	0.9–6.7	3.2–4.5	-	-	36.8–81.4
SFA	26.8–31.7	31.2–32.5	-	-	167–199
MUFA	18.5–42.5	22.7–23.8	-	-	35.9–90.3
PUFA	20.3–30.3	37.6–40.1	-	-	245–276
$\sum$ *n-6*	7.3–17	20.3–24.5	-	-	92.5–154.5
$\sum$ *n-3*	3.3–22.7	13.3–16.9	-	-	85.4–138.7
n-6/n-3	0.75–2.21	1.45–1.53	-	-	1.08–1.11
P/S	0.76–0.95	1.16–1.28	-	-	1.23–1.65
Amino Acids	***g/100 g protein***	***g/100 g protein***	***n/a***	***g/100 g protein***	***mg/100 g frog***
Lysine	5.4–6.9	6.9	-	5.9	1341–1720
Methionine	3.0–4.6	3.0	-	3.5	532–562
Threonine	3.5–4.3	4.3	-	3	500–744
Leucine	6.1–7.1	7.1	-	8.1	867–1454
Isoleucine	3.4–4.0	4.0	-	5.5	824–971
Phenylalanine	3.8–5.0	5.0	-	4.6	795.797
Valine	4.0–4.8	4.8	-	4.8	854–936
Histidine	2.4–3.1	3.1	-	2.3	521–573
Serine	4.9–5.2	5.2	-	3.1	695–905
Arginine	5.8–6.6	6.6	-	8.2	747–1177
Cysteine	1.1	1.1	-	1.5	147–196
Tyrosine	2.4–4.0	4.0	-	3.2	615–693
Alanine	5.6–6.1	6.1	-	3.2	1011–1302
Aspartic acid	6.5–9.7	9.6	-	9.7	1386–1750
Glutamic acid	10.6–13.2	13.2	-	14.7	1823–2787

(continued)

Table 13.2 (continued)

	Rana esculenta [1]	*Rana galamensis* [2]	*Rana catesbeiana* [3]	*Hoplobatrachus occipitalis* [4]	*Rana ridibunda* [5]
Glycine	5.0–8.9	5.0	-	5.1	706–851
Proline	5.1–7.7	5.1	-	3.6	373–605
Minerals	***mg/100 g***	***n/a***	***n/a***	***mg/100 g***	***mg/100 g***
Ca	7.7–15.6	-	-	27.2–59.9	22.5–24.0
Mg	6.6–8.9	-	-	18.1–27.1	17.0–23.0
P	28.6–46.4	-	-	23.8–34.4	140–160
Na	0.91–1.22	-	-	-	28.9–48.1
K	32.7–62.1	-	-	35.8–37.7	350–366
Fe	0.18–0.20	-	-	0.2–0.6	0.55–1.21

[1] (Çaklı et al. 2009; Özogul et al. 2008; Tokur et al. 2008)
[2] (Muhammad and Ajiboye 2010; Özyurt and Etyemez 2015)
[3] (Gonçalves and Otta 2008; Nóbrega et al. 2007; Olvera-Novoa et al. 2007)
[4] (Blé et al. 2016; Onadeko et al. 2011)
[5] (Cagiltay et al. 2014). n/a: data not available

(Blé et al. 2016; Davis and Kris-Etherton 2003). In this case, the n-3/n-6 ratio were in all cases within the international recommendations (<4) and ranged between 0.75 and 2.21.

About the amino acid results, different researches showed that glutamic acid, aspartic acid, alanine, leucine, lysine and arginine are dominating amino acids in frog meat. Comparing with amino acid requirements for adults people, reported by WHO (2007), it is evident that 100 g of cultured frog meat consumption may provide more than daily amino acids requirement for adult (Cagiltay et al. 2014).

Regard minerals, K was the major mineral (32.7–366 mg/100 g), followed by P (23.8–160 mg/100 g) and Ca (7.7 and 59.9 mg/100 g). In this case, the content of Fe was very low, and the values ranged between 0.12 and 1.21 mg/100 g). These data indicate that frog meat contained essential mineral for human nutrition (Blé et al. 2016). As a general conclusion, frog meat has relatively low lipid content, good amino acid and fatty acid profiles and mineral composition (Cagiltay et al. 2014; Özogul et al. 2008; Tokur et al. 2008). In fact, frogs are comparable with those of freshwater fish species (Ali et al. 2015).

13.4 Turtles

The term "turtle" is usually used for all members of the order Testudines. However, depending on the habitat they can be classified in: freshwater turtles are denominated "terrapins", while "tortoises" are land-dwelling species and "sea turtles" inhabit in saltwater. Figure 13.5 shows the main turtles species used for human consumption. In the past, turtles were hunted in their natural habitat and their meat were consumed. Nowadays, this is less common but still occurs in some parts (Magnino et al. 2009). Figure 13.6 shows the global distribution of turtles.

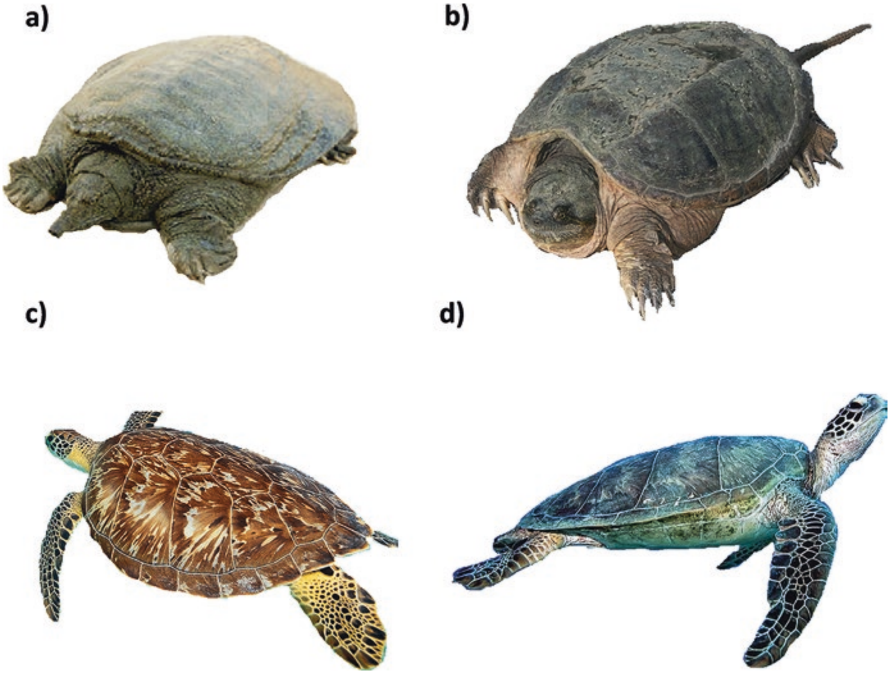

Fig. 13.5 Edible turtles: *Pelodiscus sinensis* (**a**), *Chelydra serpentine* (**b**), *Eretmochelys imbricate* (**c**) and *Chelonia mydas* (**d**)

Fig. 13.6 Global distribution (wild and farm-raised) of turtles

The terrapins differ in those with soft-shelled and hard-shelled terrapins. Soft-shelled terrapins inhabit warm ponds, marshes, lakes and rivers and feed on crustaceans, small fish and snails, insect larvae, small aquatic animals and seeds of marsh plants (Nuangsaeng and Boonyaratapalin 2001). Some characteristics, such as its rapid growth rate and high annual reproductive makes the soft-shelled terrapins especially profitable to be farmed (Magnino et al. 2009).

The native range of soft-shelled terrapin includes China, Taiwan, Japan, Korea, Thailandand and Vietnam (Lee et al. 2006; Wang et al. 2014; Zhou et al. 2011; Zhou et al. 2013). Turtle meat, especially diamondback terrapin (*Malaclemys terrapin*) is also farmed in Southern USA (Cawthorn and Hoffman 2016; Magnino et al. 2009).

The Chinese soft-shelled turtle (*Pelodiscus sinensis*) and Brazilian tortoise (*Trachemys scripta elegans*) are species of high market value in Asian countries (Chen and Huang 2011; Yang et al. 2017). In fact, the Chinese soft-shelled turtle (*Pelodiscus sinensis*) and diamondback terrapin (*Malaclemmys terrapin*) are farmed exclusively for meat production (Klein et al. 2007). Due to its high nutritional value and high economic profits, these turtle species have been an important aquaculture species in Asia (Chen and Huang 2015). According to Klein et al. (2007) the most hard-shelled terrapins farmed are the Reeves' Turtle (*Chinemys reevesii*) and the Chinese pond turtle (*Mauremys mutica*) in China, and the Chinese stripe-necked turtle (*Ocadia sinensis*) in Taiwan.

Other turtle species, such as South American river turtle (*Podocnemis expansa*) and yellow-spotted river turtle (*Podocnemis unifilis*) are distributed in many Amazon basin regions of Brazil, where they are widely eaten (Alves et al. 2012; Cawthorn and Hoffman 2016). In South American countries, the terrestrial Testudines (tortoises) such as the yellow-footed tortoise (*Chelonoidis denticulata*) and red-footed tortoise (*Chelonoidis carbonaria*) are used for food (Alves et al. 2012). In Madagascar, the radiated tortoise (*Astrochelys radiata*) is used as food source, despite it is listed as critically-endangered (Cawthorn and Hoffman 2016).

Regarding sea turtles, artificial rearing of different species is carried out in tropical regions, almost exclusively for conservation (Klein et al. 2007). The green sea turtle (*Chelonia mydas*) is farmed in the Cayman Islands, Suriname, Japan and Réunion Island (Cawthorn and Hoffman 2016; Magnino et al. 2009). Hawksbills turtles (*Erethmochelys imbricata*) are also farmed, although globally in a small number (Klein et al. 2007). Sea turtles have served for many years as food for indigenous populations, and nowadays there is certainly a tradition of meat production in the Grand Cayman Island, Réunion and in the Ogasawara Islands of Japan. However, the overexploitation contributed to a decline in many populations of sea turtles by the late 1900s (Delgado and Nichols 2005; Mancini and Koch 2009). Due to this, the CITES treaty prohibits the export of turtle meat, which can only be consumed and sold by the local population and in domestic markets (Magnino et al. 2009).

In the Table 13.3 are presented the proximate composition, fatty acids, amino acids and minerals of the main species of edible turtles. The proximate composition obtained from turtles' meat indicates protein levels between 13.9% and 20.8%. The moisture represents about 80% of all species, and range between 65.9% and 83%, while the values of ash presented a high variation. With regard to the fat amount, in

Table 13.3 Proximate composition and nutritional characteristics of turtle meat

	Pelodiscus sinensis [1]	*Chelydra serpentine* [2]	*Trionyx sinensis* [3]	*Eretmochelys imbricate* [4]	*Chelonia mydas* [4]
Proximate Composition	***g/100 g***	***g/100 g***	***g/100 g***	***g/100 g***	***g/100 g***
Moisture	65.9–79.5	83.0	74.2–81.0	77.1–82.0	78.1–81.4
Protein	13.9–20.8	15.8	16.1–17.8	15.7–19.0	16.0–20.0
Fat	1.2–10.6	0.2	0.41–4.9	0.65–1.0	0.40–1.0
Ash	0.35–8.21	1.0	0.94–3.9	1.0–1.2	0.87–1.2
Fatty Acids	***%***	***n/a***	***n/a***	***n/a***	***g/100 g meat***
C16:0	15.5–18.6	-	-	-	-
C16:1*n-7*	6.5–20.8	-	-	-	-
C18:0	4.3–4.7	-	-	-	-
C18:1*n-9*	23.8–43.7	-	-	-	-
C18:2*n-6*	2.9–26.8	-	-	-	-
C18:3*n-3*	0.3–3.3	-	-	-	-
C20:4*n-6*	1.0–1.7	-	-	-	-
C20:5*n-3*	1.7–6.6	-	-	-	0.023
C22:6*n-3*	3.7–8.1	-	-	-	0.033
SFA	23.2–26.3	-	-	-	0.13
MUFA	31.0–65.0	-	-	-	0.08
PUFA	3.2–30.1	-	-	-	0.17
$\sum$ *n-6*	4.2–27.8	-	-	-	-
$\sum$ *n-3*	5.7–18	-	-	-	-
n-6/n-3	0.73–1.54	-	-	-	-
P/S	0.14–1.14	-	-	-	1.31
Amino Acids	***n/a***	***n/a***	***n/a***	***g/100 g lyophilized sample***	***g/100 g lyophilized sample***
Lysine	-	-	-	4.14	3.70
Methionine + cysteine	-	-	-	2.07	2.09
Threonine	-	-	-	1.77	1.60
Leucine	-	-	-	3.95	3.99
Isoleucine	-	-	-	2.57	2.56
Phenylalanine + tyrosine	-	-	-	1.53	1.17
Valine	-	-	-	2.76	2.77
Histidine	-	-	-	2.43	1.86
Serine	-	-	-	-	-
Arginine	-	-	-	2.95	2.80
Alanine	-	-	-	-	-
Aspartic acid	-	-	-	-	-
Glutamic acid	-	-	-	-	-
Glycine	-	-	-	-	-

(continued)

Table 13.3 (continued)

	Pelodiscus sinensis [1]	*Chelydra serpentine* [2]	*Trionyx sinensis* [3]	*Eretmochelys imbricate* [4]	*Chelonia mydas* [4]
Proline	-	-	-	-	-
Minerals	**µg/g**	***n/a***	***n/a***	***mg/100 g***	***mg/100 g***
Ca	-	-	-	-	12.0–18.0
Mg	139.5–176.2	-	-	-	-
P	-	-	-	-	-
Na	-	-	-	-	-
K	-	-	-	-	-
Fe	18.3–25.2	-	-	1.51	1.3–1.61

[1] (Chen and Huang 2011; Chen and Huang 2015; Chen et al. 2014; Guo and Huang 2013; Huang and Lin 2002; Huang and Lin 2004; Huang et al. 2005; Wang and Huang 2015; Wang et al. 2014; Wu and Huang 2008; Zou et al. 2012; Zhou et al. 2013)

[2] (Ockerman and Basu 2009)

[3] (Huang and Lin 1999; Suyama et al. 1979)

[4] (González Olmedo et al. 2004). n/a: data not available

Chelydra serpentine (0.2%), *Eretmochelys imbricate* (0.65–1%) and *Chelonia midas* (0.4–1%) this value was low, and was maintained at values lower than 1%. In the *Pelodiscus sinensis* (1.2–10.6%) and *Trionyx sinensis* (0.41–4.9%) the fat content presented much more variation reaching even values of 10%. In the *Pelodiscus sinensis* varied between 0.35% and 8%, while the other species have values around 1%.

From the nutritional point of view, the fatty acid profile showed high variation. However, there is only information on the composition of fatty acids in *Pelodiscus sinensis* meat. The major fatty acids were MUFA (31–65%), followed by PUFA (3.2–30.1%) or SFA (23.2–26.3%) depending on the research. In this case, the essential fatty acids also presented very high variation; the C18:2*n*-6 content varied from 2.9% to 26.8% while C18:3*n*-3 content ranged between 0.3% and 3.3%. It is worth mentioning the high content of fatty acids with a high biological value such as C20:5*n*-3 (1.7–6.6%) and C22:6*n*-3 (3.7–8.1%). The ratio *n*-6/*n*-3 in *Pelodiscus sinensis* meat (0.73–1.54) remains within the internationally recommended values (<4).

Regarding the amino acids content, there are only information about the *Eretmochelys imbricate* and *Chelomnia mydas* meat. The results, expressed as g/100 g of lyophilized sample, showed that the major amino acids were lysine and leucine, followed by isoleucine, valine, histidine and arginine, with similar values. As occurs in fatty acids and amino acids, there is very little information about the mineral content of turtle meat. This meat presented low levels of iron, with levels that vary between 1.3 and 2.5 mg/100 g. In the case of turtles, except for the proximate composition, there is very little information on the composition of the meat, so it is necessary to continue researching this field to be able to clarify the goodness of this meat from a nutritional point of view.

13.5 Snakes, Lizards and Iguana

It is well known that several squamates, such iguana, lizards or snakes are important food source in some locally regions, being some of them considered as gastronomic delicacies (Cawthorn and Hoffman 2016). Figure 13.7 shows the main squamates species used for human consumption.

Mainly in America and Asia, iguanas and snakes are farmed for the consumption of their meat, while the lizard farming, such as the omnivorous tegu (*Tupinambis* spp.), is particularly high in Argentina, and the monitor lizards in Africa. However, the monitor lizards have the difficulty that they are carnivores, so their farming is considered difficult and economically low viable (Magnino et al. 2009). Figure 13.8 shows the global distribution of snakes, lizards and iguana.

The main objectives of snake farming are focused on the production of skin and meat, as well as obtaining venom. (Klein et al. 2007). Although the main interest of farming is for skin production, the meat is also harvested and highly prized as a delicacy (Magnino et al. 2009). The Reticulated python (*Python reticulatus*) and Burmese pythons (*Python molurus bivittatus*) are farmed in many Asian countries (Cawthorn and Hoffman 2016; Natusch and Lyons 2014). In USA are farmed some snake species for meat production, such as python and rattlesnakes (*Crotalus* spp.), for human consumption in USA, Mexico, Brazil and Europe (Cawthorn and Hoffman 2016; Klein et al. 2007). In Central Nepal, some commercial snake farms produce venom, meat and skins for the international market (Europe, Australia and other Asian countries). Python (*Python sebae*), cobra (*Naja nigricollis*) and adders (*Causus rhombeatus; Bitis* spp.) are harvested in Africa and some of which is traded

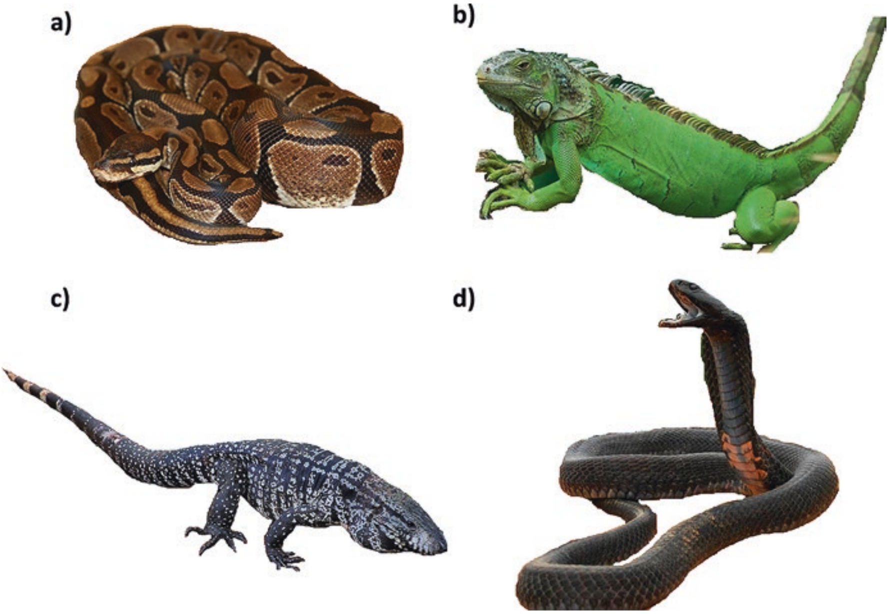

Fig. 13.7 Edible snakes and lizards: *Phyton regius* (**a**), *Iguana iguana* (**b**), *Tupinambis merianae* (**c**) and *Naja nigricollis* (**d**)

Fig. 13.8 Global distribution (wild and farm-raised) of snakes, lizards and iguanas

(Cawthorn and Hoffman 2016; Mbete et al. 2011). Finally, filesnake (*Acrochordus arafurae*) is a traditional food source for aboriginal Australians (Shine 1986) and the Boa constrictor (*Eunectes murinus*) and bushmaster (*Lachesis muta*) are eaten in Brazil (Alves et al. 2012).

On the other hand, iguanas have been served food source for more than 7000 years in part of Central and South America. The diet of iguanas consists mainly of fruit, in addition to leaves and flowers (Magnino et al. 2009). The iguana meat is consumed and distributed by many countries of Central and South America, among which are Panama, Costa Rica, Honduras, Guatemala, El Salvador, Nicaragua, Columbia, Venezuela, Peru, Paraguay and the north of Argentina (Klein et al. 2007; Saadoun and Cabrera 2008).

However, due to the destruction of its natural habitat and its excessive hunting, the population of iguanas was almost extinct in some countries. As a result of this, some countries have farmed iguanas to ensure their conservation and sell their meat for local populations. This population prefers the iguana meat before another type of meat (Magnino et al. 2009). The green iguana (*Iguana iguana*) and the black iguana (*Ctenosaura* spp.) are farmed from human consumption (Cawthorn and Hoffman 2016). In this case, as occurs with other reptiles, the products obtained from iguana are the meat and skin (Saadoun and Cabrera 2008).

Finally, with respect to lizards there are mainly 2 types of lizards that are used for their consumption. Tegu in America and Monitor in Africa and Asia. Tegu (*Tupinambis genus*) is a large South American lizard which are widely spread in regions with tropical to temperate climates such the south of Brazil, Argentina and Uruguay (Vega Parry et al. 2013). These lizards were traditionally hunted by indigenous communities for their meat, fat and skin (Caldironi and Manes 2006; Vega Parry et al. 2013). While these lizards continue to be taken from the wild for their skins and meat, farming of the species has been attempted in Argentina (Saadoun and Cabrera 2008). In this case, the main commercial cuts are back, leg and tail (Caldironi and Manes 2006).

Monitor lizards (*Varanus* spp.) inhabits in Africa, Asia and Oceania. In contrast to Tegu, the raise in captivity of Monitor lizards are considerably more difficult due they are carnivorous (NRC 1991). In West and Central Africa, Monitor lizards (*Varanus niloticus*), are harvested for bushmeat, some of which is traded (Cawthorn and Hoffman 2016; Mbete et al. 2011). The meat of Ocellated lizard (*Timon lepidus*) who lives in south western Europe including countries as Spain, Portugal, France and Italy were consumed in the past in the Iberian Peninsula. However, their deliberate capture, keeping, killing, trade and possession are nowadays prohibited (Klein et al. 2007). Finally, Australian Aboriginal communities traditionally consume certain species of lizards (Magnino et al. 2009).

In the Table 13.4 are presented the proximate composition, fatty acids, amino acids and minerals of the main species of edible squamates (snakes, lizards and iguana). The proximate composition obtained from iguana (*Iguana iguana*) and Tegu lizard (*Tupinambis merianae*) meat indicates protein levels between 18.8 and 23.6 g/100 g of fresh meat, while the protein content of snake meat was between 48 (*Phyton regius*) and 79.2 g/100 g of dry matter (*Naja nigricollis*). Regarding moisture content, fresh meat from iguana and Tegu lizard presented between 72% and 77.2%, while the values of ash ranged between 0.91 and 1.59 g/100 g of fresh meat. The ash content in snakes was 5.17–19.2 g/100 g of dry matter. Snake meat had between 3.62% and 6.35% of fat (expressed as dry matter), while the values obtained for iguana and Tegu lizard varied between 1.92% and 4.45%.

There are only data available on the content of iguana and Tegu lizard fatty acids. The content of fatty acids revealed that the major fatty acids were SFA (23.8–36.9%), followed by MUFA (35.6–50.9%) and finally PUFA (15.8–28.5%). The content of essential fatty acids such C18:2*n*-6 was 5.2% in iguana and between 17.3% and 22.7% in Tegu lizard, while the content of C18:3*n*-3 was 9% in iguana and about 1.4% in Tegu lizard. In this case, the contents of C20:5*n*-3 and C22:6*n*-3 were very low, and ranged between 0.02% and 0.6%. Regard *n*-6/*n*-3 ratio, the iguana presented values (0.53) within international recommendations (<4), due to the high content of C18:3*n*-3, while the values of this ratio in Tegu lizard were very high (15.3–17.2).

The amino acid content showed in *Naja nigricollis*, that the major amino acid was glutamic acid, followed by aspartic acid and then, leucine, lysine, arginine and alanine with similar values. However, in iguana meat, the major amino acid was the phenylalanine, followed by leucine, lysine and isoleucine. Finally, the iguana meat was characterized for their high level of K (193.8–1323 mg/100 g), P (217 mg/100 g) and Na (67.1–189.4 mg/100 g). In *Naja nigricollis*, the major mineral was P (161 mg/100 g), followed by K (71.6 mg/100 g) and finally, Ca (66.8 mg/100 g), Na (63.5 mg/100 g) and Mg (60.9 mg/100 g) with similar values. In *Phyton regius*, the major mineral was Na (699 mg/100 g), followed by Mg (480 mg/100 g), K (428 mg/100 g) and Ca (419 mg/100 g). The results obtained showed that squamates meat is nutritionally rich in protein, some valuable minerals and essential amino acids but low in fat. Therefore, it is nutritionally good for human consumption (Ogungbenle and Adaraniwon 2013).

Table 13.4 Proximate composition and nutritional characteristics of snake, lizard and iguana meat

	Phyton regius [1]	*Iguana iguana* [2]	*Tupinambis merianae* [3]	*Naja nigricollis* [4]
Proximate Composition	***g/100 g DM***	***g/100 g***	***g/100 g***	***g/100 g DM***
Moisture	5.22	73.1–77.2	72.0	6.36
Protein	48.0	18.8–20.8	23.6	79.2
Fat	3.62	1.92–4.45	4.0	6.35
Ash	19.2	0.91–1.59	1.2	5.17
Fatty Acids	***n/a***	***%***	***%***	***n/a***
C16:0	-	28.9	16.4–18.4	-
C16:1*n-7*	-	6.20	1.81–8.1	-
C18:0	-	7.00	5.14–16.4	-
C18:1*n-9*	-	34.9	33.2–42.7	-
C18:2*n-6*	-	5.20	17.3–22.7	-
C18:3*n-3*	-	9.70	1.33–1.41	-
C20:4*n-6*	-	0.10	0.51–7.90	-
C20:5*n-3*	-	0.10	0.11–0.60	-
C22:6*n-3*	-	–	0.02–0.09	-
SFA	-	36.9	23.8–35.84	-
MUFA	-	45.6	35.6–50.9	-
PUFA	-	15.8	25.9–28.5	-
∑ *n-6*	-	5.40	23.4–25.2	-
∑ *n-3*	-	10.1	1.53–2.1	-
n-6/n-3	-	0.53	15.3–17.2	-
P/S	-	0.42	0.79–1.09	-
Amino Acids	***n/a***	***mg/g N***	***n/a***	***g/100 g protein***
Lysine	-	590	-	5.81
Methionine	-	163	-	2.03
Threonine	-	468	-	3.15
Leucine	-	607	-	6.04
Isoleucine	-	553	-	3.20
Phenylalanine	-	705	-	3.67
Valine	-	334	-	4.33
Histidine	-	199	-	2.21
Serine	-	-	-	3.36
Arginine	-	349	-	5.09
Cysteine	-	-	-	0.79
Tyrosine	-	-	-	3.02
Alanine	-	-	-	4.90
Aspartic acid	-	-	-	8.90
Glutamic acid	-	-	-	12.3
Glycine	-	-	-	4.61

(continued)

Table 13.4 (continued)

	Phyton regius [1]	*Iguana iguana* [2]	*Tupinambis merianae* [3]	*Naja nigricollis* [4]
Proline	-	-	-	3.46
Minerals	***mg/100 g***	***mg/100 g***	***n/a***	***mg/100 g***
Ca	419	10.1–39.5	-	66.8
Mg	480	7.9–28.2	-	60.9
P	-	217	-	161
Na	699	67.1–189.4	-	63.5
K	428	193.8–1323	-	71.6
Fe	4.20	0.20–1.93	-	32.9

[1](Abulude 2007)
[2](Bressani 1977; Cortez 2016; Arenas de Moreno et al. 2000; Villamizar 2007)
[3](Caldironi and Manes 2006; Panella et al. 2003)
[4](Ogungbenle and Adaraniwon 2013). n/a: data not available

13.6 Conclusions and Future Trends

Exotic meats have served as an important source of protein for human populations around the world for many years. In fact, this type of meat represents a very important source of protein for those people who do not have access to domesticated animals. However, the massive capture and the increase interest and demand for exotic meats caused the overexploitation and placed many of this species on the verge of extinction. With this in mind, the captive rearing has been proposed as an alternative to the capture of wild animals.

On the other hand, the lack of hygiene and the poor rearing conditions of many exotic species can lead to health problems. In fact, most of the meat coming from amphibians and reptiles are often considered as a by-product, because the most valuable part of these animals are skins. Therefore, the manipulation of the carcasses for the extraction of the skins favour the contamination of the meat. Despite this, the fact of being able to market the meat of exotic species can turn the sector into economically more viable, makes this type of industries and farms grow and also supposes a new commercial possibility for those farmers of certain zones.

In this sense, it seems reasonable that the raising of exotic species is focused on a greater control of the hygienic conditions in the farms, as well as the quality of the water in the species reared in aquatic environments. Additionally, animal species suitable for human consumption should be transported live to abattoirs and processing plants so as to ensure that all operating procedures (slaughtering and processing) are met in hygienic conditions.

The main problem about the characterization of meat nutritional value from these exotic species is mainly that, despite being consumed in many regions, few scientific studies and very little data is available on the nutritional value of their meat. To this we must add that the rearing conditions are totally different in each study, or that animals come directly from their wild environment, so there is a great variety of factors that affect the composition of the meat, which makes it impossible to compare few studies that exist. Therefore, further investigations are needed focused on the characterization of these meats, fixing different parameters and, if possible, with species raised in captivity.

The nutritional characteristics of the exotic meats presented in this chapter show interesting aspects in comparison to the usual meat consumed. Most of these meats have high content of proteins, essential amino acids, fatty acids and minerals, with low fat content. Therefore, exotic meat is an interesting alternative to be considered as a component of the human diet. Additionally, the technological transformation of this kind of meat can open a new and very promising market. The rational and sustainable farming and use of exotic meat shows a very important potential to be considered in the economic development of many countries.

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