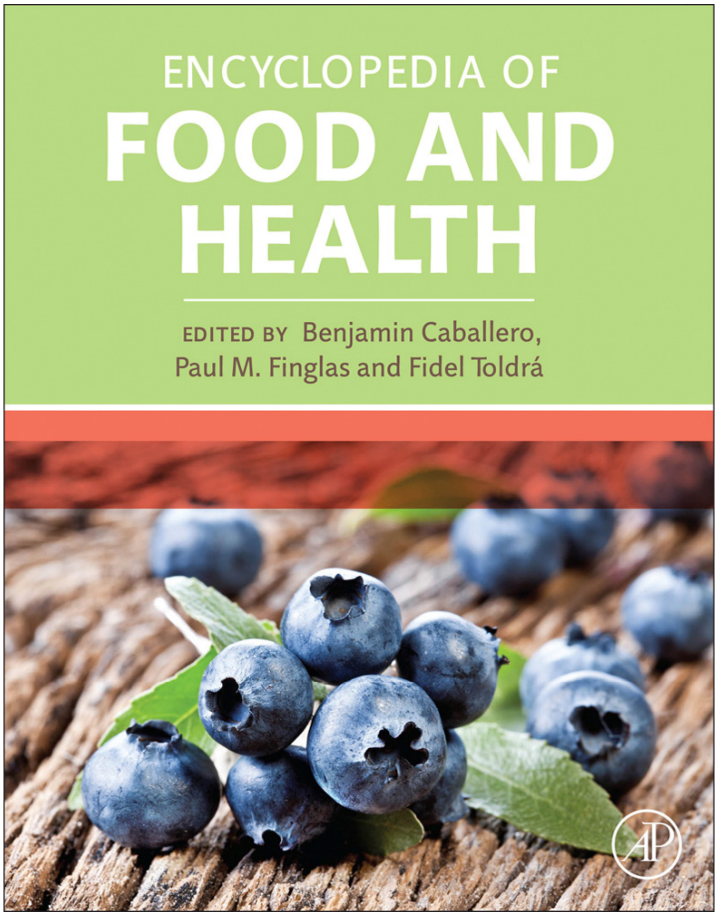




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# G

## Game: Types and Composition

**H Costa**, Instituto Politécnico de Bragança, Bragança, Portugal
**I Mafra and MBPP Oliveira**, REQUIMTE Universidade do Porto, Porto, Portugal
**JS Amaral**, REQUIMTE Universidade do Porto, Porto, Portugal; Instituto Politécnico de Bragança, Bragança, Portugal



### Game Meat

In a global sense, game refers to wild animals and birds, with the term 'game' being used for culinary purposes to describe all birds and animals that are hunted for food. In the European Union (EU), wild game is defined in the EU Regulation (EC) No. 853/2004 as being "wild ungulates and lagomorphs, as well as other land mammals that are hunted for human consumption and are considered to be wild game under the applicable law in the Member State concerned, including mammals living in enclosed territory under conditions of freedom similar to those of wild game, and wild birds that are hunted for human consumption." The same legislation also defines 'small wild game' as being wild game birds and lagomorphs (rabbits and hares) living free in the wild and 'large wild animals' as land mammals, living free in the wild that do not fall within the small wild game definition. In the United States, wild game refers to wild land mammals (including those living within an enclosed area under conditions of freedom) that are hunted and wild birds. Large native game animals in the United States include antelope, buffalo, caribou, deer, elk, moose, and reindeer, while game birds include wild turkeys, wild geese, wild ducks, grouse, quail, pheasant, and other nondomesticated species of fowl.

Around the world, a vast number of wild animals are harvested for several reasons including for food purposes and sport hunting, with the type and range of animals hunted depending on climate, animal diversity, tradition, local taste, legislation, and local perception on what can or cannot be legitimately hunted. For example, in Europe, the most frequent big game species include red deer, roe deer, fallow deer, mouflon, and wild boar, while in South Africa, the hunted game species are mainly several African ungulates including springbok (*Antidorcas marsupialis*), blesbok (*Damaliscus pygargus phillipsi*), and kudu (*Tragelaphus strepsiceros*), among other antelopes. Game meat consumption is also related to the consumers' acceptability, which is influenced by several factors including cultural, religious, and ethnic aspects, organoleptic characteristics, price, and availability, among others.

Nowadays, besides being hunted as free-running animals in the wild, originally, wild species of animals are being raised, domestically or semidomestically, for sale. Farmed game is used not only for meat production but also for animal breeding, aiming at their subsequent release into the wild for restocking the game population in private and community hunting areas. According to the EU Regulation (EC) No. 853/2004, farmed game is defined as being farmed ratites (such as ostrich) and farmed land mammals other than domestic bovine, porcine, ovine, and caprine animals and domestic solipeds (single-hoofed, e.g., horse). With the exception of farmed rabbits, which are often produced in intensive systems, most of the other farm-raised game (such as deer, reindeer, and wild boar) is generally farmed using extensive systems. In the United States, species such as the American elk, wild boar, pheasant, and antelope (blackbuck (*Antilope cervicapra*) and nilgai (*Boselaphus tragocamelus*)) are being farm-raised, while in Europe, in particular in northern countries, the most common farmed-raised animals are deer (including several different species such as red deer (*Cervus elaphus*) and fallow deer (*Dama dama*)) and reindeer (*Rangifer tarandus*). Deer production is also a well-established industry in New Zealand. To distinguish farmed-raised game from wild free-running animals, some authors proposed to designate the first as venison, associating the second as being African game antelope. However, the designation 'venison' is most frequently used as a culinary term referring to meat not only from deer but also from other cervids such as reindeer, elk, and moose.

Although production and consumption data for farmed game are scarce, according to the Food and Agriculture Organization (FAO) Statistics Division, game meat production has been steadily increasing during the last decade (from approximately 1.59 million tons in 2000 to more than 1.99 million tons in 2012), which can possibly be related to a general increased consumption of game meat.

In fact, in the last years, game meat is increasingly perceived as a delicacy product; thus, its consumption in restaurants and at home dinners has also been increasing. This can be explained by several different motivations including the perception that game meat is healthier, its particular taste and flavor, the idea that game meat can be considered as a biological product (free-running animals without the use of anabolic steroids and other drugs), and the attraction for new experiences such as tasting exotic meats.

### Game Meat: Sources and Production

Hunting has been practiced since ancestral times being one of man's main sources of food in prehistoric ages. Over millennia

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of civilization, with the development of agriculture and domestication of animals, the importance of hunting and game meat as a means of survival radically decreased in most parts of the world. Nevertheless, in the present time and particularly in developing countries, a variety of different wildlife species is still sought as food as they inevitably remain a cheap source of protein for many population groups. In Africa and other regions of the globe, such as the Amazon in South America, bushmeat (according to the Convention on Biological Diversity, bushmeat is a term used to describe any terrestrial wild animal in tropical and subtropical countries harvested for subsistence or commercial purposes) remains of major importance either for consumption or to obtain revenue from trade. Although some recent data have been published on the bushmeat consumption in some parts of the world, such as in South America where consumption in indigenous communities can attain values of 35.8 to 191.6 kg per capita year, the level of consumption is very difficult to estimate due to several factors, such as unreported data concerning harvested animals, direct sales, trade in hidden markets, and illegal poaching. However, it is generally accepted that in rural African areas, bushmeat continues to represent a vital dietary item for a vast number of people although high variations across the continent exist. Apart from being consumed by local populations, game meat is also frequently tasted by tourists who visit those regions, although this represents a minor percentage of the total game meat consumed.

During the last decades, the potential of African ungulates for meat production is also being taken into account for meat exportation, with different wild animals that roam in large enclosures being harvested for this purpose. In 2005, it was estimated that South Africa exported the deboned meat from 160 000 game carcasses, with commercially harvested antelope being predominately the springbok (*Antidorcas marsupialis*, >80%), blesbok (*Damaliscus pygargus phillipsi*), and kudu (*Tragelaphus strepsiceros*), while other species such as blue wildebeest (*Connochaetes taurinus*), impala (*Aepyceros melampus*), and gemsbok (*Oryx gazella*) were exported in smaller numbers. Nowadays, most of the game meat harvested in Africa for exportation is obtained from game ranches with the promotion of legal wild meat production through game ranching being advocated as a way to conciliate wildlife conservation, rural food security, and community livelihood improvement. With the evolution of wildlife management, recurrent droughts, and the rising demand for tourism and safari hunts, wildlife ranching industry has been increasing in countries such as Zambia, Zimbabwe, Botswana, and Namibia, being most developed in southern Africa. In game ranching, wild animals roam free and are managed on natural vegetation although they are generally maintained in defined fenced areas. The incomes of game ranching arise mostly from sport/trophy hunting and ecotourism, though animal culling for meat production also generates relevant revenue, being also important to simultaneously control animal surpluses.

In the past 50 years, the farming of different game species has grown considerably worldwide possibly related to a higher consumption of game meat as it is generally perceived as a healthy food with distinctive and appreciated organoleptic qualities. To respond to an increasing consumer's demand for venison, in some countries such as New Zealand, farmed deer production has advanced to a level where typical livestock farming is applied, thus assuring a regular supply of quality meat. In New Zealand, red deer is the major farmed species, accounting for about 85% of the total farmed deer, which nowadays corresponds to approximately 1.1 million animals. According to the European Food Safety Agency (EFSA) data, among the cervids, the fallow deer and the red deer are the most common species farmed in Europe, with approximately 280 000 animals farm-raised in 2010, although less than half of these are slaughtered annually. In some European countries (Sweden, Norway, and Finland) and in Alaska, venison production is dominated by traditional reindeer farming, which is generally performed in a less-intensive system when compared to red deer farming since the animals are free-ranging in the forests/mountains instead of being enclosed in fenced areas. The animals that pasture extensively in herds may belong to different owners, being recognized by specific cut marks on their ears. In the United States and Canada, different cervid species are being farm-raised including the elk (*Cervus canadensis*), the fallow deer, the sika deer (*Cervus nippon*), the axis deer (*Axis axis*), and the white-tailed deer (*Odocoileus virginianus*).

Regarding small game animals, as referred, rabbits are generally farmed-raised mostly using intensive systems, while hares are hunted in the wild. Several game bird species, including migratory birds such as geese and ducks, are also frequently hunted worldwide, with a small number of species, such as pheasants, also being breed in captivity for restocking hunting areas or for boosting natural populations.

## Chemical Composition of Game Meat and Nutritional Considerations

Nowadays, consumers are increasingly demanding for healthy and safe products as they are concerned about the food they eat. In general, consumers associate game to a healthier, thinner, and tasty meat arising from animals that are supposed to be free of hormones and drugs, such as antibiotics. In fact, game meat can generally be considered to be highly nutritious, as it is a valuable source of protein, minerals, and vitamins. Table 1 shows a compilation of data published on the proximate composition of different game meat. The values presented in Table 1 show that, considering the evaluated animals, protein contents are generally higher than 20%, with some species presenting levels around 25% protein. On the contrary, total fat content can be considered as being low, as it is generally inferior to 5%, with some species including different ungulates, lagomorphs, and game birds presenting levels less than 0.5% fat (Table 1).

Currently, it is of general agreement that total fat intake is certainly related to health risks; however, it is also accepted that concerning fat, both quantitative and qualitative aspects are important. Thus, the type of consumed fat or fatty acids is of critical importance. According to the 2010 FAO recommended dietary intakes for total fat and fatty acids, dietary fat should provide 20–35% of total energy and saturated fatty acids (SFA) should not exceed 10%. Individual SFA have different biological effects, with lauric, myristic, and palmitic acids increasing LDL cholesterol, while stearic acid is not considered to have such effect. Thus, the replacement of SFA (C12:0–C16:0) with polyunsaturated fatty acids (PUFA), whose consumption is

**Table 1** Proximate composition of meats from different game species (g/100 g; mean values are given)

| *Animal species* | | *Samples* | *Proximate composition (g per 100 g)* | | | |
|---|---|---|---|---|---|---|
| | | | *Moisture* | *Protein* | *Fat* | *Ash* |
| *Ungulates* | | | | | | |
| Kudu[a] | *Tragelaphus strepsiceros* | Longissimus dorsi muscle; males and females, total *n* = 18 | 74.14–74.49 | 23.60–24.30 | 1.56–1.58 | 1.23–1.29 |
| Impala[b] | *Aepyceros melampus* | 9th–10th–11th rib cut; males and females, total *n* = 8 | 70.2–74.0 | 18.9–20.0 | 1.2–4.3 | 4.4–4.6 |
| Springbok[b] | *Antidorcas marsupialis* | 9th–10th–11th rib cut; males and females, total *n* = 8 | 70.4–75.3 | 17.4–18.4 | 2.5–5.3 | 4.2–4.3 |
| Blesbok[c] | *Damaliscus dorcas phillipsi* | Longissimus dorsi muscle; 9th–10th–11th rib cut; males and females, total *n* = 73 | 68.20–75.33 | 19.30–22.43 | 0.21–6.8 | 1.24–4.2 |
| Common duiker[d] | *Sylvicapra grimmia* | Longissimus dorsi muscle; males, total *n* = 10 | 71.41 | 25.71 | 2.12 | 1.29 |
| Red deer[e] | *Cervus elaphus* | Longissimus dorsi muscle, total *n* = 10 | 76.90 | 21.70 | 0.60 | 1.11 |
| Fallow deer[e] | *Dama dama* | Longissimus dorsi muscle, total *n* = 10 | 74.90 | 22.00 | 2.50 | 1.08 |
| Roe deer[f] | *Capreolus capreolus* | Longissimus dorsi muscle; longissimus lumborum muscle, total *n* = 144 | 71.40–74.4 | 22.82–25.70 | 1.0–2.12 | 1.29a |
| Elk[g] | *Alces alces* | Longissimus lumborum muscle; total *n* = 8 | — | 22.72 | 1.33 | — |
| Mouflon[h] | *Ovis ammon* | Longissimus dorsi muscle between the 10th and 13th ribs; males, total *n* = 18 | 74.52–75.30 | 21.88–22.35 | 0.61 – 0.99 | 1.03 – 1.12 |
| Wild boar[i] | *Sus scrofa* | Longissimus muscle, 12th/14th rib; longissimus lumborum muscle; male and female; total *n* = 97 | 72.8 – 75.0 | 21.4 – 23.6 | 1.1 – 4.4 | — |
| *Leporidae* | | | | | | |
| Wild rabbit[j] | *Oryctolagus cuniculus* | Right leg, males and females, total *n* = 53 | 74.86 | 23.71 | 0.20 | 1.18 |
| Hare[k] | *Lepus europaeus* | Musculus longissimus thoracis et lumborum, total *n* = 33 | 72.83 | 24.7 | 1.48 | — |
| *Game birds* | | | | | | |
| Wild duck[l] | *Anas platyrhynchos* | Breast, total *n* = 5 | | | | |
| | | Legs, total *n* = 5 | 73.95 | 20.8 | 3.39 | 1.27 |
| | | | 74.9 | 19.6 | 3.84 | 1.27 |
| Quail[m] | *Coturnix japonica* | Musculus pectoralis major; males and females, total *n* = 144 | 73.60–73.65 | 22.94–22.96 | 2.31–2.32 | 1.56–1.57 |
| Pheasant[n] | *Phasianus colchicus* | Drumstick and breast, male, total *n* = 8 | 73.09–75.14 | 22.22–25.37 | 0.13–0.40 | 1.26–1.35 |
| Pigeon[o] | *Columba livia* | Breast and thigh, total *n* = 27 | 66.52–70.59 | 20.56–23.61 | 4.32–7.85 | 0.98–1.48 |

[a]Mostert and Hoffman (2007).
[b]Van Zyl and Ferreira (2004).
[c]Van Zyl and Ferreira (2004); Hoffman et al. (2008).
[d]Hoffman and Ferreira (2004).
[e]Zomborszky et al. (1996).
[f]Zomborszky et al. (1996); Strazdina et al. (2012); Dannenberger et al. (2013).
[g]Strazdina et al. (2012).
[h]Ugarković and Ugarković (2013).
[i]González-Redondo et al. (2010).
[j]Mertin et al. (2012).
[k]Cobos et al. (2000).
[l]Sartowska et al. (2014).
[m]Franco and Lorenzo (2013).
[n]Pomianowski et al. (2009).
[o]Strazdina et al. (2012); Dannenberger et al. (2013).

associated with health benefits, has been recommended for decreasing the LDL cholesterol and total/HDL cholesterol ratio and decreasing the risk of coronary heart disease. A similar but lesser effect could be achieved by replacing SFA with monounsaturated fatty acids (MUFA). Although the 2010 FAO recommended dietary intakes do not mention a specific n-6/n-3 PUFA ratio, a daily intake ratio of 4:1 and a ratio of PUFA to SFA above 0.4 have been suggested by different authors.

Table 2 presents the fatty acid composition reported for different game species, including ungulates (African ungulates and cervids), lagomorphs, and game birds. As can be observed, in general, game meat presents a favorable fatty acid profile, with some game meats presenting low levels of SFA and/or considerably high levels of PUFA. Total SFA ranged from 22.2% in duiker to 51.12% in impala, with several large game animals presenting higher levels of stearic acid than

**Table 2** Fatty acid composition of meats from different game species (relative %)

| Fatty acids (%) | *Animal species* | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Ungulates* | | | | | | | | | | | *Game birds* | | |
| | *Kudu*[c1] *(LDL*[a]*; n=18)* | *Impala*[c2] *(LD*[a]*; n=32)* | *Blesbok*[c3] *(LD; n=65)* | *Springbok*[c4] *(LD; n=19)* | *Common duiker*[c5] *(LD; n=10)* | *Mouflon*[c6] *(LD; n=18)* | *Red deer*[c7] *(ST*[a]*, TB*[a]*, LL*[a]*; n=34)* | *Roe deer*[c8] *(L, LL*[a]*; n=134)* | *Elk*[c9] *(LL; n=8)* | *Wild boar*[c10] *(LD, SM*[a]*, LL; n=104)* | *Wild duck*[c11] *(breast, legs; n=5)* | *Quail*[c12] *(PM*[a]*; n=108)* | *Pheasant*[c13] *(drumstick, breast; n=8)* | *Pigeon*[c14] *(breast, legs; n=27)* |
| C14:0 | —[b] | 1.10 | — | — | 0.75 | 0.93–2.63 | 4.57 | 0.8–1.32 | 2.44 | 0.8–2.92 | 0.27–0.70 | 0.872–1.017 | 0.52–0.53 | 0.54–0.92 |
| C16:0 | 16.1–17.5 | 16.66 | 16.36 | 13.34–15.06 | 0.86 | 16.10–20.87 | 21.02 | 16.4–18.72 | 18.08 | 19.2–23.12 | 16.8–20.4 | 17.34–18.51 | 22.30–25.19 | 21.14–23.62 |
| C16:1n7 | 0.52–0.69 | 0.35 | — | 0.03–0.2 | 18.58 | 1.03–1.45 | 6.66 | 1.95 | 4.35 | 4.27 | 0.94–2.22 | 3.45–3.69 | 5.66–5.82 | 7.27–11.25 |
| C18:0 | 19.7–20.0 | 22.67 | 26.08 | 23.92–27.02 | 19.68 | 15.78–16.42 | 14.46 | 15.63–20.8 | 13.56 | 10.8–14.54 | 10.2–18.6 | 9.91–12.11 | 8.99–10.89 | 6.03–10.63 |
| C18:1n9c | 19.91–21.9 | 12.22 | 16.97 | 16.33–20.45 | 18.7 | 22.42–25.09 | 17.51 | 16.3–26.15 | 27.89 | 28.0–33.9 | — | 24.63–25.71 | 35.95–37.63 | 30.42–50.84 |
| C18:2n6c | 19.0–20.5 | 14.70 | 18.39 | 18.77–21.62 | 19.91 | 13.50–19.31 | 12.34 | 11.62–16.4 | 6.90 | 11.7–20.9 | 13.5–29.4 | 24.47–27.68 | 15.81–17.87 | 7.30–15.96 |
| C20:0 | 0.11–0.20 | 0.21 | 0.30 | 0.28–0.40 | 0.81 | 0.12–0.14 | 0.06 | 0.02 | 0.08 | 0.09 | — | — | — | 0.00–0.17 |
| C18:3n6 | 0.05–0.08 | 0.28 | 0.06 | 0.09–0.15 | 0.12 | 0.05–0.06 | 0.14 | 0.07 | 0.04 | 0.03 | — | — | — | — |
| C20:1 | 0.06–0.10 | 0.5 | 0.05 | 0.08–0.12 | 0.23 | 0.40–0.47 | 0.13 | 0.04 | 0.04 | 0.24 | — | — | 0.17–0.20 | 0.10–0.34 |
| C18:3n3 | 4.67–4.85 | 1.92 | 3.71 | 3.33–3.49 | 4.19 | 2.02–3.02 | 3.31 | 3.94–4.00 | 4.77 | 1.3–1.46 | 0.76–1.5 | 0.827–0.97 | 0.44–0.45 | 0.17–0.59 |
| C20:2n6 | 0.12–0.15 | 0.49 | 0.04 | 0.22–0.28 | 0.29 | 0.08–0.09 | 0.1 | 0.07 | 0.45 | 0.26 | — | — | — | — |
| C20:3n6 | 0.92–1.14 | 0.72 | 1.60 | 0.20–0.24 | 2.94 | 0.30–0.37 | 0.32 | 0.35 | 0.2 | 0.14 | — | — | 0.09–0.13 | — |
| C20:4n6 | 7.74–8.44 | 9.80 | 10.00 | 7.63–9.30 | 7.83 | 6.24–8.42 | 4.25 | 5.00 | 4.59 | 2.02 | 5.35–17.6 | 6.63–7.703 | 4.51–4.85 | 0.01–4.03 |
| C20:5n3 | 2.50–3.17 | 1.37 | 2.24 | — | 2.1 | 1.30–1.49 | 1.36 | 2.03 | 0.95 | 0.39 | 0.26–0.86 | 0.40–0.41 | — | — |
| C22:4n6 | — | — | 0.26 | 0.21–0.37 | 0.31 | 0.18–0.29 | — | — | — | — | — | — | — | — |
| C22:5n3 | 2.42–2.75 | 1.94 | 2.23 | 2.19–2.71 | 1.14 | 1.68–2.14 | 1.29 | 1.87 | 0.72 | 0.84 | 0.5–0.88 | — | — | — |
| C22:6n3 | 2.06–2.5 | 1.05 | — | 0.94–1.26 | 1.09 | 0.44–0.47 | 0.2 | 0.39 | 0.32 | 0.08 | 1.07–2.44 | 0.09–0.10 | 1.21–2.75 | — |
| Total SFA | 35.9–37.7 | 51.12 | 43.59 | 38.40–42.69 | 22.24 | 35.20–42.24 | 42.13 | 40.9–42.13[c] | 35.75[c] | 32.8–41.76[c] | 28.4–37.52 | 28.12–31.64 | 34.05–34.92 | 28.29–34.43 |
| Total MUFA | 20.48–22.74 | 14.82 | 17.53 | 16.67–20.99 | 37.51 | 27.82–30.99 | 26.56 | 21.1–26.56[c] | 34.09[c] | 36.2[c]–42.2 | 16.5–24.0 | 30.01–31.59 | 42.57–44.03 | 45.23–62.56 |
| Total PUFA | 39.53–43.6 | 34.06 | 38.87 | 36.34–41.64 | 40.26 | 27.63–36.98 | 23.38 | 23.48[c]–37.7 | 18.99[c] | 17.26[c]–30.9 | 22.5–46.0 | 33.50–35.78 | 23.79–24.58 | 7.66–20.35 |
| PUFA/SFA | 1.09–1.23 | 0.73 | 0.92 | 0.96–1.18 | 1.81[c] | 0.70–1.08 | 0.68 | 0.68–0.92[c] | 0.53 | 0.41–0.94 | 1.07[c]–1.17[c] | 1.06–1.28 | 0.68–0.72 | 0.26–0.59 |
| n-6/n-3 | 2.29–2.42 | 3.76 | 3.68[c] | 2.83–3.44[c] | 3.55[c] | 1.05–1.48 | 2.75 | 2.07–2.8 | 1.72 | 4.81–8.7 | 8.98[c] – 10.0[c]- | 25.23–26.09 | 7.22–14.20 | 21.07–69.59 |

[a]Muscles: LDL, longissimus dorsi et lumborum; LD, longissimus dorsi; ST, semitendinosus tendon; TB, triceps brachii; LL, longissimus lumborum; SM, semimembranosus muscle.

[b]Not reported.

[c]Calculated based on the published values. (1) Mostert and Hoffman (2007), (2) Hoffman et al. (2009), (3) Hoffman et al. (2008), (4) Hoffman et al. (2007), (5) Hoffman and Ferreira (2004), (6) Ugarković and Ugarković (2013), (7) Strazdina et al. (2012), (8) Strazdina et al. (2012), Dannenberger et al. (2013), (9) Strazdina et al. (2012), (10) Strazdina et al. (2012); Dannenberger et al. (2013), (11) Cobos et al. (2000), (12) Sartowska et al. (2014), (13) Franco et al. (2013), (14) Pomianowski et al. (2009).

those of palmitic acid (the last considered as being potentially atherogenic while the former having neutral effects on health). In general, a high proportion of PUFA was reported for the species presented in Table 2, in particular for kudu, springbok, common duiker, and quail. Pheasant, pigeon, and wild boar were reported to present a higher level of MUFA than of SFA. In general, data reported for the different game meats evidenced desirable ratios of PUFA/SFA and n-6/n-3 PUFA. Ratios of PUFA/SFA ranged from 0.25 to 1.81, with all meats presenting ratios above the recommended value of 0.4, with the exception of some samples of pigeon. The high variability of values reported for some species could possibly be related to, not only different factors, such as diet, but also genetic origin, age, sex, region, and climate. A high proportion of n-3 PUFA is also evidenced by the ratios n-6/n-3 PUFA, which were below the recommended ratio of 4:1, with the exception of game birds and some wild boar samples (Table 2). For ungulates, high levels of the essential α-linolenic acid (ALA, C18:3n3) were reported, ranging from 1.92 to 4.85%. According to FAO recommendations, the minimum dietary requirement of ALA for adults to prevent deficiency symptoms is >0.5% of total energy, while a dietary intake of 0.250 g–2.0 g per day of n-3 long-chain PUFA eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) is recommended as part of a healthy diet.

## Other Health Considerations

### Microbiological Issues

The microbiological conditions of game carcasses and meat can vary widely. Carcasses from farmed game slaughtered and dressed at suitable abattoirs can present microbiological conditions comparable to that of carcasses from livestock, while those obtained from hunted animals will depend on several factors that can influence the possibility of carcass contamination and the potential growth of contaminating bacteria. These factors include the health of the animal, the types of microorganisms carried by each species (mainly on the hide and gastrointestinal tract), the circumstances in which the animal is killed, the conditions during evisceration in the field, the time before cooling, and the conditions under which the carcasses are transported, stored, and processed, among others. Currently, the vast majority of game, either hunted or farmed, is killed with a rifle or shotgun; thus, another important factor is the skill of the hunter as the anatomical shooting location is of critical influence for the carcass hygiene. For large game animals, such as deer, the hunters, generally, target the chest so the shot passes through the heart and lungs, though in deer culling, the animal is frequently shot in the head or neck to minimize the carcass damage. However, due to several reasons, such as the hunters' inexperience, the animal can be killed by shooting the abdominal area that can damage the gut, causing bacteria contamination. The skill of the hunter is also very important in the evisceration process to avoid damaging the gut.

Despite the increasing quality of hygiene standards in game meat harvesting and handling, human cases of infection can still occur. The relevant biohazards related to game meat, including parasites, bacteria, and viruses, can vary among countries according to the epidemiology and food consumption habits of each region. According to the EFSA Panel on Biological Hazards, *Salmonella* spp. in farmed wild boar and *Toxoplasma gondii* in farmed deer and farmed wild boar were recently ranked as a high priority for farmed game meat inspection, while *Trichinella* spp. in wild boar was ranked as low priority due to current controls, which should be continued.

Besides being a possible source of human infection due to foodborne diseases, wild game animals can also represent important reservoirs of zoonotic infections. In particular, due to wildlife contacts with domestic animals, there is an increasing concern regarding the possibility of disease transmissions.

### Exposure to Lead from Gunshot

The majority of game animals are killed by gunshot, with hunters generally using lead-based bullet or shot ammunition, especially for large game animals. Lead is a nonessential and toxic metal that adversely affects a wide range of systems in the human body, with some effects being observed at very low levels of lead in the blood (PbB), such as neurocognitive and neurodevelopmental deficits in children and elevated systolic blood pressure and chronic kidney disease in adults. Thus, game meat obtained from animals shot with this type of ammunition can be a potential source of dietary lead for humans, representing a potential hazard. Previously, there was a general belief that the dietary lead exposure from game meat would be low because the mass of the projectile(s) remained in one large piece that either passed through the carcass or was easily removed, the meat around the wound channel is generally removed and if fragments of ammunition were visible in the meat, they are also discarded during food preparation or, at the most, consumers avoid swallowing them. However, recent studies showed that game meat can contain small and numerous bullet fragments, visible in radiographs, which can be widely dispersed relative to the wound channel, with this being particularly noticed if bullets impact with the animal's bones. Hence, several authors have been suggesting that lead exposure from game meat can pose a potential health risk, in particular for high-level consumers, such as subsistence hunting communities and the hunters' families.

Following the request of the European Commission, EFSA recently produced a scientific opinion on the risks to human health related to the presence of lead in foodstuffs. In this report, the Panel on Contaminants in the Food Chain concluded that the provisional tolerable weekly intake (PTWI) of 25 μg $kg^{-1}$ b.w. dietary lead, previously set by the Joint Food and Agriculture Organization/World Health Organization Expert Committee on Food Additives (JECFA), was no longer appropriate as there was no evidence for a threshold for critical lead-induced effects. Based on data from different foods, game meat was among those that presented the highest levels of lead; thus, frequent consumers of game meat were included in the group with higher lead exposure levels. However, the impact of a specific diet, assuming a weekly meal of 200 g of game meat, did not appear to cause a greater risk regarding systolic blood pressure compared to other adult consumers. In general, the panel concluded that the risk of clinically important effects on either the cardiovascular system or kidneys of European adult consumers, at current levels of lead exposure, is low to negligible, but for infants, children, and pregnant women, there is a potential concern for effects on neurodevelopment. However, it should be highlighted that the panel also referred that the possibility of effects on some consumers having a diet rich in game meat could not be excluded. In fact, different studies have been pointing out an association between game consumption and lead levels in the blood, although a lack of correlation was observed in some cases.

## Adulteration of Game Meat and Processed Products

As referred, the consumption of game meat has been increasing in the last years. In general, game meat and products thereof are considered delicacy products and command higher prices compared to other meat products, thus being susceptible targets for frauds. Adulteration due to the fraudulent substitution of game by other lower-value meat species occurs mainly for economic reasons, with processed products being particularly prone to this type of unscrupulous practices. Therefore, the authentication of game meat and game meat products can contribute to avoid unfair competition among producers and to provide accurate information for consumers, being also important for safety and public health reasons, that is, in what concerns possible zoonoses affecting game animals and birds. So far, different methodologies, mainly relying on protein or DNA analysis, have been proposed for meat species identification purposes. However, in the last years, DNA-based methods have been elected for species identification as they present several advantages when compared to protein-based techniques, namely, the ubiquity of DNA in every type of cells, the higher stability of DNA molecules, and high specificity. Moreover, when evaluating processed meat products, protein-based methods present limitations, such as the possibility of protein denaturation and modification of specific epitopes associated with processing. Among DNA-based methods, polymerase chain reaction (PCR) is the most commonly used molecular technique due to its simplicity, fastness, specificity, and sensitivity. Until now, several different techniques have been proposed for verifying game meat and product authenticity, including species-specific PCR and real-time PCR, random amplified polymorphic DNA (RAPD) analysis, PCR–restriction fragment length polymorphism (PCR-RFLP) analysis, PCR sequencing, and DNA barcoding.

In RAPD, a DNA band pattern or fingerprinting is obtained by amplification using short arbitrary primers. The advantage is that species-specific patterns are generated without amplifying information about the gene fragments. However, it is difficult to obtain reproducible results and this technique is not suited for the identification of a targeted species in admixed meats or processed products. In PCR-RFLP, sequence variations within defined DNA regions are exploited to obtain characteristic restriction patterns. This technique has been proposed for the identification of different game meats with the successful identification of meats from closely related species, such as pork and wild boar meats. However, similarly to RAPD, this technique might not be applicable in complex and processed matrices since results may show a combination of miscellaneous restriction patterns that are difficult to understand.

Among the referred techniques, species-specific PCR is being increasingly used due to its simplicity, high specificity, and high sensitivity, being suitable for meat authentication studies, even in complex and processed foods. In this technique, a primary aspect consists of primer design targeting specific DNA fragments, which allows the specific identification of a target species in complex matrices containing a pool of heterogeneous DNA sequences. Even though the use of both nuclear and mitochondrial genes has already been described for the identification of game meat species, the latter offer the advantage of being several folds more abundant than nuclear DNA, thus improving sensitivity. More recently, quantitative analysis has been achieved by the use of real-time PCR since the target amplification is directly monitored along each amplification cycle. Data collection is performed by using fluorescent molecules able to provide a strong correlation and to measure minute amounts of DNA. Fluorescent compounds used in real-time PCR approaches for game meat identification include general dyes that intercalate DNA molecules, such as SYBR Green and EvaGreen, and different probe-based systems such as hydrolysis TaqMan probes. The use of dyes offers a suitable and less expensive alternative, while the use of probes that specifically bind within the target sequence adds specificity to the reaction and generally permits the use of smaller amplicons, which is especially useful for processed foods.

Although still few works report its application, DNA barcoding has emerged in the last years as a promising tool for the authentication of meats and meat products including game. In the near future, it is expected that newly and advanced technologies for high-throughput sequencing, namely, next-generation sequencing (NGS), coupled with DNA barcoding, can be applied to meat species identification, allowing the simultaneous identification of multiple species in complex matrices.

In spite of the utility of DNA-based methods in species identification for authenticity purposes, the majority of published works are devoted to the development of techniques with fewer referring to its application. Although some studies reported that several commercial processed meat products evaluated for authenticity purposes were in good agreement with the labeled game species, recently, other works reported a high incidence of species substitution and mislabeling in game meat products sold in different countries. These recent results suggest the existence of fraudulent practices, thus evidencing the importance of control and inspection programs and the need for systematically verifying labeling statements.

*See also:* Authenticity of Food; Ethnic Foods; Fatty Acids: Essential Fatty Acids; Protein: Food Sources; *Salmonella*: Properties and Occurrence.

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