Chapter

# Nutritional Composition of Game Meat from Wild Species Harvested in Europe

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## Abstract

A discussion about the nutritional composition of game meat, with specific focus on wild species harvested in Central and Mediterranean European countries has been conducted. Given the wide range of species, and the climate and vegetation differences among the harvesting areas, game meat shows heterogeneous characteristics and chemical composition, the latter being also affected by sex, age, body condition, physiological and sexual status, and hunting period. However, there are similarities which make it clearly distinguishable from livestock meat. When considering the most consumed species (red and fallow deer, wild boar, hare and wild rabbit), their meat has low fat content (<3 g/100 g for large and <4 g/100 g for small wild game species), high protein content (20–26 g/100 g) and low energy content (90–113 kcal/100 g). Wild game meat has a healthier fatty-acids profile compared to other meats, showing a higher proportion of PUFA, especially *n*-3, and consequently more favorable PUFA/SAF ratio. Wild ruminants' meat shows a favorable *n*-6/*n*-3 ratio (lower or close to 4). It has a high content of K, followed by P and micro-minerals such as Zn and Fe, together with B-group vitamins and vitamin E. Game meat from wild species harvested in Europe can diversify the market being an alternative to others red meats owing to its nutritional quality and organoleptic characteristics.

**Keywords:** game meat, chemical composition, fatty acid profile, cholesterol, vitamins, minerals, health, nutrition

## 1. Introduction

During the last decades game meat demand has increased in Europe, mainly because consumers perceive this meat as "natural and sustainable". Animals are free range, fed mainly with natural food (i.e. pasture) and their meat is free from hormones, antibiotics and other products. Meat from wild game species, meets animal welfare ethical standards, and the rearing of the animals in the wild has a lower or null impact on the ecosystems when compared to farmed species [1–3]. Therefore, consumers perceive this meat differently from traditional meat derived from domestic species, being a seasonal product that is available in fresh during the colder seasons [1], but also consumed in other seasons after being frozen or as cured meat, including specialities such as *cecina, salchichón, chorizo,* and conserves and pates. European consumers consider game meat as innovative food and are willing to pay a higher price [2], and they are likely to increase its consumption provided that it will have a higher quality and greater commercial availability [3].

However, game meat consumption is still very low in Europe, as only 2–4% of the population consumes this type of meat regularly [4]. This can be explained by its high price, seasonal availability, the lack of habit of using recipes with game meat among consumers not related with hunting, and even safety concerns [5]. As pointed by a recent study [6], the lack of knowledge on hunting may hamper game meat consumption, as hunters and their relatives show higher rates of consumption compared to people not familiarized with this activity [5]. Thus, when aiming to increase the intake of game meat and its derived products, information should be provided to sellers and consumers about the role of hunting on wildlife conservation and rural economy, but also on the nutritional quality of game meat and its possible inclusion in a balanced and healthy diet. In this way, the European Union (EU) is promoting the consumption of game meat in some countries through the program "European wild meat, nature at its purest" [7]. In France, about half of the game meat producers promote the "French game meat brand", with a strong promotion campaign targeting mainly chefs and consumers, highlighting the meat quality and its gastronomic potential [8]. In Spain, the National Association of Game Meat Producers (ASICCAZA) is conducting a programme to increase the game meat profile among consumers [9].

Meat from game species can be produced from farmed or wild animals. In some countries such as New Zealand, Australia, China and Canada, meat from farmed game is considered as an important meat subsector, and the rearing of farmed game is also growing in European countries. However, hunting of wild game remains as an important activity in Europe, including ungulates, lagomorphs and birds, being this the case of Spain, where approximately 20,000 tons are produced each year, with an estimated value of 45 million € [10].

Regulation (EC) No 853/2004 considered wild game meat as meat obtained from wild birds, ungulates and lagomorphs, as well as other land mammals that are hunted for human consumption, including animals living in enclosed territory under conditions of freedom similar to those of wild game. Among the most hunted species in Europe are wild ungulates, including red deer (*Cervus elaphus*),

**Figure 1.**
*Main wild game species harvested in Central and Mediterranean European countries.*

fallow deer (*Dama dama*), roe deer (*Capreolus capreolus*) and wild boar (*Sus scrofa*), together with birds such as ring-necked pheasants (*Phasianus colchicus*), partridges (*Alectoris spp., and Perdix spp.*), waterfowl and wader species but also mammals such as wild rabbit (*Oryctolagus cuniculus*) and hares (*Lepus spp*.) (**Figure 1**). Meat from the majority of hunted species can be legally sold in the European marked, as long it has passed a proper official *post-mortem* inspection at game-handling establishments as cutting plants, as specified with the European regulation (EC) No 853/2004.

## 2. Factors affecting chemical composition and characteristics of wild game meat

As game meat is produced from different groups of species (birds and mammals), and from different species within the same taxonomic category, there are considerable differences on quality attributes, including physicochemical and sensorial characteristics, together with microbiology, making game meat a heterogeneous product. In addition, quality attributes can be difficult to standardize and control since game meat from species hunted in the wild is affected by several *ante-mortem* and *post-mortem* factors.

### 2.1 Ante-mortem factors

Several *ante-mortem* factors affect chemical meat composition, including specie, sex, age, body condition, muscle type, hormone levels, site, climate, harvesting period and type of hunting [11, 12].

In Europe, hunting is practised all over the continent; hence a same species can be harvested in different environmental conditions, which implies different climate and habitat resulting in differences on types of food and its availability. However, for the majority of game species, hunting periods are extended from late summer to early spring (the coldest period of the year), and in all cases out of the breeding season. Hunting targets adults and juveniles (the latter in small game species), both males and females, which may have eaten natural or supplemented food depending on the location, as in many parts of Europe (especially the Mediterranean basin), there are extended periods of drought.

The different types of hunting may affect to meat quality. For example, driven hunting using dogs induce high levels of stress compared to stalking, in which the animals are often shot while being motionless. Other factors, such as hunting at day or night, with a rifle or a bow, may affect meat quality through different stress levels [13]. High stress levels before the animal being shot/captured, cause a higher consumption of muscle glycogen before the death of the animal, resulting in less *post-mortem* lactic acid generation from depleted glycogen reservoir [14], and affecting the pH meat value. An appropriate decrease on pH, and a final value ranging 5.5–5.7 [15], allows the meat to reach the desired color, tenderness, water retention capacity and other technological characteristics for transformation into meat products.

### 2.2 *Post-mortem* factors

After the death of the animal, the process to obtain meat in the field and the characteristics of the cutting plant varies depending on the location, as not all European countries have standard operating procedures. In fact, there are significant differences among countries in dressing the meat, the period of time from death to meat refrigeration, refrigeration temperatures, the type of vehicles used to transport the meat to the cutting plant/slaughterhouse, the maturation process which allows reaching the desired texture and flavor, and also the packing and storing system. All these factors affect the physicochemical, microbiological and sensory quality of game meat.

With regard to small game, after being shot, animals are usually kept unskinned and uneviscerated, and are hung in a cool, dry place until transportation to a game dealer or cutting plant. However, the majority of small game is generally kept by the hunters for personal consumption, and only a small proportion is sold.

In large game species, the evisceration is carried out by the hunter or the staff of the hunting ground. The interval from death to evisceration varies and little attention is paid to the environmental conditions in which hunting takes place, which may seriously undermine meat quality. The interval and the prevailing conditions between hunting and transport of the eviscerated carcass (previously approved by a veterinary inspection), to the cutting plant in refrigerated trucks also varies considerably. Finally, cutting plant managers often overlook the optimum conditions for carcass aging for a given species, which currently takes place over a wide range of temperatures and times, using different carcass ripening methods (mainly skinned *vs.* unskinned) [16].

The implementation of standardized procedures in the field and cutting plant, are needed to ensure safety, quality and traceability of game meat.

## 3. Nutritional composition of wild game meat

The macronutrients, micronutrients, cholesterol content and fatty acid profile for the meat from the most important hunted species in Central and Mediterranean European countries are described below. Existing literature from areas where hunting is very popular has been reviewed. Those areas are located at the countries: Italy, Spain, Portugal, Greek, Poland, Hungary, Romania, Croatia, Germany, Slovenia, Czech Republic, Slovak Republic and Republic of Lithuania. Only studies dealing with wild game (no farmed) have been cited, including animals harvested from late summer to spring, adults and juveniles, males and females.

### 3.1 Proximate composition

In **Table 1**, the proximate composition and energy content of meat from large wild game species is shown: wild red deer (*Cervus elaphus*), fallow deer (*Dama dama*), wild boar (*Sus scrofa*), and small game: brown hare (*Lepus europaeus*) and wild rabbit (*Oryctolagus cuniculus*), which have subject to a higher number of studies in Europe. The energy content has been calculated using the protein and fat content, following Regulation (EU) No 1169/2011. **Table 1** shows range of mean values or mean value when only one study available, found for the most studied parts of the carcass, loin and legs.

#### *3.1.1 Large wild game*

The most studied part of the carcass of red deer and fallow deer is the loin, both the whole *longissimus thoracis et lumborum* muscle (sometimes referred as *longissimus dorsi*) or its two parts (*longissimus thoracis and longissimus lumborum* muscles), with research also studying the legs (*semimembranosus, semitendinosus and triceps brachii* muscles). Generally speaking, the composition of both parts is similar, hence deer meat (red and fallow deer) has a high protein content ranging 20.5–22.8%, which confirms that is a relatively rich source of proteins and aminoacids [11]; and

| | | Moisture (g) | Protein (g) | Fat (g) | Ash (g) | Energy (kcal) |
|---|---|---|---|---|---|---|
| **Red deer** [17–21] | Loin | 75.22–77.11 | 21.41–22.20 | 0.10–0.96 | 1.10–1.34 | 90–98 |
| | Legs | 77.90 | 20.50–21.50 | 1.00–1.72 | 0.98 | 91–101 |
| **Fallow deer** [22–24] | Loin | 74.30–75.40 | 21.80–22.80 | 0.30–0.89 | 1.07–1.10 | 91–96 |
| | Legs | 74.70–75.50 | 21.90–22.60 | 0.41–0.81 | 1.01 | 94–95 |
| **Wild boar** [12, 25–32] | Loin | 70.50–74.72 | 21.24–25.87 | 0.69–2.80 | 1.03–1.26 | 101–117 |
| | Legs | 71.28–76.74 | 19.71–23.73 | 1.30–2.80 | 0.88–1.05 | 95–111 |
| **Hare** [33–36] | Loin | 72.48–75.15 | 21.53–25.30 | 1.23–2.73 | 0.98–1.27 | 100–112 |
| | Legs | 74.35–75.43 | 20.28–21.58 | 1.79–3.23 | 0.97–1.27 | 102–110 |
| **Wild rabbit** [37] | Loin | 75.35 | 22.05 | 1.55 | 1.00 | 102 |
| | Legs | 75.08–75.55 | 20.28–21.43 | 2.26–3.48 | 1.02–1.09 | 106–113 |

**Table 1.**
*Range of mean values (or mean value when only one study available) of proximate composition and energy content (per 100 g) of game meat from wild species hunted in Europe.*

a low fat content between 0.1–1.7%. The loin is the part with less fat content (<1%). It is well documented that fat content of game meat as a high variability as it may be affected by several factors, including climate [22, 38], sex and age [20–22], feeding regime and season [22, 23, 39], physiological and sexual status [40], and hunting period [41].

In the wild, fat content is mostly influenced by seasonal variations, nutritional and sexual status, and available vegetation. Deer species, especially those living in the wild, are known to have seasonal body condition changes, which allows speculation about seasonal variation of meat composition. Usually, body condition is at its highest at the beginning of winter and at its lowest at the beginning of spring [28], and consequently the fat content is higher in winter compared to autumn and summer [22, 41]. But this variation is influenced by the species, winter severity and population density [28, 29]. In addition, in several deer species a decrease in body weight has been recorded for adult males during the rutting season [29], while for adult females the recovery of body condition during summer may be limited by the cost of lactation [29]. The meat energetic value (calculated per 100 g) ranges from 90 to 101 kcal in red deer, and 91.5–96 kcal in fallow deer. These values are lower than beef, pork, lamb or poultry meat, whose energetic value range from 114 to 231 kcal/100 g of muscle tissue [30] owing to the higher fat content of these meats. Ash content is very similar for both deer species and in all muscles (range of mean values from 1 to 1.3%).

When comparing meat from wild and farmed deer, there are contradictory results; higher fat content has been found in wild fallow deer compared to farmed, and similar or slightly higher values have been found in farmed red deer compared to wild ones [11].

The wild boar is a generalist omnivore, which is able to eat a wide range of food items, hence its diet varies according to resources available. It has a broad geographic distribution that include arid zones (semi deserts), wetlands, high mountain environments, forest and farmland ecosystems [25], which ultimately affect to the meat chemical composition. The proximate composition of loin (*longissimus thoracis et lumborum* and *longissimus thoracis*) and legs (*semimembranosus* and *teres major*) from European wild boar shows a high protein content (21.2–25.9%) and a low fat content (0.7–2.8%). The influence of some factors on wild boar meat has been studied, and the most significant are: (i) the available food in the hunting grounds which finally determines meat composition, outstanding fat and protein content. In this way, a higher fat content has been found in wild boar meat from fenced hunting grounds, in areas where cereals are supplemented and in cultivated forest compared to areas/hunting grounds where only natural food is available [25, 31, 32, 42–44]; (ii) age, as when compared to juveniles, meat from adults has higher content of fat and protein, and lower water content [33, 43, 44]; (iii) the carcass weight, as there is a positive correlation between the protein content and the carcass weight [34]; (iv) the hunting period, because it has been demonstrated that the highest content of intramuscular fat is reached in wild boar harvested in winter compared to spring and summer, probably owing to the higher amount of available food from cultivated crops [35]. Interestingly enough, sex has no significant effect on meat proximate composition [31], though a study [44] found that younger females generally showed a higher content of protein than males, and another one observed a higher content of protein in meat from males [12]. Among the different components studied, the ash content is the less influenced and more constant [44] with mean values ranging 0.9–1.3%.

When comparing the macronutrients content of wild boar meat to pork, the main difference is the lower fat and higher protein content of wild boar meat [25]. Thus, the mean values in pork loin are 4.6% for intramuscular fat and 21.4% for protein content [12, 25, 26, 34, 42, 43]. One study has reported that the mean fat content of wild boar meat was 5.3%, being similar to pork [23].

*3.1.2 Small game*

Wild rabbit and hares are herbivorous consuming a great variety of plants, including herbs, grains, and fruits. The type and abundance of these plants vary depending on the season and from one area to another, which may cause large variation in the composition of their meat [36]. There are very few data available regarding the nutritional composition of wild hare and rabbit in Europe; in fact, only one study has been found investigating wild rabbit meat harvested in Spain [37]. The proximate composition has been evaluated in different pieces such as loin (*longissimus thoracis et lumborum*) and legs (*semimembranosus* and *triceps brachii*). For both rabbits and hares, legs have a slightly higher fat content and lower protein content compared to loin, showing an overall a high protein content (20.3–25.3%) and low fat content (1.2–3.5%), resulting on an mean energetic value of 100–113 kcal/100 g. Although the meat composition of both lagomorphs harvested in Europe is similar, more research is needed to confirm this point.

Considering the variability for each of the parameters mentioned above, it is clear that the available food where animals are harvested has a significant influence on meat composition. On the other hand, some studies have found that several factors influence protein and fat content, and consequently energetic value, the most important being: (i) sex, as meat from females has a higher fat content and lower protein content [45, 46]; (ii) the hunting period, with higher fat and protein content in winter compared to spring [47]; (iii) muscle type, with a higher fat content in the legs compared to the loin [37, 46].

Several studies have compared meat from hares and domestic rabbit [45, 48], showing that domestic rabbit have a higher fat content (2.6–3.0%) and a lower protein value (21.5–22.2%). When the same diet is provided to farmed brown hares and domestic rabbits, a higher protein content is found in hare meat [48].

The comparison of the proximate composition of meat from wild and farmed brown hares, has found similar or slightly higher fat and mineral content in farmed hares [48–50].

Although meat from wild rabbit and hare provides a balanced content of macronutrient, these meats are not as popular as the consumption of other domestic meats, because of their dark red color, characteristic strong flavor, compact texture and dryness [51].

No complete studies have been found on the chemical composition of game birds, so more research is needed for these species.

In summary, the main characteristics of proximate composition of game meat from wild species are: low fat content and caloric value, together with high protein content, which may contribute to a healthy diet and a good "marketing strategy" [52].

### 3.2 Fatty acids composition

It is widely accepted that both the amount and the structure of fatty acids (FA) play a major role in human health. Moreover, the FA composition is more relevant than fat content for human nutrition. There are four inter-related factors that have important health implications: (i) the total fat content; (ii) the distribution of specific FA; (iii) the ratio of polyunsaturated fatty acids and saturated fatty acids (PUFA/SFA); (iv) the *n*-6/*n*-3 FA ratio [53]. Each of these factors has been shown to influence the development of coronary diseases.

According to the health authorities it is recommended to decrease the intake of fat, SFA, *trans*-FA and the *n*-6/*n*-3 ratio, and to increase the intake of MUFA (monounsaturated fatty acids) and PUFA [54]. SFA are regarded as the main cause of cardiovascular diseases as they increase blood pressure and the concentration of the "bad" LDL (low-density lipoproteins) serum cholesterol concentrations, while MUFA and PUFA decrease the concentration of the "bad" LDL cholesterol and increase the concentration of the "good" HDL (high-density lipoproteins) cholesterol which results in reducing the risk of heart diseases and atherosclerosis [55]. The *n*-3 PUFA decreases serum triacylglycerols, while lowering thrombic tendencies and reducing the incidence of ventricular arrhythmias [56]. Today, the *n*-6/*n*-3 ratio in human diets is often over 10 (the recommendation is $<4.0$), indicating the deficiency of beneficial *n*-3 FA in our diets [52]. On the other hand, the PUFA/SFA ratio recommended by the British Department of Health [57] is a minimum of 0.40 to contribute to a reduction in the risk in coronary diseases in humans.

As said before, game meat is lean, with a low content of intramuscular lipids, which are primarily composed of triglycerides (neutral lipids) and phospholipids (polar lipids) with polar lipids being the less saturated. The intramuscular fat composition is related to the fat amount, because a higher fat content results on changes in FA, with a higher content of neutral lipids which tend to be more saturated [58].

In **Table 2** a review of the range of mean values found in the available literature for the total content of SFA, MFA, PUFA, *n*-6 and *n*-3 FA, are shown, and also the PUFA/SFA and the *n*-6/*n*-3 ratios for the intramuscular fat of different muscles of loin (*longissimus thoracis et lumborum*, *longissimus thoracis* and *longissimus lumborum*) and legs (*semimembranosus, semitendinosus, psoas major* and *triceps brachii*).

#### *3.2.1 Large wild game*

The range of mean values for the total amount of FA and their ratios found in wild game meat harvested in Europe are quite wide. In general, in wild red deer meat the most important are SFA, closely followed by PUFA, whereas fallow deer shows a higher amount of SFA followed by MUFA. However, only one study is available for fallow deer [58] harvested in Poland hence there is lack of studies. Considering

| | Red deer [17, 19, 59] | | Fallow deer [24] | Wild boar [26, 42, 43, 60–64] | | Hare [46, 48] | Wild rabbit [36] |
|---|---|---|---|---|---|---|---|
| | **Loin** | **Legs** | **Loin** | **Loin** | **Legs** | **Legs** | **Loin** |
| **SFA** | 30.4–38.2 | 35.6–43.3 | 55.4–63.1 | 31.6–44.7 | 28.5–40.1 | 33.7–35.1 | 28.8 |
| **MUFA** | 15.3–22.7 | 22.1–37.2 | 25.7–29.4 | 30.2–46.8 | 27.8–50.4 | 17.5–21.8 | 13.6 |
| **PUFA** | 37.6–50.1 | 25.5–37.4 | 11.2–14.9 | 17.3–30.5 | 14.7–25.5 | 41.5–45.5 | 39.7 |
| **PUFA/ SFA** | | 0.44–1.09 | 0.18–0.27 | 0.38–0.84 | 0.52–0.62 | 1.20–1.89 | 1.38 |
| *n*-**6** | 30.2–38.2 | 18.7–29.3 | | 15.7–28.0 | 17.8–24.0 | 39.3–41.1 | 28.8 |
| *n*-**3** | 7.2–11.7 | 4.6–8.1 | | 0.9–5.7 | 1.4–6.2 | 2.0–4.4 | 9.2 |
| *n*-**6**/*n*-**3** | 3.5–4.3 | 2.6–4.8 | | 3.1–22.3 | 3.0–17.6 | 14.2–25.1 | 3.8 |

**Table 2.**
*Range of mean values (or mean value when only one study available) of fatty acids profile (g/100 g total fatty acids) of intramuscular fat from game meat from wild species hunted in Europe. SFA: Saturated fatty acids; MUFA: Monounsaturated fatty acids; PUFA: Polyunsaturated fatty acids.*

all studies conducted on wild red deer, the *n*-6/*n*-3 ratio has shown values lower or close to the recommended maximum value of 4.0 [17, 19, 59] and PUFA/SFA values slightly higher than 0.40, from 0.44–0.49 [59] or slightly higher, from 0.63–1.09 [17], which is healthier. For fallow deer, this ratio was lower owing to the higher SFA content and lower PUFA content. Wild boar shows a higher amount of MUFA compared to ruminants, as shown in the majority of studies [42, 43, 59–63], and a higher *n*-6/*n*-3 ratio, between 6.9 and 17.0 which is 2 to 4 times above the maximum nutritional recommended ratio of 4.0, hence less favorable. Only a study carried out in Poland, shows lower values in wild boar loin and legs, ranging between 3.0–4.7 [26]. The majority of studies on wild boars harvested in Europe show PUFA/SFA ratios above the minimum ratio of 0.40 recommended to reduce the risk in coronary diseases in humans [60, 65].

Regarding to the FA in large game, all studies show that the most abundant are palmitic (C16:0), stearic (C18:0) and oleic (C18:1), as shown for domestic animals [66]. In general, game species contain high amounts of the long chained (C > 20) unsaturated fatty acids [67], which are healthful [68]. It is important to highlight the high amounts of arachidonic acid (C20:4 *n*-6), which can be explained by the phospholipidic origin of this fatty acid and the fact that wild animals meat is leaner than that of domestic animals [69].

In wild red and fallow deer, the FA composition is mainly influenced by the food composition despite the biohydrogenation of PUFA in the rumen. The intake of pasture produces a more favorable *n*-6/*n*-3 ratio compared to feed [68–70], which is attributed to the higher α-linolenic acid (ALA, C18:3 *n*-3) content in the grass, while the linoleic acid (C18:2 *n*-6) can be found in feed, and both are present primarily in the phospholipid fraction of deer intramuscular fat [17, 70]. Thus, it can be said that feed provided to farmed deer increases the total fat and SFA content, and decreases PUFA content, especially *n*-3 PUFA [53, 71–73]. Wild deer meat is generally speaking, a relatively good source of *n*-3 PUFA due to the presence of ALA in pasture. The high values of ALA found in red deer and fallow deer meat may be the consequence of the very low content of intramuscular fat, as well as the fact that both species are grazers.

Together with food, other factors may affect the FA profile as age, sex, area of harvesting, among others [74]. For example, meat from stags show a higher PUFA concentration than hinds in both red deer and fallow deer [58, 59, 75], and consequently the PUFA/SFA ratio is higher in the stags' meat. Regarding to the effect of age, younger animals show a higher PUFA content than older ones [19], probably due to higher intramuscular fat amounts in older animals and different relative contents of triacylglycerol and phospholipid fractions in muscle lipids. Meat from older animals shows higher n-6/n-3 ratio (> 4.0) [19], hence less healthy.

The comparison of meat from wild deer with other red meats from domestic animals, reveals a high content of PUFA, being deer meat particularly rich in C18:2 *n-6*, C18:3 *n-3* and C20:4 *n-6*. In this way, the content of C18:3 *n*-3 (ALA) in venison is markedly higher than in cattle breeds [70, 76–78]. On the one hand, red deer meat has a more favorable fat composition compared to grain-fed beef, showing a lower amount of SFA (2–3 times lower), a higher content in long-chain *n*-3 PUFA and healthier PUFA/SAF and *n*-6/*n*-3 ratios [53]. The practice of adding C18:2 *n*-6 to grain provided to cattle reduces the concentrations of *n*-3 PUFA, while simultaneously increases the concentrations of *n*-6 PUFA [53]. On the other hand, in deer meat conjugated linoleic acid, CLA (C18:2 *cis*–9 *trans*–11 isomer), has been found, an element which has been shown to be a cancer inhibitor that provides significant protection according to several models of carcinogenesis, especially in diets with a high intake of dairy products and beef, the highest known food sources. CLA may also reduce the progression of atherosclerosis via its strong antioxidant property [79], though deer meat has a lower CLA amount compared to meat from domestic ruminants [59].

In contrast to ruminants, double bonds of FA are not hydrogenated during digestion in wild boar. Similarly to other monogastric animals, the FA composition of wild boar's meat is strongly related to diet [25], as the FA profile varies depending on whether the animals eat only natural resources or are supplemented, the latter a quite widespread practice conducted by managers during harsh winter periods. In the wild, wild boars eat a great variety of indigenous plants, including grain, seeds, roots, fruits, insects, earthworms, slugs and also small mammals and carrion, though the bulk of food consumed consists of plant material [80]. Higher amounts of SFA have been found in wild boars supplemented with feed compared to those not supplemented [31], in which a higher content of *n*-3 was found [81]. In addition, the habitat influences the intramuscular FA, so wild boar meat from forest dominated habitats has a higher PUFA *n*-3 content and lower *n*-6/*n*-3 ratio compared to meat from wild boars occurring in farmland habitats [43]. It has been confirmed that the FA more affected by wild boar diet are C18:1 and C18:2 *n*-6, though SFA as C16:0 and C18:0, do not show significant variations [25]. The higher proportions of CLA in wild boar meat compared to pork [82] could be explained by the intestinal bacterial flora biosynthesis. As expected, the hunting area also influences the FA profile owing to the diversity of food items [42].

Together with the diet, it has been suggested that the hunting period has a strong influence on the FA profile. In autumn (October–November), research has found higher proportions of PUFA, lower of MUFA, more favorable values of PUFA/SFA ratio and less favorable *n*-6/*n*-3 ratio, when compared to winter (December–January) [62]. Also, in meat from wild boar hunted during winter, lower proportions of SFA and higher of PUFA, and PUFA/SFA and *n*-6/*n*-3 PUFA ratios have been found compared to summer [64].

With regard to the effect of age, conflicting results have been found, which could be attributed to the differences on age classes used among studies [62, 65]. Only small differences were detected for sex [62, 64], referring a higher total proportion of SFA in males compared to females [65]. A further influence has been found in the carcass weight, hence SFA increased with weight and PUFA proportion increased with decreased carcass weight [26].

If we look at the intramuscular FA profile in wild boars and pigs, in general higher amounts of PUFA have been found in wild boar but also a less favorable *n*-6/*n*-3 ratio [63, 83].

*3.2.2 Small game*

The FA profile of hares and rabbits is slightly different than the one shown by wild deer and wild boars, owing to the higher amount of C20:4 *n*-6, that increases the proportion of PUFA and decreases the proportion of MUFA when compared to large game species. The predominant FA in hare and wild rabbit are C18:2 *n*-6, 16:0, 18:1, 20:4 *n*-6 and 18:0 [36, 48], but hares have a higher *n*-6/*n*-3 ratio compared to rabbits. In any case, the fatty acids profile in hares and rabbits have been poorly studied, as only three studies have been conducted in Europe [36, 46, 48].

The FA composition is influenced by seasonal and territorial variations on vegetation. So, an optimal FA profile has been shown particularly during early spring, when fresh spontaneous vegetation is available, which increases the amount of PUFA, particularly *n*-3, and lower SFA and MUFA concentration, as demonstrated in wild rabbits hunted in Greece [36]. Additionally, there are differences on some FA depending on sex [46].

Higher amounts of C18:2, C18:3 *n*-3 and C20:4 *n*-4 have been found in hares and wild rabbits compared to livestock meats. In farmed hares and reared rabbits eating the same food, higher proportions of PUFA have been found in hares, particularly *n*-3, and lower proportions of MUFA and SFA [48].

*3.2.3 Fatty acid profile and organoleptic characteristics*

The FA profile not only has implications for human health, but also on meat quality, such as texture, shelf life, flavor and odor, which all affect sensory properties of deer meat [13]. Due to the different melting points, individual FA have important but diverse effects on the firmness or softness of the fat and meat. The effect of FA on meat flavor is due to the production of volatile lipid oxidation products during heat treatment or while the production of cured meat, especially unsaturated FA [70]. Natural grazing is a source of PUFA and it is considered as an important contributor for the development of "wild", "gamey "and "grassy" flavor in meat [72, 84, 85]. However, a high content of PUFA may negatively affect the oxidation stability and other technological parameters of meat and its products [52].

### 3.3 Cholesterol

Cholesterol is an essential element for body function, as it is part of the cell membrane structure and it is necessary for the sexual and adrenal hormone production. Around two thirds of cholesterol are synthesized in the liver and the remaining proportion is taken from the diet, and the cholesterol level is self-controlled. Higher serum cholesterol levels increase the risk of cardiovascular disease, though the intake reduction of food rich in cholesterol as a way to reduce this problem, has been questioned [86].

Available literature about wile game meat, shows cholesterol content only in wild red deer and wild boar, specifically in *longissimus thoracis et lumborum, semimembranosus, psoas major, semitendinosus and triceps brachii* muscles (**Table 3**). In those studies, the range of mean values are quite wide, which could explain by the differences in the method used for cholesterol determination, not

| Red deer [17, 19, 59] | | Wild boar [60, 87] | |
|---|---|---|---|
| **Loin** | **Legs** | **Loin** | **Legs** |
| 45.3–52.8 | 55.2–94.6 | 34.4 | 20.9–56.9 |

**Table 3.**
*Range of mean values (or mean value when only one study available) of cholesterol content (mg/100 g) of game meat from wild species hunted in Europe.*

excluding the effects of diet, age and the muscle studied [17, 88]. The age influence is not clear yet [17], as lower cholesterol values in meat from younger red deer were found [59] and the opposite result was found in a different study [19]. As found for the total fat content, the amount of cholesterol is also influenced by the muscle, as a lower amount is found in the loin compared to the legs (**Table 3**).

The cholesterol amount in red deer meat has been compared to beef using the same technique at the same laboratory, finding that the amount found in deer is at the same level of the one found in beef loin and legs [89]. Depending on the muscle, the values found in wild boar meat (20.9–56.9 mg/100 g) are lower or similar to the ones found in pork, which are close to 45.3–80.0 mg/100 g [60]. Generally speaking, the amount of cholesterol in game meat are similar to the ones found in lamb, chicken, pork or beef meat [11]. Contradictory results have been found when comparing the cholesterol amount between wild and farmed deer, with wild red deer showing lower values and wild fallow deer showing higher values compared to farmed deer [11].

### 3.4 Minerals

Macro- and micro-minerals serve many functions in the human organism. They are the building material of bones, teeth, skin and hair and are fundamental components for metabolic processes, maintenance of acid–base equilibrium and regulation of water and electrolyte metabolism [90]. In addition, minerals contained in meat, in comparison with those present in plants, are more easily absorbed and, therefore, more beneficial to the human organism [91].

**Table 4** shows the concentrations of macro and micro-elements, found in loin (*longissimus thoracis et lumborum*, *longissimus thoracis and longissimus lumborum*) and legs (*semimembranosus*) in wild red deer, fallow deer and wild boar. In despite of differences among species, the most abundant macro-minerals in the meat of all species are K, followed by P and Na. On the other hand, the most abundant micro-minerals are Fe and Zn, followed by Cu. The individual values for each species show wide ranges, as the studies have been conducted in different countries and areas, which results on different mineral availability. The mineral content of game meat, especially the micro-minerals, is closely linked to the availability in the environment, as soil micro-elements influence the vegetation content which is eaten by wild game [11, 12, 20, 23]. Additionally, other factors may affect mineral concentration in muscles for a given species, such as different physical activity, muscle fiber type composition, date of hunting, age, sex and other environmental factors [12, 19, 20, 74]. To date, it is known that age does not influence significantly the mineral profile, and only differences in Na have been found in red deer [19] and differences in Fe for wild boar, in which higher amounts are found in older animals [12]. Neither sex has a significant influence in wild board [92], though in red deer higher amounts of Na y Zn were found in stags [20] and in wild boar higher amounts of Cu were found in females [93]. Further research is needed to fully understand the factors influencing the mineral profile.

| | Red deer [19– 21, 23] | | Fallow deer [23] | | Wild boar [12, 23, 25, 92] | |
|---|---|---|---|---|---|---|
| | **Loin** | **Legs** | **Loin** | **Legs** | **Loin** | **Legs** |
| **Macro-minerals** | | | | | | |
| Ca (mg) | 6.0–25.1 | 9.1 | 21.0 | 9.0 | 14.8–20.8 | 10.1–11.8 |
| P (mg) | 166.1–289 | 187.9 | 226.9 | 216.8 | 202.3 | 214.3–223.2 |
| Mg (mg) | 17.5–38 | 18.6 | 21.4 | 21.3 | 20.1–55.7 | 19.6–26.9 |
| K (mg) | 217–326.9 | 282.9 | 302.0 | 303.3 | 299.7–1123.9 | 324.3–328.7 |
| Na (mg) | 45.7–121 | 83.5 | 63.5 | 76.2 | 69.4–157.2 | 60.9–68.1 |
| **Micro-minerals** | | | | | | |
| Cu (mg) | 0.17–0.93 | 0.17 | 0.18 | 0.21 | 0.15–0.58 | 0.13–0.18 |
| Zn (mg) | 1.36–7.05 | 4.86 | 2.90 | 3.41 | 2.3–11.7 | 4.1–4.5 |
| Fe (mg) | 4.17–5.36 | 4.02 | 1.66 | 3.52 | 1.9–8.2 | 2.9–3.3 |
| Mn (μg) | 17–27 | 21.8 | 49.1 | 48.2 | 36.8–19.1 | 32.2–64.0 |
| Se (μg) | 3.7 | | | | 13 | |

**Table 4.**
*Range of mean values (or mean value when only one study available) of minerals content (per 100 g) of game meat from wild species hunted in Europe.*

In general, game meat has higher amounts of micro-minerals than beef and pork, and such differences may be due to genetic background and environmental factors [23]. Muscles of wild ruminants have shown higher content of P, but less K and Na than corresponding bovine muscles [23]. In wild boar meat, higher content of Ca, P, Cu, Fe and Zn has been found than in pork, but lower content of Na and Mg, with conflicting results with regard to K [23, 92]. A 2-fold higher content of Fe have been found in wild boar [12].

### 3.5 Vitamins

Vitamins are essential elements for human nutrition as they control metabolic pathways of macronutrients, act in enzymatic reactions and take part in many physiological functions, with some vitamins having antioxidant properties [94].

Not many studies have dealt with the vitamin content of game meat, and available research focuses on vitamin E (tocopherols y tocotrienols) owing to the antioxidant properties which are key on the preservation of meat quality through the retardation of lipid oxidation and color loss. In **Table 5** it is shown the concentrations of B-group vitamins and some fat-soluble vitamins: retinol and vitamin E homologs which are at high levels, α- and γ-tocopherols, in red deer and wild boar meat.

In red deer, only one study has been conducted in B-group vitamins from loin (*longissimus thoracis*) [20], and when compared to lean meat from pork, poultry, lamb and beef [95], deer loin shows higher contents of thiamine (2-fold higher than poultry and lamb, and 3-fold higher than beef), riboflavin (being approximately 3-fold higher), and especially vitamin B12 which is between 3 and 5 times higher than all meats mentioned. One study in red deer evaluated the levels of tocopherols and tocotrienols in *psoas major* muscle, finding higher values of α-tocopherols in hinds [59].

| | Red deer [20, 59] | | Wild boar [12, 43, 60] | |
|---|---|---|---|---|
| | **Loin** | **Legs** | **Loin** | **Legs** |
| **B-group** (per 100 g) | | | | |
| B1 (thiamine, mg) | 0.18 | | | |
| B2 (riboflavin, mg) | 0.40 | | | |
| B3 (niacin, mg) | 5.53 | | | |
| B6 (pyridoxine, mg) | 0.14 | | | |
| B9 (folic acid, μg) | 3.17 | | | |
| B12 (cyanocobalamine, μg) | 5.87 | | | |
| **Retinol** (μg /g) | | | 0.01–1.11 | |
| **Tocopherols** (μg /g) | | | | |
| α | | 5.24–6.46 | 0.52–2.6 | 15.5–19.2 |
| γ | | 1.42–2.06 | 0.03–0.30 | 1.14–1.75 |

**Table 5.**
*Range of mean values (or mean value when only one study available) of vitamins content of game meat from wild species hunted in Europe.*

In wild boar meat concentrations of retinol and vitamin E homologs have been studied in *longissimus* and *psoas major* muscles. The location of the animals has a strong influence on the amount of vitamins [12, 43, 60], finding significant differences for retinol, α- and γ-tocopherol in studies conducted in Italy and Germany. A study conducted in wild boar harvested at farmland and forest areas [43], found higher amount of α-tocopherol in farmland areas, and higher amount of γ-tocopherol in forest areas owing to the differences on crops, pasture and acorns among habitats. Supplementation of vitamin E in pigs is a widespread practice, as it reduces oxidation, increasing meat shelf life. Pigs supplemented up to 700 mg/kg of feed, resulted in α-tocopherol content in *psoas major* muscle up to 15.1–16.3 μg/g of meat, values that are similar to the mean values found in wild boars [60].

## 4. Nutrition and health claims in wild red deer meat

A recent study conducted by Soriano et al. [20] has shown the nutrition and health claims from wild red deer meat according to the Regulation (EC) No 1924/2006 and the amended Commission Regulation (EU) No 1047/2012. These claims can be used legally in labeling, presentation and advertising of this meat in the market. In that study the nutritional quality of loin (*longissimus thoracis*) from 71 wild Iberian red deer (*Cervus elaphus hispanicus*) was analyzed, using both stags and hinds hunted in autumn and winter.

Regarding to the nutrition claims, in all samples the contribution of proteins to the total energetic value was at least 73%, the fat content was lower than 2 g/100 g and Na content was lower than 0.12 g/100 g, so the claims “high protein”, “low fat” and “low sodium/salt” can be assumed. When looking at the minerals and vitamins contents, significant amounts of P, Fe, Cu, Zn, and vitamins B2 (riboflavin), B3 (niacin) and B12 (cyanocobalamin) were found, indicating that 100 g of deer loin provide at least 15% of the reference daily intake for adults of these micronutrients, so this meat can be labeled as a “source of P, Fe, Cu, riboflavin and niacin”. For Zn and vitamin B12 deer loin contains at least twice the value of source, so could be labeled as “high in Zn and vitamin B12”.

Together with the mentioned nutrition claims, permitted health claims listed in the Annex of the Commission Regulation (EU) No 432/2012, could be used for wild deer meat in relation to those minerals and vitamins found in significant amounts. Similarly, claims related with children's development could also be made (Regulation (EC) No 1924/2006; Commission Regulation (EU) No 432/2012); these claims are based on the bioactivity and presence of certain components that must be found in significant amounts, such as Fe and protein, since deer loin complies as being a source of Fe and protein.

## 5. European wild game meat production and its challenges

Production of wild game meat as alternative to others red meats, offer both economic opportunities and nutritional benefits but is still a niche market to develop due to both low demand and supply limitations.

In Europe, hunting contributes only a small part to the overall meat supply, but represents a sustainable source of meat. Hunting is a legal activity and when managed properly, may contribute to wildlife conservation and rural economy [10]. Most hunting practices fulfill animal welfare requirements, though guidelines for sustainable hunting should be promoted to minimize ethical concerns.

The way in which game meat is produced differs from that of farmed animals, and prompts taking specific measures along the food chain [96]. Despite differences in game species, *ante-mortem* conditions, hunting procedures and *post-mortem* handling, there are common requirements regarding to meat safety and quality. To strengthening the wild game meat sector, it is essential to ensure that the meat is safe for the consumer through official inspections. To date, European legislation is limited to a series of general regulations on the hygiene of foodstuffs (Regulations (EC) Nos. 852/2004, 853/2004, 854/2004, 882/2004 and 2075/2005) as adapted into the legislation of state members. This means that the good practices recommended in Europe must be observed across the whole production sector: hunting grounds' owners, hunters and cutting plants. These good practices are crucial, as training is needed by those involved in this matter (including hunters, trained staff and official veterinarians), serving as reference when game carcasses or food companies trading meat from wild game are inspected. However, there are still specific unresolved questions and challenges [96].

On the other hand, the use of lead (Pb) ammunition is still widespread in many hunting modalities and it is well known that fragments of Pb can be found after impacting on the body of the animal, both in the place of impact and other nearby parts. A common practice is to eliminate the place of impact during carcass dressing. In addition, trading companies have metal detectors, which prevent the distribution of game meat with the presence of ammunition remains. However, wild animals inadvertently ingest Pb residues present at the soil and surface water in some areas, causing the Pb to be also present in their viscera. Consequently, there is a certain risk of exposure to lead in the population, mainly hunters and their families [97]. In this sense, EFSA has studied the lead dietary exposure in the European population from meat and meat products [98], finding particularly high results for wild boar meat. However, food consumed in larger quantities, as grains and grain products, milk and dairy products, non-alcoholic beverages and vegetables and vegetable products, have the greatest impact on lead dietary exposure, not being this the case for wild game meat [98]. No adverse effects from a single high intake of Pb have been reported, though chronic toxicity from repeated intakes has a toxic effect on the body, mainly on the central nervous system (particularly on the developing brain of young children and fetuses). On the other hand, inorganic Pb compounds have been classified by the International Agency for Research on Cancer (IARC) as probably carcinogenic to humans [99].

It is then clear that meat from wild game has several challenges that should be tackled to reduce detrimental effect on consumers, mainly those related to the type of ammunition used and some aspects related to handling *post-mortem* in the field.

## 6. Conclusions

Generally speaking wild game meat from Central and Mediterranean European countries, compared to livestock meat shows: (i) a lower fat content (< 3 g/100 g for large and < 4 g/100 g for small wild game species), and therefore a lower energy content; (ii) a higher or similar protein content; (iii) a positive fatty-acids profile, showing a higher proportion of PUFA, especially *n*-3, and consequently more favorable PUFA/SFA ratio, and in the specific case of wild boar, a relative adequate content of conjugated linoleic acid (CLA), and in the case of wild ruminants (red and fallow deer), an optimal *n*-6/*n*-3 ratio; (iv) a higher minerals content, mainly micro-minerals as Zn and the bioavailable form of heam Fe. Wild game meat has also optimal amounts of B-group vitamins, as riboflavin, niacin and B12, and vitamin E, with antioxidant properties. Overall, wild game meat meets current demands from consumers owing to its sustainable production which guarantees animal welfare standards, and its nutritional quality that may contribute to a balance and healthy diet. Hence wild game meat is a good alternative to others red meats and it can diversify the European meat market.



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