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Rabbit and quail: Little known but valuable meat sources

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Abstract: In the actual scenario of increasing demand of animal food and the need to develop sustainable production systems, rabbit (*Oryctolagus cuniculus*) and quail (*Coturnix japonica*) represent animal species of undeniable potential, profoundly linked to human's eating habits in several parts of the World, yet not fully exploited. Given the remarkable adaptability of quail and rabbit to different farming contexts, they can be successfully farmed both in specialised and technologically advanced production systems targeting market diversification, as well as in such areas of the World where malnutrition is a severe issue and technological limitations are present. Together with the above-mentioned socio-cultural aspects, rabbit and quail possess intrinsic traits that make them meat species of interest to improve the sustainability of the livestock sector, challenge of utmost importance for present and future development strategies. Furthermore, available nutritional data indicate that quail and rabbit provide food (meat) that has the potential to improve the nutritional adequacy of any diet. It also emerged that about 130 g of rabbit and quail meat are sufficient to meet the daily dietary recommendations for essential amino acids provided by the World Health Organization. Despite the dietary quality of the meat obtained from these two animal species, the present review also unveils that, while the factors affecting meat quality have been extensively studied, little focus has been devoted on those specifically affecting the protein content and quality, thus emphasising that this is a key aspect for future researches.

Keywords: *Coturnix japonica*; *Oryctolagus cuniculus*; meat; protein quality; amino acids; food security

The Japanese quail (*Coturnix japonica*)

The Japanese quail (*Coturnix japonica*) belongs to the order Galliformes, family Phasianidae. It is an Old World quail, closely related to the European common quail (*Coturnix coturnix*), that can naturally be observed in eastern Asia where it inhabits grasslands, croplands, riversides, grass steppes and mountain slopes close to water sources. The Japanese quail is a popular animal model for different research purposes, such as embryogenesis studies, health and disease (Baer et al. 2015). Furthermore, it is also a poultry species of interest for commercial purposes: the first intensive production records date back to the 1920s in Japan, where the first egg lines were developed. Later on, the Japanese quail was introduced to America, Europe, Middle East and Africa for egg and meat purposes (Minvielle 2004). Despite meat production is quantitatively negligible compared to that of chickens, quail meat represents a niche business in some coun-

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tries and main producers are the European Union (Spain, France, Italy, and Portugal), USA and China. In these countries, quails farmed for meat production (Figure 1) can be classified into dual-purpose (egg-meat) and heavy (meat) types (Lukanov and Pavlova 2020a) even if, unlike chickens, no specific selection schemes have been performed resulting in commercial farms often having heterogeneous genetics (Baer et al. 2015). The selective breeding performed on the Japanese quail to improve meat and egg production have generated important intraspecific differences with the wild ancestors (morphology, behaviour and productivity). For this reason, *Coturnix japonica domestica* (domestic quail) has recently been proposed as new scientific name to define quails for commercial meat and egg production (Lukanov and Pavlova 2020b). Besides top-producing countries, quail meat signifies an alternative protein source for developing countries where achieving the dietary requirements for daily animal protein intake is still a challenge. In this context, quail is a promising poultry species thanks to the relatively small size, short production cycle and generation interval, resistance to several diseases, and good adaptation to different environmental conditions (Minvielle 2004).

The farming cycle of the Japanese quail under intensive conditions takes 28–35 days to produce a slaughter weight of 160–259 g, and an edible carcass of 142–169 g (Cullere et al. 2016; Lopez-Pedrouso et al. 2019; Cullere et al. 2023). Quails can be farmed either in battery cages, indoor floor pens, or semi-natural outdoor aviaries at a temperature comprised between 22 and 25 °C. The space requirements for this poultry species indicate 0.023 m^2/bird and, when farmed in cages, a maximum roof height of 20–25 cm in order to allow birds from heavy strains to stand up in a normal postural position, but avoiding head injuries associated with the escape response (Baer et al. 2015).

Figure 1. Broiler quail for meat production (source: Dalle Zotte A)

The European rabbit (*Oryctolagus cuniculus*)

The European rabbit (*Oryctolagus cuniculus*) belongs to the order *Lagomorpha*, family *Leporidae* to which also hares belong to. The family comprises 11 genera: among them, *Lepus* accounts for 30 species of hares from the Old World, and *Oryctolagus* has the sole species European rabbit (Dalle Zotte 2014). The rabbit has a long history as meat species, since the first rudimental attempts to farm it for gastronomic and economic purposes date back to Phoenicians around 1100 BC. However, it is only from the 1920s, in Southern California and from the 1970s in some European countries, that specialised rabbit farming for meat purpose started. This was possible thanks to several technological achievements including artificial insemination, the development of cycling system, the selection of highly productive hybrid strains, and a better awareness of the dietary needs of this animal species (Cullere and Dalle Zotte 2018). Rabbits are herbivores, concentrate selectors, and hindgut fermenters. They perform caecotrophy, a further specialisation than coprophagy which is the simple re-ingestion of hard faeces. It consists in the ingestion of soft faeces (caecal digesta) directly form the anus; soft faeces (or caecotrophes) undergo a second passage through the digestive systems which leads to the final excretion of hard faeces. The rabbit benefits from the nutritional properties of soft faeces, as they encompass vitamins and proteins synthesised within the caecum (Hornicke 1981).

Rabbit meat consumption is not popular worldwide, being considered a niche market (0.19 kg estimated World yearly per capita consumption; Szendro et al. 2020), and it is mainly limited to the Mediterranean region (Italy, Spain, France, Portugal, Egypt, Algeria Cyprus and Malta), to some other European (Germany, Belgium, Czech Republic and Luxembourg) and Asian (China, Republic of Korea) countries. In modern farming systems, i.e. specialised or intensive,

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commercial crossbred rabbits (hybrid strains) are exploited, and they are obtained by crossing lines from pure breeds (Figure 2) selected by genetic suppliers. Rabbit breeds, instead, are farmed only in low-input or alternative production systems such as organic or free-range (D'Agata et al. 2009). Together with the use of rabbit hybrids, specialised systems involve artificial insemination, pelleted diets formulated to meet the nutritional requirements of rabbits at different growth/production phases, and they are organised in cycled systems (continuous and closed). Rabbits can currently be farmed in different conditions, including conventional cages, structurally enriched cages, elevated pens, or floor pens. The slaughter age for growing rabbits varies greatly (i.e. 63–90 days) among producing countries, mainly depending on the considered farming system, consumer preferences and local market. Consequently, the slaughter weight of a rabbit varies too ranging from 2.2 kg to more than 2.6 kg (Cullere and Dalle Zotte 2018).

Nutritional quality of meat

Meat is recognised as a key food source to satisfy human's nutritional requirements, including protein. Protein quantity, however, is not sufficient to define the quality of a protein source: to establish the nutritional value of proteins, the content and digestibility of the essential amino acids (AA) must be considered. Protein quality can be calculated by applying the Digestible Indispensable Amino Acid Score (DIAAS), which exploits information regarding the essential AA content of a food and the true ileal digestibility. When the score of a food is 1 (or higher) it means that the dietary protein is completely absorbed and used, whereas lower scores indicate that not all the ingested protein can be utilised. For instance, meat was reported to have a DIAAS score ranging from 0.80 to 1.40 (Leroy et al. 2023). Animal proteins are generally recognised to be more digestible than plant ones which results in a superior AA availability which, in turn, serves

Figure 2. New Zealand (A; source: https://pethelpful.com/rabbits/Bunny-Breed-Guide-New-Zealand-White-Rabbit) and Californian (B; source: https://petkeen.com/californian-rabbit-breed) rabbits: breeds used in selection schemes to obtain rabbit hybrids for meat production. Vienna Blue and Burgundy Fawn (C; source: Dalle Zotte A.) rabbits: breeds used in extensive production systems

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as anabolic stimulus for the synthesis of muscle protein. This is important at any stage of life, also when age advances and a loss of muscle mass and physical function (sarcopenia) typically occurs (Carbone and Pasiakos 2022). Meat showed that, even at a moderate intake, has the potential to stimulate the synthesis of muscle protein also in older men and women, when the so-called anabolic resistance is occurring (Lynch and Koopman 2018).

Table 1 presents the protein and AA contents of rabbit and quail meat, along with the dietary recommendations for essential AA provided by the World Health Organization (WHO), intended for 70 kg adults. The AA content of rabbit and quail meat shows that, for both species, lysine and leucine are the most abundant essential AA, while glutamic and aspartic acid are the most represented among the non-essential ones (Lopez-Pedrouso et al. 2019). From presented values, it can be noticed that both rabbit and quail meat have excellent protein and essential AA contents; in fact, about 137 g and 138 g of rabbit and quail meat, respectively, are a sufficient intake to meet the WHO nutritional recommendations for essential AA. This highlights that these two less known and consumed meat species (Figure 3) can effectively contribute to satisfy the global growing demand of quality protein, having the potential to improve food security and the nutritional adequacy of any diet.

Table 1. Crude protein and amino acid contents (g/100 g edible portion) in rabbit and quail meat, and WHO recommendations (for 70 kg adult, g/day)

Meat species[1]	Rabbit	Quail	WHO[2]
Nr. studies[4]	7	7	–
Crude protein	22.5 ± 0.82	22.1 ± 0.89	–
Histidine	0.85 ± 0.18	0.72 ± 0.47	0.70
Isoleucine	1.12 ± 0.30	1.16 ± 0.29	1.40
Leucine	1.72 ± 0.44	1.98 ± 0.16	2.73
Lysine	2.10 ± 0.30	1.78 ± 0.78	2.10
Methionine	0.60 ± 0.18	0.60 ± 0.13	0.70
Phenylalanine	0.76 ± 0.17	0.99 ± 0.41	1.75[3]
Threonine	0.94 ± 0.09	1.00 ± 0.21	1.05
Valine	1.20 ± 0.20	1.13 ± 0.34	1.82
Sum essential AA	9.44 ± 1.18	9.36 ± 1.54	12.9
Alanine	1.29 ± 0.16	1.41 ± 0.28	–
Arginine	1.28 ± 0.22	1.46 ± 0.28	–
Aspartic acid	2.06 ± 0.06	2.21 ± 0.26	–
Cysteine	0.32 ± 0.09	0.22 ± 0.08	–
Glutamic acid	3.10 ± 1.19	3.69 ± 0.48	–
Glycine	1.16 ± 0.17	1.18 ± 0.26	–
Proline	0.50 ± 0.35	0.84 ± 0.17	–
Serine	0.69 ± 0.25	0.64 ± 0.31	–
Tyrosine	0.77 ± 0.24	0.97 ± 0.47	–
Sum non-essential AA	11.2 ± 1.78	12.6 ± 0.98	–

[1]Rabbit (*Longissimus thoracis et lumborum muscle*) and quail (breast meat cut)

[2]WHO recommendations (WHO 2007)

[3]Phenylalanine + Tyrosine

[4]Rabbit: Simonova et al. 2010; Bivolarski et al. 2011; Nasr et al. 2017a; Simonova et al. 2020; Semenova et al. 2021; Morshdy et al. 2022; Simonova et al. 2022. Quail: Genchev et al. 2008; Nasr et al. 2017b; Cullere et al. 2018; 2019; Sabow 2020; Quaresma et al. 2022; Lukanov et al. 2023

Along with the protein quantity and quality, the meat obtained from rabbit and quail has an overall excellent nutritional profile. Quail meat has an intramuscular fat content ranging between 2.21% and 2.90% for breast and 3.26–3.39% for thigh cuts, the cholesterol is reported to be 70.2 mg/100 g

Figure 3. Quail (A; source: Dalle Zotte A) and rabbit (B; source: https://www.eater.com/22149324/why-you-should-be-eating-rabbit-meat): Little known but valuable meat sources

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meat and the heme iron content is 0.64 mg/100 g meat (breast meat cut). Quail meat is also notable for its quality and quantity of vitamins, especially pyridoxine (0.52–0.68 mg/100 g meat), niacin (6.0–10.3 mg/100 meat), thiamine (0.10–0.17 mg/100 g meat), pantothenic acid (0.66–1.10 mg/100 g meat) and riboflavin (0.16–50 mg/100 g meat). As for other meat species, quail meat is a source of minerals too, especially potassium (14 925 mg/kg meat), phosphorus (8 930 mg/kg meat) and magnesium (1 092 mg/kg meat). The amount of selenium in the breast and leg meat of adult quail was reported to be 13.2 µg/100 g meat, that can increase to 39.8 µg/100 g meat in Se-supplemented diets. The fatty acid (FA) profile of quail meat is characterised by about 33% saturated FA (SFA), 16% monounsaturated FA (MUFA), 43% polyunsaturated FA (PUFA), and a *n*-6/*n*-3 of 11.2, even if values can vary greatly depending on the dietary treatments (Cullere et al. 2018; 2019; Lopez-Pedrouso et al. 2019).

Rabbit meat has excellent nutritional features too having a healthy lipid profile, which is characterised by > 60% of unsaturated FA, very low sodium (37–50 mg/100 g meat) and cholesterol (47.0–61.2 mg/100 g meat) contents, high phosphorus (222–234 mg/100 g meat) and potassium (428–431 mg/100 g meat) amounts, as well as a good quantity of selenium (9.3–15.0 µg/100 g in non-supplemented; 24–40 µg/100 g in Se-supplemented diets). Furthermore, given that meat in general is an important source of bioavailable B vitamins, rabbit meat is particularly rich in vitamin B_{12} (8.7–11.9 mg/100 g meat), as 100 g of rabbit meat are known to provide three times the recommended daily intake of this vitamin (Dalle Zotte and Szendro 2011).

Factors affecting the protein content and quality

The main factors affecting rabbit meat quality have been extensively studied in past decades (Dalle Zotte 2002) and they include: feeding (energy concentration, chemical composition of feedstuffs), farming systems (i.e. conventional cages, mobile cages, pen, free-range), environmental conditions (i.e. heat stress), age and weight at slaughter, pre-slaughter transport and post-slaughter processing treatments (i.e. carcass chilling rate, meat refrigeration, packaging). Differently, studies specifically focusing on protein quantity and quality (AA profile) are scarce. Crude protein amount has been considered as one of the traits in research focusing on the effect of the above-cited factors on different meat quality attributes, including pH, colour, water holding capacity (WHC) among physical, and proximate composition, FA profile, shelf-life and sensory characteristics among chemical ones. Amongst all the considered factors, it was observed that age at slaughter can affect protein quantity, with more mature rabbits (110 days of age) showing higher amounts than younger (90 days of age) ones and this goes parallel to the intramuscular fat content (Cavani et al. 2000). Tumova et al. (2014) observed that different rabbit breeds displayed different protein contents at slaughter (loin and hind leg meat cuts), but this was attributed to the age of the rabbits rather that to the breed. Since slaughter age was fixed (90 days) for all breeds, different growth patterns affected the chemical composition of meat. In fact, with maturation rabbit meat changes its nutritional profile, becoming progressively richer in fat and protein to the detriment of the moisture fraction (Pascual and Pla 2007).

Among the post-mortem factors that can affect rabbit meat protein content, but especially quality, there is retail display. During refrigerated storage, meat in general suffers different oxidation processes, including myoglobin autoxidation, lipid oxidation and protein oxidation. Since rabbit meat is rich in PUFA and sulphur-containing AA, both vulnerable to oxidative phenomena, a target of future research on the chemical reactions taking place in rabbit meat should be oxidative deterioration. The magnitude of these deteriorations is strongly affected by the refrigeration temperature, as highlighted in the study by Wang et al. (2021).

The fact that quail still represents a niche species for meat production clearly emerges from the scientific literature: a research on Scopus (September 28, 2023) using the keywords "broiler quail" and "quail meat" produced a total of n = 287 (first publication in 1976) and n = 854 (first publication in 1960) results, respectively. Conversely, the keywords "broiler chicken" and "chicken meat" retrieved n = 34 124 (first publication in 1931) and n = 22 619 (first publication in 1909) documents, respectively. Given this premise, it's easily understood that the factors affecting quail meat quality have not been adequately investigated, and even less emphasis has been given to the factors affect-

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ing protein quantity and quality. From available literature, however, emerges that some of the factors affecting chicken meat protein (Mir et al. 2017) are relevant also for the quail.

The degree of maturity of quails was indicated as meaningful factor affecting the protein amount of broilers (Boni et al. 2010). While the meat of young (eight weeks) quails had the highest protein and moisture contents, with age it was suggested that quails deposit more intramuscular fat to the detriment of the protein amount. However, this conclusion was biased by the sex and production attitude effects, as the study considered two types of quail: eight week-old broilers and eight month-old spent quails (former layers). Available knowledge on this topic indicates that with age, both protein and fat tend to increase to the detriment of moisture content (Fanatico et al. 2007). Regarding a possible sex effect on protein quantity, even if a study by Raji et al. (2015) reported that breast meat of female quails had higher amounts than that of males of the same age, this has not been demonstrated by other researches (Genchev et al. 2008).

Genotype is surely a factor affecting quail meat protein amount and quality: already more than 30 years ago, Caron et al. (1990) observed that quail lines with lower live and carcass weights had higher protein amounts in breast and thigh muscles than quails selected for higher live and carcass weights, which tended to deposit more abdominal fat. This was further confirmed by the study of Marks (1993), where quails selected for high body weight had a decrease in protein and water contents of meat, in favour of lipids. More recently, a study by Nasr et al. (2017b) comparing the nutritional characteristics of different Japanese quail genotypes differing in plumage colour (white, golden, black and brown), highlighted that also the AA profile of meat can be affected by genotype which is connected with genetic growth potential and thus pattern.

Scientific literature indicates that broiler chickens have an average protein gain efficiency of 33.3% (meat protein/dietary protein × 100) and that the dietary protein quantity, but particularly quality, strongly affects the efficiency of conversion into meat protein (Macelline et al. 2021). Regarding broiler quails, Kirkpinar and Oguz (1995) found that increasing the dietary protein content led to carcasses with increasing protein amount, to the detriment of water and fat, but it was unclear if the dietary protein of basal diet was adequate for the considered birds, both in terms of quantity and quality (AA contents and balance). Overall, it is unclear to what extent dietary protein amount and quality affect protein deposition in broiler quails, especially considered that such birds have not been selected as extensively as broiler chickens.

Research on chickens showed that, when comparing meat obtained from animals reared under extensive or intensive production systems, the observed differences in meat quality traits, including protein amount, are mostly attributable to the different genetic origin of the animal used in different production systems rather than the production environment (Mir et al. 2017).

Sustainability and socio-cultural aspects

The target of modern livestock systems is to work in the direction of sustainably, also improving global food security. In this context rabbit and quail are species of unquestionable interest. The rabbit is very prolific as a doe can successfully deliver 8–12 kits every parturition (kindling), and with a short reproductive cycle of averagely 30–32 days. Mating can be performed just after parturition, but it is typically carried out 11–18 days later;. This interval allows to obtain 8–9 kindlings per year, maintaining a rhythm that ensures sufficient energy recovery for the doe. Therefore, a doe under this so-called semi-intensive reproductive rhythm can generate 64–108 kits/year (Dalle Zotte 2014). Once born, a hybrid rabbit averagely takes about 78 days to achieve a live weight of 2.4–2.6 kg and a dressing out percentage between 55% and 61%, thus being a species characterised by a rapid growth rate. A further strength point of this meat species it related to feeding habits, since it efficiently (feed conversion index of about 3) relies on forage and agricultural by-products for growth, therefore limitedly competing with humans for feed resources. Last but not least, the rabbit has a great adaptability to different ecological environments: while hybrid rabbits have been selected to maximise production efficiency in closed environments/systems, there are several local breeds (https://www.fao.org/dad-is/browse-by-country-and-species/en) that can be exploited in different farming systems and/or in areas of the World with different climatic conditions and where affordable or low-cost management tools are available (Jochova et al. 2017;

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North et al. 2019). If, on the one hand, promoting and valorising the exploitation of rabbit breeds is a key factor to ensure a reservoir of genetic variability for rabbits (also those used in selection schemes for strains production), this would also allow to face future environmental changes, evolving markets and production systems.

The quail is a species of interest in terms of market diversification worldwide, as it represents an alternative meat to that of most common poultry species. Besides this, quail has been identified a key animal species to be considered in food security programs, particularly for developing countries (Geldenhuys et al. 2013; Jeke et al. 2018). Food security is a fundamental aspect to be considered given that recent data indicated that there are more than 100 countries where dietary protein supply is considered inadequate, which is also linked to limited access to foods of animal origin (Moughan 2021). In Bangladesh, quail farming has been identified as a strategic sector that should be promoted to provide gainful employment, women empowerment, supplementary income, as well as to provide animal protein and other key nutrients: all these factors contribute to country's economic and social development (Redoy et al. 2017). Technically, the quail is a promising candidate to improve food security because farming requires low investments (and a quick return from them), mainly thanks to limited floor area necessities, and the slaughter weight is reached within 28–35 days, depending on genetics and management factors. In addition, this poultry species has a limited daily feed requirement, as it is comprised between three to six folds less than the that of a chicken. Quails are also resilient birds: they have been found to be more resistant than chickens to diseases such as ulcerative enteritis, fowl pox and Newcastle, but also salmonellosis, coccidiosis, infectious coryza, enteric diarrhoea, and pneumonia. This contributes to make quail a sustainable poultry species in the perspective to limit the use of antibiotics (Minvielle 2004).

Another aspect that is worth to be highlighted is that in the current and future scenario of increasing global demand of animal products, livestock production, and consequent pressure on natural resources, an imperative is to identify sustainable feed ingredients, complementary/alternative to the conventional ones (Cullere et al. 2016). Research is demonstrating that quail, as other poultry species, is an adaptable bird since it can successfully exploit emerging feedstuffs such as insects (Cullere et al. 2016; 2018; 2019), algae (Yusuf et al. 2016), and low-impact crops (Yalcin et al. 2018; Cullere et al. 2023). In fact, an adequate dietary incorporation of such feedstuffs, is showing to guarantee satisfactory productive performance and product quality, without compromising animal health. Last but not least, literature data indicate that quails' average heat stress temperature threshold is 35.3 °C, which make this poultry species very interesting also in the perspective of finding resilient animals for meat production in areas of the world where the effect of global warming is particularly challenging for common livestock species (Abdulkadir and Reddy 2023).

Conclusion

In the current scenario of increasing demand of animal food and the need to strive for the development of sustainable livestock production systems, rabbit and quail represent two interesting animal species of undoubted potential. On the one hand they can conquer a niche in specialised and technologically advanced production systems, providing market diversification. On the other hand, the potential of rabbit and quail as meat species is particularly relevant for those areas of the World where the request of food of animal origin is rapidly growing and malnutrition is a severe issue. Rabbit and quail are species that can adapt to a wide variety of production systems, and ecological zones, and are efficient producers of high-quality protein for everyday consumption. Given the potential of these animal species, research efforts should be directed to provide a better understanding of all the factors possibly affecting meat quality, including protein amount and quality. This would ensure the possibility to maximise product quality for consumers' health.

Conflict of interest

The authors declare no conflict of interest.

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