The composition of the lipid, protein and mineral fractions of quail breast meat obtained from wild and farmed specimens of Common quail (*Coturnix coturnix*) and farmed Japanese quail (*Coturnix japonica domestica*)

M. A. G. Quaresma,[*,1] I. C. Antunes,[*] B. Gil Ferreira,[*,†] A. Parada,[*] A. Elias,[†] M. Barros,[‡] C. Santos,[§] A. Partidário,[§] M. Mourato,[†] and L. C. Roseiro[§]

[*]*CIISA - Centre for Interdisciplinary Research in Animal Health, Faculty of Veterinary Medicine, University of Lisbon (FMV/ULisboa), Lisbon, 1300-477 Portugal;* [†]*LEAF - Linking Landscape, Environment, Agriculture and Food, Institute of Agronomy, University of Lisbon, Lisbon, 1349-017 Portugal;* [‡]*INTERAVES - Sociedade Agro-Pecuária, Abrigada, 2580-067 Portugal; and* [§]*Food Technology and Safety Division, National Institute for Agricultural and Veterinary Research (INIAV, IP), Oeiras, Portugal*

ABSTRACT The present study was intended to answer 2 scientific hypotheses: 1) the quail species has a significant influence in quail breast meat composition; 2) the wild quail's meat presents healthier composition than their farmed counterparts.

An analysis of the pectoral muscles of wild and captive common quails (*Coturnix coturnix*) and domestic quails (*Coturnix japonica domestica*) was performed. The content of fatty acids (FA), amino acids, total cholesterol, and vitamin E, some basic macro- and microminerals in the pectoral muscles of the 2 species of the genus Coturnix were analyzed.

Regarding the quail species influence on meat composition, Japanese Quail (JQ) revealed better lipid composition, characterized by lower saturated FA (SFA; less 3.17 g/100 g of total fatty acids), higher polyunsaturated FA contents (PUFA; more 5.5 g/100 g of total fatty acids) and healthier polyunsaturated FA/saturated FA (P/S) and n-6/n-3 ratios and TI value (1.08, 9.54 and 0.60 vs. 0.76, 12.58, and 0.75, correspondingly). The absence of differences observed on amino acids partial sums and ratios reveals equality between species on protein nutritional quality. On the other hand, Common Quail (CQ) proved to be a better source of copper (0.181 mg/100 g of meat), iron (2.757 mg/100 g of meat), manganese (0.020 mg/100 g of meat), and zinc (0.093 mg/100 g of meat) than JQ.

The comparison of farmed and wild specimens within CQ, showed that wild birds presented lower total cholesterol (less 8.32 mg/g of fresh meat) and total PUFA (less 4.26 g/100 g of total fatty acids), and higher n-3 PUFA contents (more 1.53 g/100 g of total fatty acids), which contributed to healthier P/S and n-6/n-3 ratios, but worst PI (1.60, 8.08, and 113.1 vs. 0.76, 12.58, and 100.8, respectively). The wild species revealed higher α-tocopherol content (2.40 vs. 1.49 μg/g of fresh meat. Differences observed on their mineral composition counterbalance each other.

Under intensive production system and similar feeding and management conditions, the CQ develops better nutritional qualities than JQ. The comparison of wild and farmed species within CQ reveals more similarities than differences. Quail's meat presents good nutritional quality and introduces variability to human's diet, which is much valued by consumers.

Key words: Quail, *Coturnix coturnix*, *Coturnix japonica*, breast meat, fatty acids, amino acids, essential minerals

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INTRODUCTION

The hunting of birds is a widespread traditional activity with an important socio-economic impact, engaging 6.4 million hunters across Europe, with a total annual hunting bag of at least 52 million birds (Hirschfeld et al., 2019). Among EU member states, the Directive 2009/147/EC, specifies the conditions under which 82 species of birds may be legally hunted in one or more countries. Several migratory species are listed in Annex II of the Directive, including the Common Quail (*Coturnix coturnix*).

The Common Quail (**CQ**) is a species belonging to the Phasianidae Family, within the Galliformes Order, it ranges over almost the entire Palearctic zone south of 60° N. and up to 1,200 m altitude. Breeding areas (between 28 and 55−60° N) and wintering areas

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[1]Corresponding author: mquaresma@fmv.ulisboa.pt

(between 10−12° and 38−39° N) overlap broadly. The species wintering areas comprise the Southern Europe, North Africa, the Sahel, the Nile, and Jordan valleys (Guyomarc'h and Perennou, 2009). The CQ is a popular game species particularly among Southern European countries (Sanchez-Donoso et al., 2014), it was estimated that 4.2 million specimens are killed in Europe in a single hunting season (Guyomarc'h and Perennou, 2009), despite that it is classified as a least concern species (BirdLife, 2020a).

In Portugal, the general hunting law allows the release of native game fowl species both for short-term hunting purposes and for long-term objectives (population recovery). The CQ, is among the species produced for hunting purposes, but the number of CQs used in driven-shooting activities or used in training fields (below 10,000 specimens, produced by a single company) is relatively scarce relatively to the number of quails harvested in a single hunting season (around 400,000 specimens; European Communities, 2009). Moreover, the genetic purity of the CQ raised in Portugal is tested by the official authorities (ICNF).

On the other hand, the Japanese quail (*Coturnix japonica*) has its roots in East Asia, it can be found in Mongolia, eastern regions of Russia, north-eastern China, Japan, North and South Korea. Some populations in Japan are resident, but most flocks migrate south, wintering in southern China, Laos, Vietnam, Cambodia, Myanmar, Bhutan, and North Eastern India. Despite its widespread distribution in the wild in the past, the species has become uncommon in the wild due to loss of habitat, shifts in agriculture practices and overhunting, because of that it was listed as Near Threatened since 2010 (BirdLife, 2020b). In East and Southeast Asia, the Japanese quail (**JQ**) have been reared as fighting, singing or decorative bird since ancient times, and its true domestication occurred in Japan by the end of the 19th and beginning of the 20th centuries (Lukanov, 2019).

The quail production is an emerging branch in the poultry industry, it introduces diversity among the poultry meat, and several strains have been selected for both egg and meat yield (Minvielle, 2004; Nasr et al., 2017; Sabow, 2020), and the JQ has been used extensively for both purposes. Quail is an attractive species, offering some advantages relatively other poultry species, namely: rapid growth; high productivity; early onset of lay; high reproduction rates; low feed intake; low investment, and resistance to diseases (Santos et al., 2011).

The breast meat is a prime meat portion in most poultry species, as que chicken broiler, turkey, duck and quail. In poultry production flying is an undesirable behavior, for that reason, Japanese quail has been selected against this trait, that is not the case of CQ. CQ has the flying ability, but inside the production facilities does not possess the best conditions to exert its flying behavior, which is exerted by the wild specimens on a daily basis. Therefore, considering the genetic differences between species, and differences in muscle fiber differentiation between wild and farmed specimens of CQ, differences in breast muscle fiber composition are expectable. Such differences will condition muscle composition and meat's nutritional quality.

The present study is sustained by 2 scientific hypotheses: 1) the species has a significant influence in quail breast meat composition obtained from farmed quail; 2) the wild quail's meat presents a better nutritional composition than their farmed counterparts.

MATERIALS AND METHODS

Birds and Sampling

The farmed CQ (*Coturnix coturnix*; n = 20) and JQ (*Coturnix japonica domestica*; n = 20) specimens used in this study were provided by INTERAVES (Abrigada, Portugal), a company specialized in poultry meat production. Farmed quails from both species were raised under the same management plan, established for intensive quail production.

Quail production starts after the collection, selection and disinfection of the eggs. Selected eggs are transferred to the incubator where they remain the next 14 d, at a constant temperature and relative humidity (36.7°C. and 55%). Then, they are transferred to the hatcher's trays where they stay for more 3 d (at a constant temperature and relative humidity (36.7°C. and 70%). After hatching, they are allocated to pavilions under controlled temperature and humidity. The pavilion's temperature in the first week of life ranges between 28°C and 35°C, gradually descending (1°C per wk) throughout the production cycle. Quails are fed ad libitum, with concentrate feeding and watered according to needs. The feeding management included a starter diet (until the 21 days old), and a grower diet between the 21 and 35 days old (Table 1), Between 32 and 35 d of life (according to commercial needs) they are slaughtered and fully processed in the INTERAVES abattoir in full compliance with the EU legislation.

Quail carcasses of both FCQ and JQ, randomly selected among the production batches were provided by INTERAVES to the study. Quails were slaughtered in an official slaughterhouse, and stored under refrigeration (<5°C) during 24 h preceding the delivery at the laboratory.

The wild CQ (*Coturnix coturnix*) specimens (n = 20) used in the study were hunted in accordance with the national laws on game and hunting, on 4 hunting reserves located in different Councils: Mirandela; Valeflor, Coruche, and Beja, representing the North, Center and South of Portuguese territory. The wild CQ were frozen a few hours after being shot, and kept in freezing for a month. The wild specimens used in this study were provided by FENCAÇA (Portuguese National Federation of Hunting) and 2 individual hunters that offered part of their hunting bag to the study. It is important to highlight that none of the quails used in the study were explicitly shot dead for the study, nor was there a need to organize any hunting to obtain the specimens required for the study. To conclude, the carcasses of

Table 1. Composition and ingredients of quail feeds used in the experiment.

	Starter (<21 days old)	Grower (22−35 days old)
Ingredients		
Corn	36.20%	42.30%
Soybean meal (44% of CP)	44.60%	34.70%
Extruded soybean	10.00%	14.00%
Soybean oil	4.30%	4.30%
DL-Methionine	0.47%	0.36%
L-Lysine	0.28%	–
Monocalcium phosphate	1.90%	1.50%
Calcium carbonate	0.95%	1.50%
Sodium chloride	0.14%	0.15%
Preservative*	0.10%	0.10%
MV supplement	1.00%	1.00%
MV supplement		
Vitamin A (IU/kg)	14.700	9.600
Vitamin D3 (IU/kg)	2.950	2.950
Vitamin E (IU/kg)	55	50
Copper sulfate (mg/kg)	10	10
Proximate composition		
Total protein	26.2%	23.5%
Total fat	8.4%	8.7%
Crude cellulose	4.7%	4.5%
Total ash	6.5%	6.1%
ME (kcal/kg)	3,000	3,080

*Preservative composition: The misture of formic (25%), propionic (19%), acetic (3%), lignosulfonic(32%) acids and propilenoglicol (2%).

farmed quails of both species were delivered to our facilities under refrigeration. The wild CQ specimens were gathered by the research team, but they were delivered as frozen quails. In the laboratory, farmed carcasses, of both CQ and JQ, were skinned, while the wild specimens required an overnight defrosting and full plucking before skinning. Afterward, breast muscles (*M. pectoralis major* and *M. pectoralis minor)* from skinned quail carcasses, of all groups included in the study, were collected from both carcass sides. Breast muscles were trimmed of visible connective tissues, before being individually grinded in a domestic food processor (Moulinex, France). Subsequently, half of the blended breast meat, of each quail, was vacuum packed and frozen at −70°C. until analysis, while the remaining portion was frozen, lyophilized (−60°C. and 2.0 hPa; Edwards High Vacuum International, UK), and maintained desiccated at room temperature, until analysis (an overall period of 30 d).

Reagents

General pro-analysis grade chemicals (hydrochloric acid, sodium acetate, potassium hydroxide, sodium tetraborate, 2-mercaptoethanol) were purchased from Merck Biosciences (Darmstadt, Germany) and absolute ethanol (99.8% v/v) from AGA (Lisbon, Portugal). n-Hexane and isopropanol, HPLC grade, were purchased from Merck Biosciences, ortho-phthalaldehyde, methanol and tetrahydrofuran, all HPLC-grade, were supplied by Sigma Aldrich and Milli Q water was HPLC-grade. α-Tocopherol and cholesterol standards were obtained from Calbiochem (Merck Biosciences, Darmstadt, Germany) and Sigma Chemical Co. (St. Louis, MO), respectively. The amino acids standards (aspartic acid, asparagine, glutamic acid, glutamine, serine, histidine, glycine, threonine, arginine, alanine, tyrosine, valine, methionine, cysteine, tryptophan, phenylalanine, isoleucine, leucine, lysine, proline, hydroxyproline, and ornithine) were supplied by Sigma Aldrich.

Fatty Acid Methyl Esters Analysis

The fatty acid methyl esters (**FAME**) separation and quantification was performed on a Trace 2000 gas chromatograph (Thermo Quest, Milan, Italy), with a split/splitless injector and a flame ionization detector (**FID**). The analytical column was a DB 23 (J & W, Folson, CA) fused silica capillary column, with 60 m length, 0.25 mm inner diameter, and 0.25 μm film thickness. Column oven programmed temperatures were as follows: The initial oven temperature of 70°C was increased to 195°C at 5°C/min and held for 30 min, then increased to 220°C at 5°C/min and was maintained for more 60 min. The injector and detector temperatures were set at 220°C and 280°C, respectively. Helium was used as carrier gas at a constant pressure of 70 kPa (a flow rate of 0.4 mL/min).

The fatty acids (**FA**) were identified by comparison of the relative retention times (**RRT**), the relation between the retention time (**RT**) of each FA to the RT of C16:0 (methyl hexadecanoate), obtained in the samples, with those obtained in a standard mixture of 52 FAME (Nu-Chek-Prep, Inc, Elysian, MN). Quantification was made after converting the relative areas percentages (% area) into weight percentage of total fatty acids (g/100 g), by multiplying % area with the correction factors, calculated from the analysis, of a standard mixture of known composition, in the same conditions (52 FAME -Nu-Chek-Prep, Inc. Elysian, MN).

Lipid Quality Indices

The peroxidability index (PI) was calculated according to the equation previously proposed by Arakawa and Sagai (1986) as follows:

$$\begin{aligned}\mathrm{PI} = {} & (\%\text{monoenoic} \times 0.025) + (\%\text{dienoic} \times 1) \\ & + (\%\text{trienoic} \times 2) + (\%\text{tetraenoic} \times 4) \\ & + (\%\text{pentaenoic} \times 6) + (\%\text{hexaenoic} \times 8).\end{aligned}$$

The indices of Atherogenicity (AI) and Thrombogenicity (TI), were estimated as proposed by Ulbricht and Southgate (1991):

$$\mathrm{AI} = (\mathrm{C12:0} + 4 \times \mathrm{C14:0} + \mathrm{C16:0})/\left[\left(\sum \mathrm{MUFA} + \sum (\mathrm{n-6}) + \sum (\mathrm{n-3})\right]\right.;$$

$$\begin{aligned}\mathrm{TI} = {} & (\mathrm{C14:0} + \mathrm{C16:0} + \mathrm{C18:0})/\left[\left(0.5 \times \sum \mathrm{MUFA} + 0.5\right.\right. \\ & \left.\left. \times \left(\sum \mathrm{n-6}\right) + 3 \times \left(\sum \mathrm{n-3}\right) + \left(\sum \mathrm{n-3}\right)/\left(\sum \mathrm{n-6}\right)\right]\right.;\end{aligned}$$

where MUFA mean monounsaturated fatty acids.

The hypocholesterolemic/hypercholesterolemic ratio (h/H) was calculated using the equation previously proposed by Santos-Silva et al. (2002), as follows:

$$h/H = [(C18:1n-9 + C18:2n-6 + C18:3n-3 + C20:4n-6 + C20:5n-3 + C22:5n-3 + C22:6n-3)/(C14:0 + C16:0)].$$

The nutritional ratio P/S was calculated as previously established (British Department of Health, 1994), while the n-6/n-3 was calculated considering all detected n-6 and n-3 polyunsaturated fatty acids (**PUFA**):

$$P/S = [(18:2n-6) + (18:3n-3)]/[(14:0 + 16:0 + 18:0)]; n-6/n-3 = \left[\left(\sum n-6\right)/\left(\sum n-3\right)\right].$$

Total Cholesterol and Vitamin E Analysis

The determination of total cholesterol (TC) and vitamin E contents was performed in duplicate, as previously described (Prates et al., 2006). Briefly, 0.75 g of quail breast meat sample was placed in a screw teflon-lined cap tube, to which 0.2 g of L-ascorbic acid and 5.5 mL of saponification solution (11% w/v potassium hydroxide in a mixture of ethanol: deionized water (55:45 v/v; weekly prepared)) were added. The air inside tube was eliminated from the reaction, by flushing with nitrogen gas. Then, the tube was shaken until the ascorbic acid was completely dissolved. The saponification was carried out in a shaking water bath (200 rpm at +80° C) for 15 min. After saponification, samples were cooled in tap water for 1 min. After cooling, 1.5 mL of distilled water and 3 mL of n-hexane (25 μg BHT /mL of n-hexane) was added. The samples were vigorously vortexed for 2 min and centrifuged at 1,500 g for 5 min, to accelerate phase's separation. An aliquot of the upper layer (n-hexane) was transferred into a small screw teflon-lined cap tube and a spatle tip of anhydrous sodium sulphate was added. Finally, the tube was briefly shaken, and an aliquot of the n-hexane layer was filtered through a 0.45 μm hydrophobic membrane into an amber screw-cap vial with teflon septa.

After the saponification procedure, samples were injected in an HPLC system (Agilent 1100 Series, Agilent Technologies Inc., Palo Alto, CA) using a normal-phase silica column (Zorbax RX-Sil, 250 mm × 4.6 mm i.d., 5 μm particle size, Agilent Technologies Inc.), with fluorescence detection for tocopherols (excitation wavelength of 295 nm and emission wavelength of 325 nm) and UV−visible photodiode array detection for cholesterol (202 nm) in series. The contents of total cholesterol and tocopherols in quail's meat were calculated, in duplicate for each sample, based on the external standard technique from a standard curve of peak area vs. concentration using DL-α-tocopherol and cholesterol standards. The analysis was performed using the High-Performance Liquid Chromatography (HPLC) technique following the methodology previously described (Prates et al., 2006).

Amino Acid Analysis

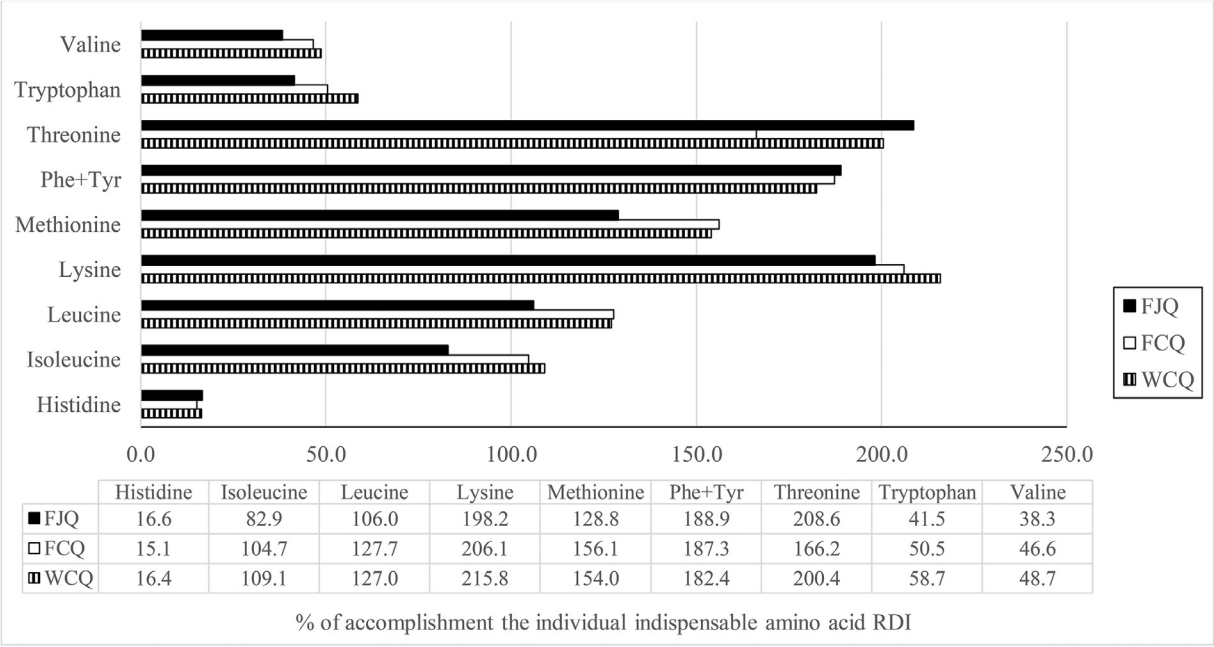
Quail breast meat amino acid (AA) composition was analysed according the protocol previously described (Aristoy and Toldrá, 1991), with minor modifications. Briefly, 500 mg of breast meat sample was hydrolysed for 24 h at 110°C in an oven (Heraeus, Hanau, Germany) with 10 mL of 6 N HCl in sealed pyrex test tubes (Thomas Scientific, Sheldon, NJ). After cooling in tap water, the hydrolysed sample was diluted to 100 mL with deionized water, afterwards 1 mL of it was further diluted to 10 mL with deionized water in a volumetric flask and then filtered through an Acrodisc syringe filter with PTFE membrane 0.45 μm (Waters, Milford, MA). Pre-column derivatization of AA was performed with ortho-phthalaldehyde (**OPA**). For derivatization, 200 μL of the AA extract was mixed with 800 μL of a mixture of 25 mg OPA, 0.5 mL methanol, 5 mL borate buffer 0,7 M and 25 μL 2-ME. After vortexed for 1 min, the reaction mixture was immediately injected in HPLC system.

AA were identified and quantified using a Waters HPLC system consisting of an Alliance 2695 separation module (Waters) and a fluorescence detector (Waters 2475 MultiFluorescence, Waters). Chromatographic separation was performed in a reverse phase column (Spherisorb ODS2 C18, 250 × 4.6 mm, 5 μm, Waters), at room temperature, using an elution gradient with a mixture of 2 solvents. Solvent A − 0.1M sodium acetate: methanol:tetrahydrofuran (905:90:5) and solvent B − methanol. The gradient changed from 0 to 25% of solvent B in 20 min and from 25 to 100% in 30 min at a flow rate of 1.0 mL/min. The column was equilibrated during 10 min before the next analysis. The separation was monitored using a fluorescence detector at 338 nm (excitation) and 425 nm (emission).

The AA were identified by comparison with the retention time of standards and their quantification was based on the external standard technique, from a standard curve of peak area vs. concentration.

Amino Acid Assessment

Figure 1 represents the fulfilment of the recommended dietary intake (RDI) on indispensable amino acids, based on the adult maintenance pattern and the daily protein requirements for maintenance (0.66 g/kg/d), accordingly to the values established by the international authorities (WHO/FAO/UNU and Expert Consultation, 2007), considering an average adult human weighting 70 kg. The maintenance amino acid pattern (mg/g protein) recommends the daily ingestion of histidine (15 mg/g protein), isoleucine (30 mg/g protein),



	Histidine	Isoleucine	Leucine	Lysine	Methionine	Phe+Tyr	Threonine	Tryptophan	Valine
FJQ	16.6	82.9	106.0	198.2	128.8	188.9	208.6	41.5	38.3
FCQ	15.1	104.7	127.7	206.1	156.1	187.3	166.2	50.5	46.6
WCQ	16.4	109.1	127.0	215.8	154.0	182.4	200.4	58.7	48.7

Figure 1. The fulfilment of the Recommend Dietary Intake (RDI) on indispensable amino acids based on the amount of quail's protein content required to accomplish RDI on protein, based on an average adult human (weighing 70 kg). Abbreviations: FCQ, Farmed Common Quail; JQ, Farmed Japanese Quail; WCQ, Wild Common Quail.

leucine (59 mg/g protein), lysine (45 mg/g protein), methionine (16 mg/g protein), phenylalanine plus tyrosine (38 mg/g protein), threonine (23 mg/g protein), tryptophan (6 mg/g protein), and valine (39 mg/g protein) (WHO/FAO/UNU and Expert Consultation, 2007).

Mineral Element Quantification

Samples were freeze-dried and an appropriate amount (no less than 0.3 g) was powdered and digested in 7.5 mL concentrated nitric acid, 2.5 mL concentrated hydrochloric acid and 1 mL hydrogen peroxide (30%). The digestion was performed for 2 h at 95°C in an SCP Science DigiPrep MS digestion system. Simultaneous digestions of blanks (only the acids) and certified standard materials were performed simultaneously. After the digestion, the samples were diluted to 25 mL with ultrapure water (Ribeiro et al., 2020).

The digested samples were then analysed in an ICP-OES (Thermo Scientific iCAP 7200) using appropriate calibration curves (prepared using the methodology used in sample analysis) and selected emission wavelengths.

Statistical Analysis

Throughout the results and discussion, the term superiority (expressed as %) was calculated as (maximum value − minimum value)/minimum value, while the term inferiority was calculated as (maximum value − minimum value)/maximum value.

Preliminary analysis (GLM procedure), showed that no significant differences ($P > 0.05$) were observed between wild CQ specimens obtained from different origins, therefore, they were analyzed as a single group, the wild CQ.

Data were analyzed using the PROC MIXED procedure of the Statistical Analysis SAS (SAS Inst., Cary, NC; version 9.3.), considering the conjugation of species and origin as single effect. A total of two orthogonal contrasts were used to evaluate the effect of the species within farmed quail (CQ vs. JQ) and origin within the CQ (farmed vs. wild). The least square means and the standard error of the mean (**SEM**) are presented in tables. Significance was declared at $P < 0.05$.

RESULTS AND DISCUSSION

The study encloses 3 different groups: common quail (*Coturnix coturnix;* CQ) from both wild and farmed specimens and domesticated form of Japanese quail (*Coturnix japonica domestica;* JQ). The data analysis was focused on 2 comparisons: 1) the comparison of the species (CQ vs. JQ, both obtained from farmed specimens); and 2) the comparison of origins (wild and farmed specimens of CQ), which provide information to understand the influence of the species and origin on quail's meat composition.

FA Profile

The detailed breast meat FA profiles of farmed quail species (CQ and JQ) and wild CQ specimens are presented in Table 2, while their respective FA partial sums, FA ratios and nutritional quality indices are depicted on Table 3.

Table 2. Breast meat fatty acid profile (expressed as g/100 g of total fatty acids) from common quail (*Coturnix coturnix;* CQ) obtained from farmed (FCQ) and wild specimens (WCQ) and farmed Japanese quail (*Coturnix japonica domestica;* JQ).

	Farmed quail		Wild quail		Contrasts	
Fatty acids	CQ	JQ	CQ	SEM	FCQ/JQ	FCQ/WCQ
C14:0	0.197	0.223	0.198	0.019	0.349	0.993
C15:0	0.041	0.060	0.046	0.009	0.147	0.725
C16:0	15.52	16.17	14.83	0.521	0.381	0.351
C17:0	0.161	0.236	0.264	0.015	0.001	<0.001
C17:0 anteiso	0.108	0.134	N.D.	0.011	0.094	–
C18:0	16.13	12.11	18.38	0.666	<0.001	0.019
C20:0	0.113	0.134	0.103	0.014	0.192	0.580
C21:0	0.045	0.081	0.196	0.039	0.491	0.003
C22:0	0.064	0.070	N.D.	0.009	0.646	–
C16:1 *cis*-9	1.478	1.078	1.466	0.181	0.123	0.962
C17:1 *cis*-9	0.172	0.106	0.539	0.104	0.644	0.011
C18:1 *cis-9*	18.27	16.64	20.62	1.468	0.437	0.256
C18:1 *cis-11*	1.973	1.456	1.739	0.102	<0.001	0.097
C20:1 *cis-9*	0.150	0.219	0.205	0.025	0.040	0.111
C16:1*trans*-9	0.188	0.197	0.309	0.038	0.876	0.058
C18:1*trans*-9	0.149	0.142	0.187	0.019	0.801	0.144
C18:2 *t,t*	0.129	0.197	0.154	0.029	0.059	0.505
C18:2n-6	29.76	37.11	20.76	1.005	<0.001	<0.001
C20:2n-6	0.210	0.391	0.235	0.019	<0.001	0.321
C20:3n-6	0.160	0.317	0.288	0.018	<0.001	<0.001
C20:4n-6	11.79	7.69	15.10	0.776	<0.001	0.003
C22:4n-6	0.177	0.512	N.D.	0.042	<0.001	–
C18:3n-3	0.762	1.596	1.078	0.166	<0.001	<0.001
C20:3n-3	0.166	0.156	0.314	0.033	0.819	0.002
C20:5n-3	0.103	0.263	0.507	0.037	0.003	0.008
C22:5n-3	0.320	1.048	0.489	0.051	<0.001	0.021
C22:6n-3	2.232	2.142	2.795	0.207	0.763	0.057

ND, not detected; FCQ/JQ, Contrast of farmed quail species; FCQ/WCQ, Contrast of origins within Common Quail (Farmed vs. Wild specimens).

The evaluation of the species influence on meat FA profile revealed that CQ presented higher ($P = 0.006$) content of total saturated fatty acids (**SFA**; a superiority of 10.9%) and lower ($P < 0.001$) content of total PUFA (an inferiority of 10.7%) than their JQ counterparts. The difference observed between quail species on PUFA occurred on both n-3 ($P < 0.001$) and n-6 ($P = 0.005$) families, and the JQ revealed a superiority over CQ in both PUFA families, more pronounced in the n-3 (superiority of 44.8%) than on n-6 family (superiority of 9.3%).

The analysis of individual FA shows that, among farmed quail, the CQ breast presented significant higher contents of C18:0 (stearic acid; $P < 0.001$), C18:1*cis*-11 (*cis*-vaccenic acid; $P < 0.001$) and C20:4n-6 (arachidonic acid; $P < 0.001$) than JQ counterparts, but displayed lower contents of C17:0 (margaric acid; $P = 0.001$), C20:1 *cis*-9 (gondoic acid; $P = 0.040$), C18:2n-6 (linoleic acid; $P < 0.001$), C20:2n-6 (eicosadienoic acid; $P < 0.001$), C20:3n-6 (dihomo-γ-linolenic acid; $P < 0.001$), C22:4n-6 (adrenic acid; $P < 0.001$), C18:3n-3 (linolenic acid; $P < 0.001$), C20:5n-3 (eicosapentaenoic acid;

Table 3. Breast meat fatty acid partial sums (expressed as g/100 g of total fatty acids), fatty acid ratios and lipid quality indices from common quail (*Coturnix coturnix;* CQ) obtained from farmed (FCQ) and wild specimens (WCQ) and farmed Japanese quail (*Coturnix japonica domestica;* JQ).

	Farmed quail		Wild quail		Contrasts	
	CQ	JQ	CQ	SEM	FCQ/JQ	FCQ/WCQ
Sums						
$\sum$ SFA	32.25	29.08	33.89	0.785	0.006	0.141
$\sum$ MUFA	22.04	19.72	24.67	1.45	0.262	0.202
$\sum$ PUFA	45.70	51.20	41.44	1.06	<0.001	0.005
$\sum$ n-6 PUFA	42.05	45.97	36.31	0.942	0.005	<0.001
$\sum$ n-3 PUFA	3.53	5.11	5.06	0.308	<0.001	0.001
Ratios						
P/S	0.755	1.075	1.602	0.061	<0.001	<0.001
n-6/n-3	12.58	9.54	8.08	0.669	0.002	<0.001
h/H	4.09	4.14	4.27	0.209	0.889	0.556
Indices						
AI	0.241	0.244	0.239	0.009	0.851	0.833
TI	0.749	0.595	0.738	0.023	<0.001	0.748
PI	100.8	99.52	113.1	4.147	0.838	0.042

Abbreviations: AI, atherogenicity index; FCQ/JQ,Contrast of farmed quail species (Common vs. Japanese); FCQ/WCQ, Contrast of origins within Common Quail (Farmed vs. Wild specimens); h/H, hypocholesterolemic/hypercholesterolemic ratio; MUFA, monounsaturated fatty acids; PI, peroxidability index; PUFA, polyunsaturated fatty acids; SFA, saturated fatty acids; TI, thrombogenicity index.

$P = 0.003$), and C22:5n-3 (docosapentaenoic acid; $P < 0.001$).

The evaluation of the origin effect within CQ, showed that farmed CQ displayed higher contents of total PUFA ($P = 0.005$) and total n-6 PUFA (<0.001) than their wild counterparts (a superiority of 10.3 and 15.8%, respectively), but wild CQ exhibited higher n-3 PUFA content ($P = 0.001$; a superiority of 43.3%). The analysis of individual FA, shows that higher total n-3 PUFA in wild specimens was a consequence of significant ($P < 0.05$) higher contents in four n-3 PUFA, namely C18:3n-3 (alpha-linolenic acid), C20:3n-3 (eicosatrienoic acid), C20:5n-3 (eicosapentaenoic acid), C22:5n-3 (docosapentaenoic acid), and a strong statistical tendency ($P = 0.057$) associated to C22:6n-3 (docosahexaenoic acid). On the other hand, farmed quail superiority on n-6 PUFA was consequence of higher contents of C18:2n-6 (linoleic acid), which was not observed in the other fatty acids of the n-6 PUFA family. Moreover, the adrenic acid (C22:4n-6) was detected on farmed CQ, but not on wild CQ. The total SFA and total MUFA contents on CQ breast meat showed no significant differences ($P > 0.05$) between farmed and wild specimens, averaging 33.1 and 23.4 g/100 g of total FA, respectively. Despite that, the wild CQ presented significantly ($P < 0.05$) higher contents of 3 individual SFA (C17:0, C18:0, C21:0) and one individual MUFA (C17:1 *cis*-9) than their farmed counterparts. Moreover, the anteiso margaric and the docosanoic acids (C17:0 anteiso and C22:0) were only detected on farmed CQ, but not on wild CQ.

Meat's FA profile gathers the FA of the neutral lipid fraction (majorly composed by triacylglycerols) and the polar lipid fraction (generally composed by phospholipids). Within the same muscle or meat portion, the phospholipids content is quite stable, but the triacylglycerols content is variable, depending on the amount of fat depots. Consequently, an increase in fat depots results in higher proportion of the FA predominantly stored on the triacylglycerols and the dilution of those FA primarily found on phospholipids. Otherwise, long fasting periods result in the reduction of fat depots and lower contents of those FA predominantly stored on the triacylglycerols and increased proportion of FA found in phospholipids. Quail's breast meat total lipids encloses on average 3.6 to 9.2 % of phospholipids and 59.7 to 63.1% of triacylglycerols (El-Dengawy and Nassar, 2001).

To the best of our knowledge, there is quite little information regarding the FA composition of quail breast meat polar and neutral lipid fractions. In the available literature, Ben-Hamo et al. (2013) were the only ones studying the issue on quail's breast meat, but their FA profile is quite short, with just 13 individual FA. Similar information was published on chicken breast meat, but presented just 16 individual FA (Marion and Woodroof, 1965). Therefore, the available data on FA distribution between polar and neutral lipid fractions is quite limited for comparison with the FA profile presented herein, comprising 28 individual FA.

The comparison of quail's FA profile presented herein with their results (Marion and Woodroof, 1965; Ben-Hamo et al., 2013) reveals some discordant information. Since, breast meat from CQ presented higher contents of C18:0 and C20:4n-6, but exhibited lower contents of C18:2n-6, C18:3n-3, C20:3n-6, and C20:5n-3 than their JQ counterparts. Such result is associated with contradictory information, since C18:0, C18:2n-6, C20:3n-6, and C20:5n-3 are predominantly found on the polar lipid fraction, while C18:3n-3 and C20:4n-6 are predominantly found on the neutral lipid fraction. Therefore, differences in the proportion of polar/neutral lipid fraction cannot explain differences observed on individual FA. Regarding five of the individual FA involved in significant differences ($P < 0.05$) between quail species (C17:0, C18:1 *cis*-11, C20:1 *cis*-9, C20:2n-6, and C22:5n-3) there is no available information in this species relatively to their distribution between the polar and neutral lipid fractions.

Fatty acids present in quail breast meat are originated from dietary FA, by de novo synthesis and endogenous regulation (Price, 2010). In this study, differences between quail species (CQ vs. JQ) on the breast meat FA profile cannot be associated with different dietary FA since farmed quails received equal feeding, independently of the quail species, and shared similar production conditions and management. To conclude, we should say that differences between species (CQ and JQ) should have a genetic basis and are the result of differences in endogenous regulation of FA synthesis (de novo synthesis) or β-oxidation.

Concerning the differences on breast meat FA profiles of farmed and wild CQ specimens, they should not be genetic dependent, since the comparison made within a single species, the CQ (*C. coturnix*). Nevertheless, there is the possibility of minor differences in the genome of farmed and wild quail populations. Nevertheless, differences in the diet between wild and farmed species are obvious, consequently differences in the diet's FA profile are also expectable, but we have no information on wild CQ diet's FA profile. The quails age could also influence the composition on breast meat FA profile, such has been previously reported in Japanese quail (Boni et al., 2010; Khalifa et al., 2016), but unfortunately we could not determinate the wild CQ's age.

In Spain, the majority of quail sold for restocking purposes were not CQ (Sanchez-Donoso et al., 2012). No increase in non-native or hybrid numbers was detected during the study period, indicating that restocking poses no serious conservation problems at present (Puigcerver et al., 2007).

Despite all the considerations previously presented, the comparisons (CQ/JQ and FCQ/WCQ) showed remarking similarities in the results, once the contents of C18:0, C18:2n-6, C20:3n-6, C20:4n-6, C18:3n-3, C20:5n-3, and C22:5n-3 were associated with significant differences in both comparisons. Even so, we could not establish cause-effect relationship to explain such resemblances.

Beyond significant differences observed in individual FA, the prime FA of SFA, MUFA, and PUFA, were the

same ones independently of the quail group. Together the palmitic and stearic acids of SFA, the oleic and *cis*-vaccenic acids of MUFA and the linoleic and arachidonic acids of PUFA, were accountable for 91.2 to 93.4% of total FA in quail breast meat, which is close to the range of values previously published on quail breast meat (86.2−91.8% of total FA) (Ertas et al., 2005; Genchev et al., 2008; Gecgel et al., 2015; Sabow, 2020). Independently of the species and origin effects, the quail breast meat FA profile is dominated by the UFA, which were accountable for 66.1 to 70.9% of total FA, among which PUFA were responsible for 41.4 to 51.2% of total FA (62.7−72.2% of total UFA). Despite its small body weight, quail is a quite interesting meat option, based on their FA profile.

Among commercial poultry meats, the quail breast meat presents high PUFA proportion, similar to turkey breast, the highest proportion of n-3 PUFA among all commercial poultry species and high proportion of UFA, as observed in broiler breast, as it is possible to confirm accessing the United States Food Data Base (USDA, 2020).

The comparison of breast meat from wild CQ with the breast meat from other game fowl species, such as pheasant and red-legged partridge (Quaresma et al., 2016; Antunes et al., 2019), shows that wild quail presents considerably higher proportion of PUFA (41.4 vs. 30.0−32.6% of total FA). Herein, we show that the PUFA content of farmed JQ is even higher (51.2% of total FA). Therefore, it is possible to say that quail breast meat obtained from farmed JQ is an excellent source of PUFA to the human diet. Moreover, the long-chain n-3 PUFA (C20:5n-3, C22:5n-3, and C22:6n-3) were accountable for 2.65−3.45% of total FA in farmed quails and 3.79% of total FA in wild quail, which is considerably above the values observed in meat from free-range broilers (1.76−2.09% of total FA) (Ponte et al., 2008).

Among farmed quails, JQ presented higher P/S and lower n-6/n-3 ratios and lower values of the TI than farmed CQ. Therefore, JQ presented an healthier P/S and n-6/n-3 ratios, and better TI value than farmed CQ. On the other hand, the origin effect had a significant ($P < 0.001$) influence on the P/S and n-6/n-3 ratios and on PI ($P < 0.05$). The wild CQ specimens presented higher P/S and lower n-6/n-3 ratios and higher PI value, which represents a nutritional advantage over their farmed counterparts. The h/H ratio and the AI were not significantly influenced ($P > 0.05$) by neither the quail species nor by the origin within CQ. The results observed herein on farmed quail fatty acid ratios and lipid quality indices are within the range of values previously presented by Tavaniello et al. (2017).

Total Cholesterol, Total Vitamin E, and Individual Tocopherols Contents

The total cholesterol, total vitamin E and individual tocopherols contents in quail's breast meat is depicted on Table 4. The quail's breast meat total cholesterol content revealed no significant difference ($P = 0.666$) between farmed quail species, averaging 71.89 mg/100 g of meat. On the other hand, significant difference ($P = 0.031$) on breast meat total cholesterol was observed between wild and farmed specimens within CQ, farmed specimens presented a superiority of 12.9% on the total cholesterol content (more 8.32 mg/g of meat). The total cholesterol content observed in quail's breast meat obtained from farmed quails (71.1−72.7 mg/100 g of meat) is inside the range of cholesterol content previously presented in quail's breast meat (67.2 −76 mg/100 g of meat) for domestic quails (*Coturnix japonica*) (Ioniţă et al., 2010; Fakolade, 2015; Tavaniello et al., 2017; Cullere et al., 2018). Whereas, the total cholesterol content observed in wild CQ (64.4 mg/100 g of meat) is quite below that range, but we found no comparison for it. The total cholesterol content of poultry meat is influenced by several variables, as food composition (Skřivan et al., 2000; Ponte et al., 2004), and gastrointestinal microbiome (Al-Fataftah et al., 2013). Thus, differences in the diet composition, together with differences in gastrointestinal microbiome between wild and farmed quails could influence meat's cholesterol content of quail's breast meat.

Among farmed quails, the species had no significant influence ($P > 0.05$) on total vitamin E content neither on the contents of all individual tocopherols (α-, β-, and δ-tocopherols). The breast meat from farmed quail averaged 1.84, 1.46, 0.21, and 0.18 μg/g of meat of total vitamin E, α-tocopherol, β-tocopherol, and δ-tocopherol, respectively. However, within the CQ quail, the wild

Table 4. Breast meat total cholesterol, total vitamin E and tocopherols contents from common quail (*Coturnix coturnix;*CQ) obtained from farmed and wild specimens and farmed Japanese quail (*Coturnix japonica domestica;* JQ).

	Farmed quail		Wild quail		Contrasts	
	CQ	JQ	CQ	SEM	FCQ/JQ	FCQ/WCQ
Total cholesterol[1]	72.70	71.07	64.38	2.658	0.666	0.031
Total vitamin E[2]	1.86	1.82	2.67	0.294	0.894	0.059
α-Tocopherol[2]	1.49	1.43	2.40	0.294	0.874	0.033
β-Tocopherol[2]	0.22	0.19	0.08	0.012	0.102	0.001
δ-Tocopherol[2]	0.15	0.20	0.19	0.027	0.255	0.405

FCQ/JQ, Contrast of farmed quail species (Common vs. Japanese).
FCQ/WCQ, Contrast of origins within common quail (Farmed vs. Wild specimens).
[1]Expressed as mg/100 g of fresh meat.
[2]Expressed as μg/g of fresh meat.

specimens presented higher content of α-tocopherol (more of 61.1%; $P = 0.033$) and lower content of β-tocopherol (less 63.6%; $P = 0.001$) than farmed specimens, but no difference was observed on δ-tocopherol content ($P = 0.405$). Total vitamin E content within CQ was associated with a strong statistical tendency ($P = 0.059$). In this regard, the wild CQ presented higher total vitamin E content than their farmed counterparts (2.67 vs. 1.86; a superiority of 43.5%).

The α-tocopherol is the predominant vitamin E homologue in quail's meat, accountable for 78.6 to 89.9% of total vitamin E content. The supremacy of α-tocopherol (relatively to all other tocochromanols) has been demonstrated in the breast meat of other game species as red-legged partridge (Antunes et al., 2019), common pheasant (Quaresma et al., 2016) and also in broiler chickens (Ponte et al., 2008). The higher total vitamin E content observed on wild CQ relatively to the farmed specimens, is in agreement with the results previously observed on red-legged partridge (Antunes et al., 2019), and suggest that the diet of the wild specimens is richer in vitamin E than the concentrate feeding provided to the farmed counterparts.

Despite α-tocopherol predominance over the remaining tocochromanols, the total vitamin E (the sum of all identified tocochromanols) is the parameter with the highest biological value, since tocochromanols display comparable antioxidant activity to α-tocopherol (Müller et al., 2010). The total vitamin E content provides information regarding tissue antioxidant protection, while the PI evaluates the propensity to lipid oxidation, estimated by the tissue's FA unsaturation degree. Herein, no significant differences were observed between quail species on total vitamin E and PI (Tables 3 and 4), but the wild CQ presented simultaneously higher total vitamin E content and PI value, suggesting that an higher predisposition to oxidation is balanced with higher antioxidant protection.

Total AA Content and Profile

The quail breast meat total AA (**TAA**) content is depicted on Table 5, along with AA partial sums, namely indispensable amino acids (**IAA**), conditionally indispensable amino acids (**CIAA**), and dispensable amino acids (**DAA**), together with the amino acid ratios. The quail breast meat detailed AA profile is presented in Table 6.

Farmed quail species presented no significant ($P > 0.05$) differences in their TAA content, neither on AA partial sums. Nevertheless, their AA profile revealed two significant differences ($P < 0.05$) and five statistical tendencies ($0.05 < P < 0.10$) The CQ showed significant higher contents of phenylalanine (superiority of 18.6%; $P = 0.035$) but lower contents of serine (an inferiority of 35.5%; $P = 0.002$) relatively to JQ. The statistical tendencies detected between CQ and JQ, showed a superiority of CQ over the JQ in four AA, namely isoleucine (more 18.6%), methionine (more 13.8%), valine (more 14.3%), and arginine (more 16.3%), but presented lower content of glycine (less 43.8%).

Among CQ, the wild specimens presented a superiority of 9.6% on TAA (more 2.1 g/100 g of meat) over farmed specimens, a difference that was associated with a statistical tendency (P = 0.081). The superiority of

Table 5. Breast meat amino acid total content (TAA), partial sums and ratios from common quail (*Coturnix coturnix;* CQ) obtained from farmed (FCQ) and wild specimens (WCQ) and farmed Japanese quail (*Coturnix japonica domestica;* JQ), expressed as g/100 g of meat.

	Farmed		Wild		Contrasts	
	CQ	JC	CQ	SEM	FCQ/JQ	FCQ/WCQ
Total amino acid and partial sums of AA major groups						
∑ TAA	21.8	22.5	23.9	0.817	0.579	0.081
∑ IAA	8.34	8.11	9.38	0.385	0.672	0.062
∑ CIAA	4.50	4.88	4.63	0.304	0.384	0.767
∑ DAA	8.99	9.49	9.88	0.329	0.289	0.062
Ratios						
IAA/TAA	0.38	0.36	0.39	0.009	0.118	0.499
DAA/TAA	0.41	0.42	0.41	0.007	0.273	0.996
CIAA/TAA	0.20	0.21	0.19	0.009	0.465	0.502
IAA/DAA	0.93	0.86	0.95	0.031	0.105	0.616

FCQ/JQ, Contrast of farmed quail species (Common vs. Japanese).

FCQ/WCQ, Contrast of origins within common quail (Farmed vs. Wild specimens).

Abbreviations: CIAA, conditionally indispensable amino acids; DAA, dispensable amino acids; IAA, indispensable amino acids; TAA, total amino acids.

Table 6. Breast meat amino acid profile (expressed as g/100 g of meat) from common quail (*Coturnix coturnix;*CQ) obtained from farmed (FCQ) and wild specimens (WCQ) and farmed Japanese quail (*Coturnix japonica domestica;* JQ),

	Farmed		Wild		Contrasts	
	CQ	JQ	CQ	SEM	FCQ/JQ	FCQ/WCQ
Indispensable amino acids						
Histidine	0.06	0.07	0.07	0.006	0.161	0.077
Isoleucine	0.83	0.70	0.93	0.050	0.071	0.197
Leucine	1.99	1.76	2.13	0.099	0.110	0.334
Lysine	2.45	2.51	2.76	0.244	0.861	0.362
Methionine	0.66	0.58	0.70	0.030	0.078	0.361
Phenylalanine	0.78	0.67	0.85	0.039	0.035	0.262
Threonine	1.01	1.35	1.31	0.150	0.116	0.167
Tryptophan	0.08	0.07	0.10	0.010	0.304	0.330
Valine	0.48	0.42	0.54	0.029	0.099	0.173
Conditionally indispensable amino acids						
Arginine	2.36	2.03	2.64	0.120	0.056	0.108
Glycine	0.54	0.96	0.57	0.152	0.053	0.877
Proline	0.50	0.53	0.30	0.068	0.733	0.044
Tyrosine	1.10	1.35	1.12	0.146	0.232	0.937
Dispensable amino acids						
Alanine	1.77	1.70	1.92	0.113	0.647	0.407
Asparagine	1.25	1.33	1.42	0.063	0.404	0.073
Aspartic acid	2.58	2.71	2.69	0.133	0.489	0.589
Glutamic acid	2.74	3.02	3.19	0.193	0.307	0.099
Hydroxiproline	0.38	0.37	0.25	0.038	0.863	0.019
Ornitine	0.07	0.05	0.14	0.045	0.860	0.205
Serine	0.20	0.31	0.27	0.024	0.002	0.035

FCQ/JQ, Contrast of farmed quail species (Common vs. Japanese).

FCQ/WCQ, Contrast of origins within common quail (Farmed vs. Wild specimens).

wild over farmed specimens in TAA is sustained by 2 other statistical tendencies: on IAA (more 12.5%; $P = 0.062$) and DAA (more 9.9%; $P = 0.062$). The origin's influence was limited to the contents of 3 amino acids: proline ($P = 0.044$), hydroxyproline ($P = 0.019$), and serine ($P = 0.035$). In this respect, farmed CQ presented higher contents of proline and hydroxyproline (a superiority of 66.7 and 52.0%, respectively), but presented lower contents of serine (an inferiority of 25.9%) than wild CQ.

Beyond the species and origin effects, the quail breast meat AA profile presented, independently of the quail's group, 20 amino acids, 9 IAA, 4 CIAA and 7 DAA. The IAA were accountable for 36.0 to 39.2% of TAA, CIAA were responsible for 19.4 to 21.7% of TAA and DAA were liable for the remaining 41.2 to 42.2% of TAA. Among individual AA, glutamic acid, aspartic acid, lysine, and arginine were the predominant AA in quail breast meat, among them, the glutamic acid was the prime AA in quail's meat (accountable for 12.6−13.4% of total AA, or 2.74−3.19 g/100 g of meat), independently of the quail's group. In farmed quail, and independently of the species, the aspartic acid (11.8−12.0% of total AA) and lysine (11.2%) were the second and third most predominant AA, respectively. However, in wild CQ, these 2 AA inverted the predominant ranking order. The arginine was for all quail groups, the least predominant of the 4 prime AA, liable for 9.0 to 11.0% of total AA.

The quail species in comparison and different origins within CQ showed no significant differences ($P > 0.05$) on all the AA ratios tested herein (Table 5). The IAA/TAA, CIAA/TAA and DAA/TAA ratios in quail breast meat averaged 0.38, 0.20, and 0.41, respectively, and the IAA/DAA ratio averaged 0.91, which means that quail's breast meat AA profile is dominated by the DAA (41% of total TAA), followed by the IAA (38% of TAA) and the CIAA (20% of TAA). The ratio IAA/DAA shows that IAA stand on average for 91% of the DAA.

The predominance of glutamic acid over all other AA and the predominance of DAA over IAA are in accordance with previous studies on quail's meat AA profile (El-Dengawy and Nassar, 2001; Genchev et al., 2008; Khalifa et al., 2016; Nasr et al., 2017), and also in agreement with the composition of breast meat from other poultry species as chicken (Gálvez et al., 2020), turkey (Gálvez et al., 2018) and Pekin and Muscovy ducks (Aronal et al., 2012).

The similarities observed on quail breast meat amino acid profile, partial amino acid sums and amino acid ratios between CQ and JQ and between farmed and wild specimens of CQ exceed by far the differences observed. Such similarities in the amino acid composition of breast muscle from different quail groups are in agreement with the results obtained in other comparisons performed with poultry, which means that the amino acid profile of breast meat is scarcely influenced by factors such as diet, breed, production system or slaughter age (Gálvez et al., 2020). The similarities found in the amino acid profile of breast meat from different quail species or in different populations of the same species are probably consequence of: 1) genes expressing the predominant structural proteins in muscle and prime enzymes involved in muscle physiology are well conserved between different quail species and populations; 2) breast muscles from different populations exhibit similar levels of gene expression. Such suggestion has been previously used by De Smet and Vossen (2016), in a broader context.

To evaluate the nutritional quality of quail's breast meat, we need to know the daily protein requirements for maintenance in healthy adults, which has been established in 0.66 g of protein/kg of body weight/day (considering 27 and 73% of IAA and DAA, respectively) (WHO/FAO/UNU and Expert Consultation, 2007). Therefore, a healthy adult human, weighting 70 kg, requires on a daily basis 12.6 g of IAA plus 33.6 g of DAA, which represent a total of 46.2 g of TAA (WHO/FAO/UNU and Expert Consultation, 2007). Considering quail breast meat TAA content, the previously presented daily protein requirements for maintenance in healthy adult (weighting 70 kg) and meat digestibility, the fulfilment of the daily needs exclusively with quail breast meat protein, as the single protein source in the diet, would require 205.6 to 225.5 g of meat to supply the daily requirements on TAA. However, such evaluation remains incomplete, it is essential to evaluate if the total amount of protein required is enough to fulfill the requirement pattern for all individual indispensable AA. Such evaluation was performed using the information presented herein on quail breast meat AA profile and actual data on adult indispensable amino acid requirements (WHO/FAO/UNU and Expert Consultation, 2007), and the result is present in Figure 1. Thus, the amount of protein required, on a daily basis, by an healthy adult human weighting 70 kg (46.2 g/day), presented exclusively as quail's breast meat, is not enough to provide the daily requirements on histidine (15.1−16.6%), valine (38.3−48.7%), and tryptophan (41.5−58.7%). CQ breast meat, independently of the origin, was able to provide the daily requirement of isoleucine (104.7−109.1%), but that was not the case for JQ, which provided just 82.9% of the nutritional needs on isoleucine. On the other hand, breast quail meat was a good provider of leucine (106.0−127.7%), methionine (128.8−156.1%), threonine (166.2−208.6%), phenylalanine plus tyrosine (182.4−188.9%), and lysine (198.2−215.8%).

Consequently, the present study reveals that, tryptophan, valine and histidine are limiting AA in quail's breast meat. Limiting amino acids are by definition indispensable amino acids in digested protein that are in shortest supply relative to body requirements for absorbed amino acids (Hambræus, 2014).

In foods regarded as a potential protein source to human diet, four indispensable amino acids dominate as limiting AA: lysine and threonine in cereals, sulfur amino acids in legumes, and tryptophan in maize (Hambræus, 2014). Considering the limiting AA in vegetables, we could say that cereals, legumes and the quail breast

meat, as a food source, could complement each other and provide a complete AA profile to humans. Histidine and tryptophan are, with no doubt, the most limiting IAA in quail's meat, and these concluding remarks are applicable to the breast meat obtained from all quail groups in comparison. Nevertheless, the AA profile of the diet, based on a mixture of protein sources from vegetable and animal food products is of greater interest than that from single protein sources (Hambræus, 2014).

Mineral Profile

Essential minerals, including the trace elements, are inorganic elements regarded as nutritionally essential to maintain normal physiological functions. Essential minerals are traditionally divided into macrominerals, those required in amounts of 100 milligrams or more per day and microminerals or trace minerals, which are also necessary, but in a smaller amount (below 100 milligrams). Despite this categorization, essential minerals are all vital to homeostasis, they are just required in different amounts. Macrominerals, include calcium, chlorine, magnesium, phosphorus, potassium, sodium and sulphur, while microminerals include, at least, the transition metals (vanadium, chromium, manganese, iron, cobalt, copper, zinc, and molybdenum) and the non-metals (selenium, fluorine, and iodine).

The essential mineral contents in quail breast meat are presented in Table 7, and the comparison of farmed quail species shows the existence of significant differences in 3 macrominerals, namely phosphorous ($P = 0.032$), potassium ($P = 0.015$) and sulphur ($P = 0.033$), and the occurrence of significant differences in all 4 microminerals ($P = 0.005$ for zinc and < 0.001 for others). In this regard, CQ displayed higher contents of phosphorous (more 2.8%), sulphur (more 12.7%), copper (more 129.3%), iron (more 148.8%), manganese (more 35.7%), and zinc (more 11.0%), but lower content of potassium (less 8.3%) than their JQ counterparts.

The comparison of farmed and wild CQ specimens revealed significant differences in calcium ($P < 0.001$), magnesium ($P = 0.024$), phosphorous ($P = 0.013$), and sodium ($P = 0.004$). Farmed CQ presented higher contents of magnesium and phosphorous (a superiority of 4.0 and 3.2%, respectively), but displayed lower contents of calcium and sodium (an inferiority of 5.5 and 10.0%) than their wild counterparts.

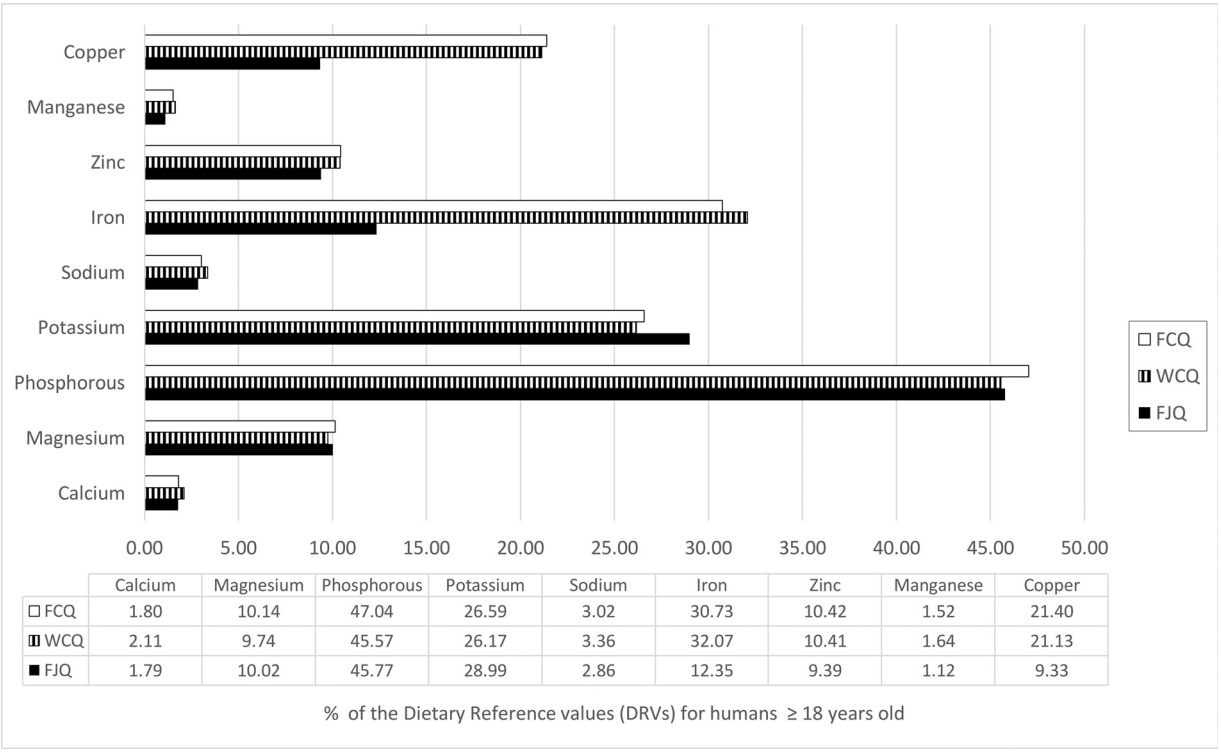
Meat is an important dietary source of bioavailable essential minerals, particularly magnesium, phosphorus, iron, selenium, zinc, and copper (Wyness et al., 2011; Pereira and Vicente, 2013). The evaluation of quail's meat as source of essential minerals to human diet was made using the Dietary Reference values (**DRVs**) established by the European Food Safety Authority (**EFSA**), and is presented in Figure 2. Data analysis (Figure 2) shows that 100 g of quail breast meat provide almost half of dietary needs of phosphorous (45.8−47.0% of the DRVs) and provides an important amount of DRVs of iron (12.4−32.1% of the DRVs), copper (9.3−21.4% of the DRVs), but in this 2 microminerals, JQ offers less than half of the DRVs that is provided by the CQ, independently of their origin. Quail's meat offers also zinc (9.4−10.4% of the DRVs) and magnesium (9.7−10.1% of DRVs). Meat's mineral composition shows that among farmed quails, the CQ is a better source of iron, copper and zinc than their JQ counterparts. Significant differences observed between farmed and wild specimens of CQ were presented in Table 7, when mineral contents are expressed in mg/100 g of meat, but such differences resulted in minor differences when data is presented as % of DRVs (Figure 2). In % of the DRVs, the differences on calcium, magnesium, phosphorous and sodium represent 0.31, 0.40, 1.47, and 0.34% of the DRV, respectively.

The comparison of quail breast meat mineral contents with the breast meat of other poultry species reveals that CQ presents the highest iron contents, above: duck (4.1−4.2 mg/100 g of meat) (Kokoszyński et al., 2019); pheasant (1.2 mg/100 g of meat) (Franco and Lorenzo, 2013); turkey (0.5−0.6 mg/100 g of meat), and broiler chickens (0.34−0.44 mg/100 g of meat) (Gálvez et al., 2018, 2020). As source of copper and zinc it is not as good supplier as the duck (0.4−0.5 and 1.1

Table 7. Breast meat mineral profile (expressed as mg/100 g of meat) from common quail (*Coturnix coturnix;*CQ) obtained from farmed (FCQ) and wild specimens (WCQ) and farmed Japanese quail (*Coturnix japonica domestica;* JQ).

	Farmed quail		Wild quail		Contrasts	
	CQ	JQ	CQ	SEM	FCQ/JQ	FCQ/WCQ
Macrominerals						
Calcium	18.02	17.87	21.10	0.505	0.824	<0.001
Magnesium	40.54	40.09	38.97	0.479	0.503	0.024
Phosphorous	329.3	320.4	319.0	2.867	0.032	0.013
Potassium	531.8	579.8	523.36	13.55	0.015	0.661
Sodium	45.36	42.9	50.38	1.186	0.149	0.004
Sulphur	691.9	604.3	703.7	11.67	0.033	0.619
Microminerals						
Copper	0.321	0.140	0.317	0.011	<0.001	0.783
Iron	4.610	1.853	4.810	0.190	<0.001	0.459
Manganese	0.076	0.056	0.082	0.002	<0.001	0.159
Zinc	0.938	0.845	0.937	0.022	0.005	0.989

FCQ/JQ, Contrast of farmed quail species (Common vs. Japanese).
FCQ/WCQ, Contrast of origins within common quail (Farmed vs. Wild specimens).



	Calcium	Magnesium	Phosphorous	Potassium	Sodium	Iron	Zinc	Manganese	Copper
FCQ	1.80	10.14	47.04	26.59	3.02	30.73	10.42	1.52	21.40
WCQ	2.11	9.74	45.57	26.17	3.36	32.07	10.41	1.64	21.13
FJQ	1.79	10.02	45.77	28.99	2.86	12.35	9.39	1.12	9.33

Figure 2. The contribution of 100 g of quail breast meat from common quail obtained from farmed (FCQ) and wild (WCQ specimens and farmed Japanese quail (JQ) to the accomplishment of the dietary reference values (DRVs) for essential minerals.

−1.2 mg/100 g of meat, respectively) (Kokoszyński et al., 2019), but represents an excellent source of calcium, magnesium, phosphorus, potassium and sodium, displaying an higher concentration of these minerals than most of the poultry species.

CONCLUSIONS

Regarding the quail species influence on meat composition, JQ revealed a better lipid composition characterized by significant lower SFA and higher PUFA contents and significantly healthier P/S and n-6/n-3 ratios and TI value. The absence of differences observed on amino acids partial sums and ratios reveals equality between species on protein nutritional quality. On the other hand, CQ proved to be a better source of copper, iron, manganese, and zinc than JQ.

The comparison of farmed and wild specimens within CQ, showed that wild birds presented lower total cholesterol and total PUFA and higher n-3 PUFA contents, which contributed to healthier P/S and n-6/n-3 ratios, but worst PI. The wild species revealed higher α-tocopherol content. Differences observed on their mineral composition counterbalance each other.

Under intensive production system and similar feeding and management conditions, the JQ reveals a better lipid profile, while the CQ presented a better mineral profile. The comparison of wild and farmed species within CQ reveals more similarities than differences.

Quail's meat presents good nutritional quality and introduces variability to human's diet, which is much valued by the consumers.

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DISCLOSURES

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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