Scientific Papers. Series D. Animal Science. Vol. LXVII, No. 2, 2024
ISSN 2285-5750; ISSN CD-ROM 2285-5769; ISSN Online 2393-2260; ISSN-L 2285-5750

EFFECT OF SEX ON CHEMICAL COMPOSITION AND MEAT QUALITY OF JAPANESE QUAIL (*Coturnix japonica*)

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Abstract

Japanese quail (Coturnix japonica) is used for egg production, as laboratory animals, in amateur breeding as an ornamental bird and for meat production. Quail meat is becoming more and more popular in Poland. The aim of the study was to analyze the chemical composition of Japanese quail meat from a Polish breeder, taking into account the sex of the birds. The research was carried out on 20 chilled quail carcasses - 10 females and 10 males. Meat pH, basic chemical composition, amino acid levels, fatty acid profile, cooking loss and color parameters were determined in the breast muscle. The analyzed meat was characterized by high cooking loss. The chemical composition of quail meat, especially the high protein content and low fat content, make this meat characterized by a low caloric value. The meat of males was characterized by a higher content of lysine and glutamic acid and a lower content of histidine, arginine, tyrosine and methionine compared to the meat of females. The gender of quails had no significant impact on meat quality parameters.

Key words: *chemical composition, color, Japanese quail, meat, quality.*

INTRODUCTION

The common quail (*Coturnix coturnix*) is a representative of the genus Quail (*Coturnix*) belonging to the family Curlews (Phasianidae) and order Burrowing Owls (Galliformes), which does not lead a sedentary lifestyle and spends the winter in the Sahel (Kosicki et al., 2014). In Poland, it is under strict species protection. It is on the Red List of Polish Birds, where it has been classified as a vulnerable species (VU), and agricultural intensification is considered to be the cause of its endangerment. The Japanese quail (*Coturnix japonica*) belongs to the same genus as the European field quail (*C. coturnix*). It was domesticated in the sixteenth century in China, but it was not until the twentieth century that breeding work began in Japan to improve the utility value of these birds. In Poland, interest was taken in the breeding of Japanese quail in 1963 after the first flocks were imported by Professor Jerzy Szuman. Since the 1990s, a steady increase in interest in this species has been observed (Kraszewska-Domańska, 1978). Japanese quails are used in several ways. Meat use is of interest to breeders in China, Europe and the USA, while quail egg production takes place mainly in China, Japan and Brazil (Carvalho et al., 2020; Ionita et al., 2011; Minvielle, 2004). In France and the USA, Japanese quail are used for hunting purposes (Minvielle, 2004). Established colour varieties are of importance for amateur breeding, also from an exhibition point of view, especially in the USA and Western Europe. Japanese quails are also used as a model organism and laboratory animal in many research centres (Quaresma et al., 2022). The main producers of quail meat are China, the USA and Europe (Tserven-Gousi & Yannakopoulosa, 1986). Quail meat is tasty, tender and healthy, as well as being lean and low in calories. The quality and composition of this meat depends, among other factors, on the variety, slaughter age, and diet (Genczew, 2003; Jakubowska & Karamucki, 2020; Vargas-Sánchez et al., 2019; Sabow, 2020). Pharaoh quails, selected in the USA, are characterised by their wild colouration and highest body weight of all varieties. The breed is suitable for broiler production and is characterised by a very well-developed pectoral muscle. Females are larger and heavier than males (Kraszewska-Domańska, 1978).

The aim of this study was to analyse the effect of the sex of Pharaoh quails, on the chemical composition and quality of meat.

MATERIALS AND METHODS

The study was conducted on 20 chilled quail carcasses (10 females and 10 males) of the Pharaoh breed, slaughtered at 10 weeks of age. The birds were fed Starter feed (protein 25.5%, lysine 16.7 g, methionine 7 g, threonine 9 g, 12.5 MJ of metabolizable energy) followed by Grower feed (protein 22%, lysine 14.4 g, methionine 6 g, threonine 7.6 g, 12.15 MJ of metabolizable energy). Quails were slaughtered in an official slaughterhouse, and stored under refrigeration (<5°C) during 24 h preceding the delivery at the laboratory. Carcasses were weighed, and 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. Thermal losses during roasting were determined on the right breast muscle. Thermal treatment in an electric furnace was carried out at a temperature of 180 ± 2°C until reaching a muscle temperature of 72 ± 2°C. The temperature inside the muscles was measured with a digital thermometer using a probe needle. After heat treatment and cooling on ice, cooking loss was determined from meat weight loss. The left breast muscle was subjected to physical and chemical analysis. The following analyzes were performed in raw meat: (all analyzes were performed in duplicate):

• Water content according to the standard PN-ISO 1442:2000 (Polish Committee for Standardization, 2013);

• Fat content according to the standard PN-ISO 1444:2000 (Polish Committee for Standardization, 2013) (Tecator's Soxtek HTZ-2 apparatus);

• Protein content by Kjeldahl method PN-75/A-04018 (Polish Committee for Standardization, 2002) (Büchi Labortechnik AG, a B426 mineralization furnace and a B339 distiller made in Switzerland);

• Total ash content according to the standard PN-ISO 936:2000 (Polish Committee for Standardization, 2013);

• Total carbohydrates content was calculated assuming that the all total solids and water stand for 100%.

The energy value was calculated using conversion factors, according to the Guide to Regulation (EC) No. 1169/2011.

Meat colour was determined using a Konica Minolta CM-600d spectrophotometer (Minolta Co., Ltd., Tokyo, Japan) with a 50-mm diameter measuring head in the CIE L*a*b* system, where the L* parameter corresponds to the degree of lightness (L* = 0: black, L* = 100 : white), a* and b* are colour components (a*>0 red, a*<0 green, b*>0 yellow, b*<0 blue). The chromametre was calibrated against a white tile (Y = 93.8, x = 0.3136, y = 0.3192) (CIE, 1986).

Fatty acid profile was determined by two analytical methods: lipid extraction from meat according to Folch et al., (1957), and esterification according to AOAC (1995). The fatty acid methyl esters were separated by gas chromatography using a Trace GC Ultra (Thermo Electron Corporation, Milano, Italy) with a flame ionization detector (FID) using Supelcowax 10 column (30 m × 0.25 mm × 0.25 µm). The separation conditions were as follows: helium as the carrier gas, 1 mL/min; FID detector temp. 250ºC; injector temp. 220ºC; oven temp. Was held at 160ºC and increased (3ºC/min) to 210ºC (35 min); split ratio 10 mL/min. To the obtained fat (around 10 mg), 0.5 mL of 0.5M KOH in methanol was added and heated at 85ºC, after which 1 mL of 12% BF3 in methanol was added and reheated at 85ºC. After cooling to room temperature, 1 mL of hexane and 5 mL of saturated NaCl solution were added. 1 µL of the solution was injected on the chromatograph.

Individual fatty acid methyl esters (FAME) were identified by comparing with a standard mixture of 37 FAME components (Supelco Bellafonte PA, USA, Sigma-Aldrich Co. St. Louis, MO, USA) and CLA isomers (Sigma-Aldrich Co. St. Louis, MO, USA).

Determination of the amino acid profile

Determination of the amino acid profile was carried out by reversed-phase liquid chromatography using the ACCQ Tag analytical kit from Waters (Millford, MA, USA). Hydrolysis of approximately 30 mg of the sample was carried out with 4 mL of 6M HCl (POCH, Poland) and the addition of 15 µL of phenol (Sigma Aldrich St. Louis, MO, USA) at 110°C for 24 hours. The sample was sealed under a nitrogen atmosphere. The resulting hydrolysate

was filtered through 0.45 µm syringe filters and then dried using nitrogen. The sample thus prepared, after appropriate dilution, was subjected to an derivatization procedure according to Waters' recommendations. For this purpose, 10 µL of the sample was mixed with 70 µL of borate buffer (pH in the range 8.2 to 9.0) and then 20 µL of 6-aminoquinolyl-N-hydroxysuccinimidylcarbamate (AQC) reagent at a concentration of 3 mg/mL acetonitrile was added. Standards (company Waters USA) were handled analogously. Chromatographic separation was performed using a liquid chromatograph from Thermo Scientyfic: a Dionex Ultimate 3000 equipped with an LPG - 3400 SD gradient 4-channel pump, a WPS 3000 TSL autosampler and a FLD-3400RS 4-channel fluorescence detector. The column used for the analysis was a Nova -Pak C 18, 4 µm (150x 3.9 mm) column from Waters. Separation temperature 37°C. Elution was carried out in a two-component gradient and a flow rate of 1 mL/min: eluent A acetate-phosphate buffer pH = 5.2, B acetonitrile/water 60:40. Gradient: 0 min - 100% A, 0.5 min - 98% A, 15 min - 93% A, 19 min - 90% A, 32 min - 67% A, 33 min - 67% A, 34 min - 0% A, 37 min -0% A, 38 min - 100% A, 64 min - 100% A, 65 min - 0% A. Detection Excitation wavelength 250, Emission wavelength 395. Quantitative analysis was performed using 1-point calibration (using an analytical standard of 100 pmol each). Development of results using Chromeleon 7.0 software. All reagents from Waters (Millford, MA, USA) kit: Standards, borate buffer, AQC. Eluent acetate-phosphate buffer (pH 5.2). Water, Acetonitrile Sigma Aldrich (St. Louis, MO, USA)

Statistical analysis

The results were analyzed with ANOVA and present as means with standard deviation. The calculations were performed with licensed software - Statistica version 13.1. (2019). The least square means and the standard deviation (SD) are presented in tables. Significance was declared at $P< 0.05$.

RESULTS AND DISCUSSIONS

Pharaoh quails are among the meat breeds suitable for broiler production. The carcass weight of 10-week-old birds ranged from 163 g in males to 179.8 g in females (Table 1). The content of hydrogen ions in the breast muscles after 24 hours of cooling (pH_{24}) was within the limits 5.70-5.71 and was similar to the results obtained by Genchev et al. (2005), who analyzed the pectoral muscles of 31-day old Pharaoh quails (5.61-5.66). These results are consistent with other publications in which the pH range of quail meat ranges from 5.30 to 6.58 (Genchev et al., 2008; Zerehdaran et al., 2012; Narinc et al., 2013). The breast muscles of males were characterized by a non-significantly higher value of color parameters a* and b*. According to Wilkanowska & Kokoszyński (2011), the L* value (color lightness) of breast muscles of Pharaoh quails was higher in birds slaughtered at 33 days of age (57.0). In quails reared until the 56th day of life, Boni et al. (2010) found lighter muscles (L*-61.54), greater yellowness (b*-19.81), less redness (a*-6.84) compared to the birds analyzed in our study. Cooking loss of the breast muscles of female pharaoh quails was greater (35.2%) than that of males (34.11%). These results are similar to those obtained by Tarasewicz et al. (2007) (35.6-35.8%) and Gardzielewska et al. (2012) (35.6-37.37%), but too high compared to the study of Kaye (2014), who found thermal leakage of 17.7-20.3%, the study of Nasr et al. (2017) (19.21-20.6%) and the study of Genchev et al. (2008) - 21.68% for quail pectoral muscle.

Table 1. Slaughter and quality characteristics of meat from breast muscles of Japanese quails

Indications	Gender		Significance of differences
	female ♀	male ♂	
Carcass weight (g)	179.8±10.28	163.0±15.59	NS*
pH_{24}	5.71±0.08	5.70±0.10	NS
Color parameters			
L*	33.20±2.08	32.02±2.54	*
a*	11.40±0.96	12.65±1.17	*
b*	8.95±0.82	9.05±0.96	NS
Cooking loss (%)	35.20±3.86	34.11±2.67	*

Notes: NS - the difference is not significant; *- the difference is determined at P<0.05.

Previous research has shown that the quality and composition of quail meat is influenced by many factors, such as genotype of birds (Genchev et al., 2005; Alkan et al., 2010), divergent selection (Maiorano et al., 2009), feeding (Gardzielewska et al., 2005), sex (Genchev et al., 2008), age (Tserveni-Gousi & Yannakopoulos, 1986), and stress (González et al., 2007). Table 2 shows the chemical composition of breast muscles of Japanese quails. The meat of the quails analyzed

contained 71.0-71.49% water. According to other authors, quail breast and leg meat can contain 71 to 74% water (Hamm et al., 1982; Maron-Fuenmayor et al., 2008). Particularly valuable characteristics of quail meat include its high content of protein, essential vitamins and fatty acids. The protein content of quail breast meat ranged from 24.26% (females) to 24.70% (males). This is a higher result compared to studies done by other researchers who found the protein content of quail meat at 17-23% (Hamm et al., 1982; Maron-Fuenmayor et al., 2008). The fat content of the meat of the quails analyzed ranged from 2.70 to 2.79%. Genchev et al., (2008) found 2.5% fat in the breast meat of Japanese quails, while in studies by other authors the fat content ranges from 2-8% (Hamm et al., 1982; Maron-Fuenmayor et al., 2008). Khalifa et al. (2016) showed that meat from older quails (8 months old) was characterized by higher caloric content compared to meat from 6-week-old quails. Ionita et al. (2011) showed that quail meat had lower caloric content in comparison to the chicken and duck meat. Quail meat, due to its low fat content, is one of the low-calorie products, so this type of meat is increasingly popular among consumers (Ikhlas et al., 2011).

Table 2. Chemical composition breast muscles of Japanese quails

Parameter	Gender		Significance of differences
	female ♀	male ♂	
Total solids (%)	28.51±0.35	29.00±0.31	NS
Protein (%)	24.26±0.48	24.70±0.39	NS
Fat (%)	2.70±0.32	2.79±0.38	NS
Ash (%)	1.24±0.26	1.26±0.22	NS
Carbohydrates (%)	0.31±0.08	0.25±0.07	NS
Caloric value			
kcal/100 g	126±0.52	125±0.24	NS
kJ/100 g	517±6.2	529±3.7	NS

Notes: NS - the difference is not significant.

The composition of fatty acids in the quail meat is presented in Table 3. The fat content of Japanese quail breast meat was 2.70-2.79% and was dominated by four fatty acids: oleic (C18:1), palmitic (C16:0), linoleic (C18:2) and stearic (C18:0), which accounted for 86.6% of all fatty acids. Similar results were obtained by Genchev et al. (2008), Bonos et al. (2010), Sartowska et al. (2014) and Gecgel et al. (2015). According to Gecgel et al. (2015), Japanese quail meat can be included in a preventive diet for heart disease due to its high C18:1 content. An important indicator of the health-promoting properties of a given fat is the ratio of PUFA to SFA, which according to World Health Organization (WHO) (2014) recommendations should be above 0.4. In our study, this ratio was 0.59. An even more favorable PUFA to SFA ratio in the fat on Japanese quails of the Pharaon breed of 0.73 was found by Genchev et al. (2008). A high oleic acid (C18:1) content of 37% is also beneficial, as this acid has a beneficial effect on lowering blood cholesterol levels and reducing the risk of ischemic heart disease. On the other hand, the PUFA n6/n3 ratio in the meat of the quail analyzed in our study was not favorable to consumers, ranging from 22.76-22.89. No particularly significant differences were found between females and males in the fatty acid profile.

Table 3. The fatty acids profile breast muscles of Japanese quails

Fatty acids	Gender		Significance of differences
	Female ♀	Male ♂	
C10:0	0.043±0.014	0.039±0.015	NS
C12:0	0.079±0.017	0.081±0.004	NS
C14:0	0.788±0.142	0.832±0.079	NS
C14:1	0.134±0.018	0.135±0.015	NS
C15:0	0.249±0.043	0.240±0.042	NS
C16:0	23.54±0.541	23.604±0.229	NS
C16:1 n9	0.520±0.012	0.527±0.028	NS
C16:1 n7	7.266±0.146	7.313±0.057	NS
C17:0	0.267±0.037	0.263±0.030	NS
C17:1	0.108±0.009	0.105±0.010	NS
C18:0	7.824±0.360	7.823±0.448	NS
C18:1 n-9	37.07±0.095	36.952±0.242	NS
C18:1 n-7	1.776±0.140	1.788±0.021	NS
C18:2 n-6	18.186±0.13	18.187±0.183	NS
C18:3 n-6	0.10±0.003	0.097±0.006	NS
C18:3 n-3	0.67±0.048	0.657±0.018	NS
CLA	0.10±0.006	0.099±0.004	NS
C20:0	0.17±0.018	0.17±0.008	NS
C20:1	0.54±0.029	0.53±0.029	NS
C20:2	0.09±0.022	0.09±0.016	NS
C20:3 n-6	0.02±0.005	0.02±0.004	NS
C20:4n-6	0.29±0.069	0.27±0.073	NS
C20:4n-3	0.005±0.001	0.006±0.001	NS
C20:5 n-3	0.056±0.005	0.059±0.006	NS
C22:4 n-6	0.009±0.001	0.009±0.001	NS
C22:5 n-6	0.014±0.004	0.016±0.002	NS
C22:5 n-3	0.064±0.006	0.066±0.004	NS
C22:6 n-3	0.027±0.008	0.026±0.004	NS
Other	0.01±0.001	0.005±0.003	NS
SFA[1]	32.963±0.10	33.05±0.385	NS
UFA[2]	67.028±0.10	66.945±0.416	NS
MUFA[3]	47.45±0.131	47.346±0.285	NS
PUFA[4]	19.61±0.151	19.599±0.200	NS
PUFA n-6	18.61 ±0.18	18.602±0.203	NS
PUFA n-3	0.818±0.017	0.813±0.015	NS
PUFA n6/n3	22.76±0.663	22.895±0.341	NS
PUFA/SFA	0.595±0.006	0.593±0.012	NS
PUFA/MUFA	0.414±0.004	0.414±0.012	NS
UFA/SFA	2.034±0.009	2.026±0.036	NS

Notes: NS - the difference is not significant; [1]SFA - saturated fatty acids; [2]UFA - unsaturated fatty acids; [3]MUFA - monounsaturated fatty acids; [4]PUFA - polyunsaturated fatty acids.

Table 4 shows the profile of amino acids in the breast muscle of the analyzed quails.

Table 4. The amino acids profile breast muscles of Japanese quails

Amino acids	Gender		Significance of differences
	Female ♀	Male ♂	
Essential AA			
Lysine	5.95±0.92	6.71±0.29	*
Methionine	3.81±0.62	3.35±0.79	NS
Isoleucine	7.40±0.95	7.76±0.84	NS
Leucine	8.99±0.40	8.95±0.23	NS
Phenylalanine	5.10±0.13	4.64±0.42	*
Threonine	5.11±0.35	4.80±0.68	NS
Valine	5.48±0.21	5.46±0.08	NS
Cysteine	0.93±0.16	0.74±0.13	NS
Tyrosine	4.07±0.23	3.89±0.60	NS
Total EAA	46.82±0.64	46.31±1.31	NS
Non-essential AA			
Histidine	4.44±0.03	3.98±0.27	*
Arginine	7.70±0.34	7.24±0.45	NS
Glutamic acids	12.85±0.11	13.67±0.66	NS
Glycine	5.80±0.29	5.76±0.27	NS
Serine	4.25±0.24	4.37±0.34	NS
Alanine	5.59±0.27	5.70±0.26	NS
Proline	4.24±0.30	3.82±0.20	*
Asparagine acids	8.30±0.21	9.13±0.49	*
Total non-essential AA	53.18±0.64	53.69±1.31	NS
Protein content	24,26±0,48	24,70±0,39	NS
Ratio nonessential/essential	1.14±0.029	1.16±0.061	NS
Ratio essential/nonessential	0.88±0.023	0.86±0.046	NS
Protein/essential	0.519±0.015	0.534±0.012	NS

Notes: NS - the difference is not significant; *- the difference is determined at P<0.05.

Nonessential amino acids predominated in the meat of the analyzed quails (53.18-53-69%); however, the essential/nonessential ratio ranged from 0.86 (males) to 0.88 (females). This meat was very tasty rich in essential amino acids that constituted approximately 46.31-46.82% of the meat protein. In a study by Khalifa et al. (2016), essential amino acids constituted about 41% of meat protein, and the essential/nonessential ratio was 0.60-0.63. Similar results are reported by Uherova et al. (1992). Glutamic acid and Asparagine acids predominated in the protein of the quail meat analyzed, which is consistent with the results of Genchev et al. (2008), Khalifa et al. (2016), Nasr et al. (2017). In our study, the meat protein of males contained more of these amino acids compared to that of females. Genchev et al. (2004) showed that the presence in quail meat of the limiting amino acids, protein, (methionine and lysine) accounts for about 11.8% of the total protein content of the product. In our study, the proportion of methionine and lysine in the meat of females accounted for 9.76% and in the meat of males for 10.06% of the total protein content of the product.

Quail meat owes its tenderness to thin muscle fibers Walasik et al. (2006). In addition, these authors found a lower intensity of pathological changes in muscle fibers, which can be explained by the high number of red fibers with oxidative metabolism.

Quail muscles are morphologically similar to the pectoral muscles of aquatic poultry in which relatively low intensity of pathological changes is found. Costăchescu et al. (2018) found no differences in the chemical composition of the meat of young female and male quail, while the meat of older males had a statistically significantly lower fat content compared to females. In addition, these authors showed that the pectoral muscles of female quails were characterized by lower cutting power compared to males. Quail meat is one of the products with low cholesterol content. Maiorano et al. (2011) reported a cholesterol level of pectoralis muscle in quail to vary from 23.57 to 37.20 mg. 100 g^{-1}, which was lower than the cholesterol content found by Maiorano et al. (2009) in the breast muscle of 35 day old Japanese quail (ranking from 27.83 to 43.38 mg.100 g^{-1}). Genchev et al. (2008) observed that the cholesterol content in quail carcass was 0.097 and 0.094 g.100 g^{-1} for males and females, respectively. Pavelková et al. (2020) observed differences between females and males in cholesterol content only in the pectoral muscles (females - 0.86 g.100 g^{-1}, males - 0.72 g.100 g^{-1}).

CONCLUSIONS

The chemical composition of quail meat, especially the high protein content and low fat content, make this meat characterized by a low caloric value. Quail meat is considered a good source of essential amino acids and fatty acids mainly from oleic, linoleic, palmitic and stearic acids. The meat of males was characterized by a higher content of lysine and glutamic acid and a lower content of histidine, arginine, tyrosine and methionine compared to the meat of females. The gender of quails had no significant impact on meat quality parameters.

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