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Quality characteristics and shelf-life of meat of quail birds-fed diets supplemented with grape pomace

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ABSTRACT

This investigation aims to determine the effect of grape pomace supplementation on quail meat's quality and shelf life. Growing 121-day-old quail males were separated into groups of 30 birds each (3 replicates of 10 birds each). For 42 days, the quails were fed a diet enriched with 0, 2.5, 5, or 10 g/kg of grape pomace (control group and experimental groups). After the feeding session, ten quails were chosen randomly and slaughtered humanely to test the meat quality. Except for redness, which showed a lower value for experimental groups compared to the control group, neither the physicochemical characteristics nor the eating quality of breast meat varied significantly across treatments. The experimental groups also produced alterations in the fatty acid profile, with an increase in polyunsaturated fatty acids mainly due to an increase in linoleic acid concentration. The addition of grape pomace reduced lipid oxidation in meat at 1 and 5 days post-mortem. On post-mortem day 5, the control group meat had more bacteria than the experimental group meat. Overall, supplementation with grape pomace significantly improved the fatty acid profile and showed the capacity to extend shelf life.

Keywords: Fatty acid profile, Grape by-products, Lipid oxidation, Meat traits, Microbiology, Quail

Grape pomace (GP) is a polyphenol residue with high antioxidative potential. At the moment of purchase, food safety and final quality are essential for consumers when making food choices. Quail has become the most popular poultry for meat production due to its low-fat content, especially saturated fatty acid and cholesterol level, and a source of polyunsaturated fatty acids (PUFA), including conjugated linoleic acid (Sabow 2020). The excessive intake of n-6 fatty acids compared to n-3 fatty acids is a problem for consumers (Lukasiewicz *et al.* 2020). Enriching quail diets with PUFA n-3 vegetable oil sources is a feasible approach for boosting the concentration of essential fatty acids in meat (Ebeid *et al.* 2011, Arulnathan *et al.* 2019). However, because n-3 PUFA is particularly vulnerable to peroxidation, which affects both meat quality (nutritional value, palatability, and shelf life) and consumer acceptability, there is a direct relationship between n-3 fatty acid content and oxidative rancidity values (Domnguez *et al.* 2019). Grape pomace has excellent nutritional value due to its high concentration of phenolic compounds, including catechin, anthocyanin, and epicatechin, all-natural antioxidants (Kasapidou *et al.* 2016, Hak *et al.* 2021). Due to its alleged positive effects on performance (Pascariu *et al.* 2017, Aditya *et al.* 2018), as well as enhancing the quality of meat and its shelf life (Kasapidou *et al.* 2016, Bennato *et al.* 2020, Juraga *et al.* 2021), grape pomace has recently attracted considerable interest for use in broiler diets. However, few exhaustive studies on the nutritional supplementation of quails with grape by-products improve meat shelf life, microbiological quality, and eating quality. This study aimed to determine how grape pomace altered the physicochemical parameters, fatty acid composition, lipid oxidation, and microbiological activity of quail breast muscles after five days of storage at 4°C.

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MATERIALS AND METHODS

All birds received humane care according to the standard local guidelines. The experimental protocol was approved by the local animal care and use committee of the Agriculture College, Salahaddin University-Erbil, Kurdistan Region, Iraq.

Preparation of grape pomace: Black grape skins, seeds, and a few stems comprised the grape pomace (*Vitis vinifera L.*). The grape pomace was dried for 72 h at 60°C in a hot air oven (CS101-beb ventilation oven, Chonping Sida instrument, China), then finely powdered and stored at 4°C until used as a feed additive. In a Univex Mixer (SRM20 Counter Mixer, USA), the dried grape pomace was combined for 5 min with 1 kg of basal feed before being mixed with the authorised feed. The chemical components of grape pomace (based on the dry matter) were 928.31 g/kg

of dry matter, 124.15 g/kg of crude protein, 99.16 g/kg of crude fat, 266.45 g/kg of crude fibre, 62.13 g/kg of ash, and 448.12 g/kg of nitrogen-free extractive chemicals.

Bird management and sampling: This experiment was carried out on a commercial farm, and the birds were managed following the national animal care legislation outlined by Sabow (2020). A total of 120 male Japanese quail (*Coturnix japonica*) chicks were procured from a population of local commercial farms in Erbil, Iraq's Kurdistan region. Hatched chicks were assigned at random to one of four experimental treatments. Each treatment had three repetitions of 30 birds each. Each duplicate was housed in its indoor enclosure with rice husk floors under temperature and light control. At the beginning of the trial, a 24 h lighting plan was developed, using natural light and fluorescent lighting during the day and night, respectively. The temperature and relative humidity were maintained throughout the experiment between 20 and 24°C and 50 and 60%, respectively. The 42-day trial was carried out. On the recommendation of the National Research Council, a complete basal diet was devised to meet the nutritional demands of the quails during this period (NRC 1994). The experimental groups were set up as follows: the birds in the control group were fed a basic diet with no supplementation. The quails in the other three experimental groups were fed basal diets containing + 2.5, 5, and 10 g/kg dried black grape pomace red. The birds had unrestricted access to food and water. Table 1 shows the ingredients and composition of the baseline diet.

Bird slaughter: At the end of the feeding period (6 weeks), 10 quails were chosen randomly and humanely slaughtered using the traditional halal slaughtering process after 9 h of feed withdrawal. Following evisceration and bleeding, carcasses were immediately transported to the laboratory and chilled at 4°C for 24 h for meat quality measurements.

Muscle sampling: Two sections of the breast (pectoralis major) muscle were removed from the frozen body. On the first day, the right pectoralis major muscle, which had been tagged, vacuum-packed, and preserved at -20°C, was measured. The parameters measured were *p*H, colour, cooking loss, water holding capacity, shear force, fatty acid profile, lipid oxidation, and microbiological count. The left pectoralis major muscle was separated into two halves in the second part. While the second portion was vacuum-packed and refrigerated at 4°C for five days, the first portion was used to analyse palatability characteristics. After the ageing process was complete, muscle samples were collected, labelled, vacuum-packed, and stored at -20°C for further lipid oxidation and microbiological enumeration analysis.

Physico-chemical meat quality determination: The *p*H of the breast muscle was indirectly determined using a portable *p*H metre (PHS-3C, China). Each sample was homogenised in 10 ml of ice-cold deionised water for 30 sec. The *p*H of the resultant homogenates was then measured at *p*H 4.0 and 7.0 using a portable *p*H metre that had been previously calibrated. The drip loss percentage was determined by dividing the weight change after storage by the percentage of weight change. Individual breast muscle fresh meat samples were weighed, and their initial weights were recorded (W1). The samples were weighed in polyethene plastic bags, labelled, vacuum sealed, and chilled at 4°C for 5 days. The samples were taken from the bags after 5 days, gently wiped dry using paper towels, weighed, and recorded as W2. The drip loss was estimated and expressed as a percentage of the difference between the original weight of the sample and the weight after 5 days of storage divided by the starting weight of the sample. To determine cooking time, about 20 g of breast muscle meat samples were cooked in an 80°C pre-heated water bath (HAAKE C10, UK). The cooking was extended for another 10 min after the internal temperature of the samples reached 78°C, as measured with a stabbing temperature probe. The cooking loss percentage was computed and reported as the difference between the sample's initial weight (before cooking) and final weight (after cooking) divided by the initial sample weight (per cent drip loss = [(initial weight − final weight) / initial weight] × 100). The breast flesh samples used to calculate cooking loss were collected and utilised to measure tenderness using the Volodkovitch biting jaw attached to a Brookfield Texture Analyzers (CT3TM, USA), as described by Sabow (2020).

Table 1. Ingredient and composition of the experimental diet

Ingredient	(%)
Wheat	17.50
Corn	20.00
Wheat flour	25.00
Soyabean meal	29.00
Protein concentrate (fish meal concentrate)	5.00
Di - Calcium phosphate	0.50
Methionine	0.09
Lysine	0.05
Choline chloride	0.05
Salt	0.09
Soyabean oil	1.30
Limestone	1.00
Vitamins premix[1]	0.05
Mineral Premix[2]	0.10
Toxin binder[3]	0.10
Feed sterilizes	0.10
Anticoccidial	0.05
Analysed feed composition[4]	
Crud protein (g/kg)	23.26
Energy metabolism (kcal/kg)	2930.00

[1]Supplied per kg diet: Vitamin A 11,494 IU; Vitamin D 1,725 IU; Vitamin E 40 IU; Vitamin K3 2.29 mg; Cobalamin 0.05 mg; Thiamine 1.43 mg; Riboflavin 3.44 mg; Folic acid 0.56 mg; Biotin 0.05 mg; Panthothenic acid 6.46 mg; Niacin 40.17 mg; Pyridoxine 2.29 mg. [2] Supplied per kg diet: Fe 120 mg; Mn 150 mg; Cu 15 mg; Zn 120 mg; I 1.5 mg; Se 0.3 mg; Co 0.4 mg). [3]Toxin binder contains natural hydrated sodium calcium aluminum silicates (HSCAS). [4]Diets were formulated using feed live international software (Thailand).

A Colour Flex spectrophotometer was used to quantify the colour of breast muscle [L* (lightness), a* (redness), b* (yellowness), c* (chroma), and h* (hue angle) (Shenzhen 3nh Technology Co., Ltd, China]. The colorimeter was calibrated before usage with black and white tiles. Pectoralis major muscle samples of approximately 12 mm thickness were equilibrated at room temperature and allowed to bloom for 30 min before being evaluated for colour (Sabow 2020).

Proximate analysis: Abdulla *et al.* (2017) methods were utilised to determine the approximate composition of the breast muscle. To determine moisture, the oven method was used. The crude protein was calculated using the Kjeldahl technique; 6.25 N% crude protein was determined. The fat content of the muscle was determined using petroleum ether and the Soxhlet extraction method. The amount of ash in the muscle was determined by burning a sample of the meat at 550°C for three h in a muffle furnace.

Fatty acids composition: The fatty acid content of breast muscle tissue samples was determined by extracting the fat in chloroform: methanol (2:1, v/v) mixture and producing fatty acid methyl esters (FAME) using the method described by Ebrahimi *et al.* (2018). (Agilent 7890A, Agilent Technologies Inc., Santa Clara CA, USA). For capillary separation, the chromatograph is outfitted with a flame ionisation detector and a Supelco SP-2560 capillary column (100 m, 0.25 mm internal diameter, 0.20 mm film thickness). Fatty acids were identified by comparing relative FAME peak retention lengths of fatty acid methyl standards with heneicosanoic acid as an internal standard.

Lipid oxidation: Aminzade *et al.* (2012) method for measuring thiobarbituric acid reactive substances (TBARS) to quantify lipid oxidation was somewhat modified by Sabow *et al.* (2020). The TBARS values were obtained by multiplying the optical density by 7.843 and measuring them at 538 nm using a spectrophotometer (Spectronic Instruments, USA). The final values were milligrams of malondialdehyde (MDA) per kg of meat.

Microbiological analyses: Each sample was diluted from 10-1 to 10-9 with deionised water. Using these dilutions, the aerobic and Pseudomonas spp. populations were determined. Then, 100l of each of the various dilutions were dropped and scattered in duplicate before computing the mean. After three days of incubation at 25°C on *Pseudomonas* Isolation Agar (Neogen®, Lansing, Michigan, United States), Pseudomonas spp. Ahmad *et al.* (2019) determined Aerobic plate counts on selective agar plates (Neogen®, Lansing, Michigan, USA) after 72 hours at 32°C. The overall population was estimated as log10 colony-forming units (CFU) per gramme of beef following the incubation phase.

Sensory evaluation: Ten panelists carried out the sensory evaluation of the breast meat sample. The samples were individually wrapped in aluminium foil, labelled, and roasted to an internal temperature of 80°C using a special thermometer. Following cooling, the meat samples were evaluated within 10 min using a five-point scale ranging from 5 = intense appreciation to 1 = extreme hate, as described by Kasapidou *et al.* (2016). The sensory qualities evaluated were tenderness, juiciness, flavour, and overall acceptance.

Statistical analysis: The experiment's design was entirely random. The parameters were fitted as dependent variables using the SAS Version 9.2 software's generalised linear model (GLM) technique (Statistical Analysis System, SAS Institute Inc., Cary, NC, USA). In contrast, the experimental treatment groups were modelled as a fixed effect. Before the compound symmetry covariance structure, regression analysis was performed to investigate the impact of linear and quadratic contrasts, which were found to be insignificant. Duncan's multiple range test was used to determine the significance of variance between the means of the tested parameters. The statistical significance level for all sets was greater than $p < 0.05$. The results were presented as mean values with pooled standard deviations.

RESULTS AND DISCUSSION

Meat quality traits: The term quality refers to a composite of characteristics that distinguish units of a product and are essential in determining consumer acceptance of that unit. As a result, appealing meat traits include both visual and sensory, that are thought to be safe and healthy, and more ethereal attributes like clean and green of the production process. It is typical to consider visual quality, health quality, and eating quality to be the most important factors influencing customers' willingness to spend. The meat quality is especially significant for customer decisions. The average meat quality values of quail meat-fed diets supplemented with various quantities of grape pomace are shown in Table 2. The *p*H at 24 h post-mortem (ultimate *p*H) did not differ substantially between the control and treatment groups ($p \geq 0.05$). Ultimate *p*H is an essential indicator of meat quality since it is connected to the rate of glycogen breakdown and lactate liberation before and after slaughter. The eventual *p*H of the control group was higher than that of the experimental groups while not being statistically different. These findings are consistent with Bennato *et al.* (2020) and Turcu *et al.* (2020) who found that the ultimate *p*H of broiler chicks was slightly

Table 2. Effect of grape pomace supplementation on meat quality of Japanese quail

Parameter	Grape pomace level (g/kg diet)				SEM
	0	2.5	5	10	
*p*H	6.34	6.22	6.19	6.18	0.23
Drip loss (%)	2.03	1.92	1.93	1.93	0.09
Cooking loss (%)	21.95	21.63	20.91	21.73	1.45
Shear force (kg)	0.79	0.79	0.81	0.80	0.01
Lightness	49.13	48.39	48.91	48.83	1.11
Redness	15.85[a]	15.74[a]	13.65[b]	12.49[b]	0.50
Yellowness	10.09	10.71	10.88	10.11	0.34

[a,b] Means within the same row for each parameter with different superscripts are significantly different ($p \leq 0.05$). SEM, pooled standard error of the mean.

higher in the control group compared to the grape pomace supplementation groups, although there were no significant differences (p≥0.05). Table 2 demonstrates that the ability of quails fed diets including grape pomace at levels ranging from 0 to 20 g/kg feed to store water in combinations of drip loss and cooking loss of breast muscle did not differ substantially (p≥0.05). This is because the final *p*H did not change considerably. Decreased body temperature after death and muscle *p*H influence water holding capacity (Bowker and Zhuang 2015). According to Bennato *et al.* (2002), supplementing broiler chicks with grape pomace did not influence their ability to retain water (WHC). Shear force, one of the most important characteristics impacting customer preference for meat, is adversely related to softness. In the current study, the quail meat in the dried grape pomace supplementation groups was somewhat softer than in the control groups. However, this difference was not statistically significant (p≥0.05). This could be because beef, independent of nutritional treatment, loses water while cooking. This reasoning supports Mir *et al.*'s (2017) claim that the amount of water bound inside the fibres influences meat tenderness. Colour is an important factor that people use to determine the acceptability and quality of meat. Colour influences customer purchasing decisions since it is the major sign of freshness. The current study used three standard CIE Lab outputs to quantify colour values: lightness (L*), redness (a*), and yellowness (b*). Compared to the control group, adding grape pomace at varied doses had no discernible effect on the meat's lightness or yellowness (Table 2). According to the data on muscle colour coordinates, varying the amount of grape pomace had no noticeable effect on the lightness or yellowness. In terms of redness, there were significant treatment variations (p≥0.05). Paler flesh (lower a* values) added up to 2.5 g/kg of grape pomace to the meal, with samples from quails receiving the highest supplementation quantity displaying the lowest redness values (Turcu *et al.* 2020). The presence of anthocyanin pigments in grapes could explain the variations in the redness measured. Kasapidou *et al.* (2016) and Aditya *et al.* (2016) found similar results. They discovered that the meat of quails fed diets containing grape pomace at quantities ranging from 2.5 to 10 g/kg feed had lower redness values than the control group.

Table 3. Effect of grape pomace supplementation on meat chemical composition of Japanese quail

Parameter (%)	Grape pomace level (g/kg diet)				SEM
	0	2.5	5	10	
Moisture	72.12	71.37	71.69	71.53	1.19
Crude protein	22.71	22.56	22.52	22.68	0.25
Ether extract	3.08	3.43	3.46	3.47	0.11
Ash	2.09	2.64	2.34	2.31	0.14

SEM, pooled standard error of the mean.

Chemical composition: Poultry, particularly quail meat, is becoming increasingly popular among meat consumers due to its low-fat content and superior proteins compared to similar cuts of red meat such as beef and mutton, as well as similar pieces of white meat such as broiler chicken and ducks (Sabow 2020). Table 3 summarises the findings from the chemistry of quail breast flesh. The only difference, in this case, was the fat concentration, which was higher in samples taken from quails-fed diets enriched with grape pomace than in the control group. However, the difference was not statistically significant. When total antioxidants are higher than free radicals, oxidative damage in the body tissues decreases and increases the number of total lipids. In agreement with the present findings, Bennato *et al.* (2020) also found no significant effect of the dietary supplementation with grape

Table 4. Effect of grape pomace supplementation on meat fatty acid profile of Japanese quail

Parameter	Grape pomace level (g/kg diet)				SEM
	0	2.5	5	10	
Myristic (C14:0)	0.71	0.675	0.63	0.65	0.11
Palmitic (C16:0)	20.49^{a}	19.50^{ab}	19.17^{ab}	18.48^{b}	1.52
Stearic (C18:0)	15.68	15.28	14.61	14.79	0.34
Myristoleic (C14:1 n-9)	0.05	0.05	0.04	0.04	0.00
Palmitoleic (C16:1 n-9)	3.02	3.45	3.57	3.53	0.07
Oleic (C18:1 n-9)	34.43	34.88	33.74	34.32	1.18
Linoleic (C18:2 n-6)	23.06^{c}	24.58^{b}	26.6^{a}	26.47^{a}	1.94
Gama-Linolenic (C18:3 n-6)	0.12	0.13	0.13	0.16	0.03
α-Linolenic (C18:3 n-3)	1.44	1.46	1.51	1.56	0.06
SFA[1]	36.88^{a}	35.45^{b}	34.41^{bc}	33.92^{c}	1.59
MUFA[2]	37.5	38.38	37.35	37.89	2.17
PUFA[3]	24.62^{c}	26.17^{b}	28.24^{a}	28.19^{a}	1.92
PUFA:SFA	0.67^{b}	0.74^{ab}	0.82^{a}	0.83^{a}	0.06

[1]SFA, sum of C14:0+C16:0+C18:0; [2]MUFA, sum of C14:1+C16:1+C18:1; [3]PUFA, sum of C18:2 n-6+C18:3 n-3+ C18:3 n-6; [a,b] Means within the same row for each parameter with different superscripts are significantly different (p≤0.05). SEM, pooled standard error of the mean; SFA, saturated fatty acid; MUFA, Monounsaturated fatty acids; PUFA, polyunsaturated fatty acid; PUFA n-3, omega-3 polyunsaturated fatty acids ratio; PUFA n-6, omega-6 polyunsaturated fatty acids; n6:n3 ratio, omega-3 polyunsaturated fatty acids : omega-6 polyunsaturated fatty acids; PUFA : SFA, polyunsaturated fatty acid : saturated fatty acid.

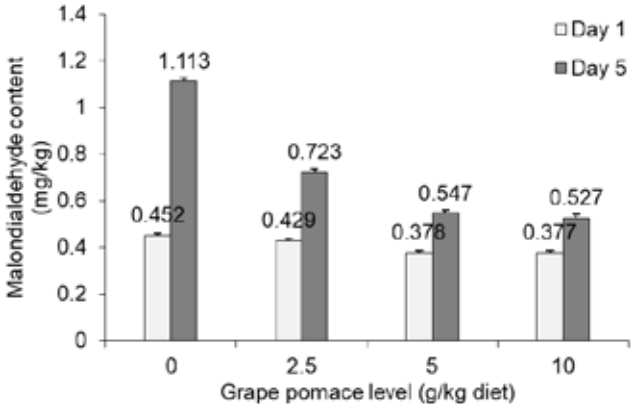

Fig. 1. Effect of grape pomace supplementation on lipid oxidation of Japanese quail breast muscles during post-mortem aging periods. (Values with different superscripts differ significantly at p≤0.05; Values are means ± 1 standard error bar)

pomace on the nutritional composition of broiler chickens. Aditya *et al.* (2018) reported no significant difference in the chemical characterisation of chicken breast meat-fed dietary supplementation with or without grape pomace.

Fatty acid composition: Over the past two decades, researchers have investigated various feeding strategies to improve meat's omega-3 fatty acid content in ruminants and monogastric animals. These omega-3 fatty acids have beneficial anti-inflammatory, anti-thrombotic, and anti-atherosclerosis characteristics. In this analysis of the fatty acid profile of quail meat, only a substantial increase in the concentration of linoleic acid was found in grape pomace samples from birds fed 5 and 10 g/kg of grape pomace as dietary supplements (Table 4). This may be explained by linoleic acid, the most prevalent fatty acid in grape pomace (Manso *et al.* 2016). With the addition of grape pomace, the amount of saturated fatty acids (SFA) in the 5 and 10 g/kg groups were significantly less than in the control group. This is explained by the difference in palmitic acid levels between treatment groups. The 5 and 10 g/kg linoleic acid group samples successfully induced an increase in total polyunsaturated fatty acids (PUFA) (p≤0.05); this result also considerably raised the PUFA/SFA ratio in the same samples. However, supplementing quails' diet with grape pomace did not influence their levels of monounsaturated fatty acids (Table 4). Bennato *et al.* (2020) demonstrated that diets containing varying percentages of grape pomace affected the fatty acid profile of broiler chickens, increasing polyunsaturated fatty acids, primarily due to an increase in linoleic acid concentration.

Lipid oxidative stability: The economic impact of producing lipid-containing commodities like beef under pro-oxidative storage conditions on lipid breakdown is significant. It has been associated with deterioration in meat flavour, colour, texture, and other meat quality features. Furthermore, the meat's appeal, nutritional value, and safety are diminished. Recently, techniques that incorporate natural antioxidants in broiler chicken diets have been employed to boost the oxidative stability of meat and meat production. The effect of dietary interventions on the lipid oxidation (MDA values) of quail breast meat maintained in the refrigerator at 4°C is shown in Fig. 1. Lipid oxidation rose considerably with the storage period in all treatment groups. The MDA value of the control group did not change significantly from that of the dietary supplementation with up to 5 g/kg of grape pomace on day 1. It was greater than adding 10 g/kg feed of grape pomace. On day 5 of storage at 4°C, all experimental groups of thigh meat had considerably lower MDA readings than the control (p≤0.05). These results are consistent with previous studies on the influence of grape pomace on meat lipid oxidation in broiler chickens (Bennato *et al.* 2020, Turcu *et al.* 2020). According to this study, the dietary intake of grape pomace by quails significantly preserved the lipid component from peroxidation. This is likely due to the pomace's phenolic chemicals, which protect cells via various action pathways, such as activating antioxidant enzymes or scavenging free

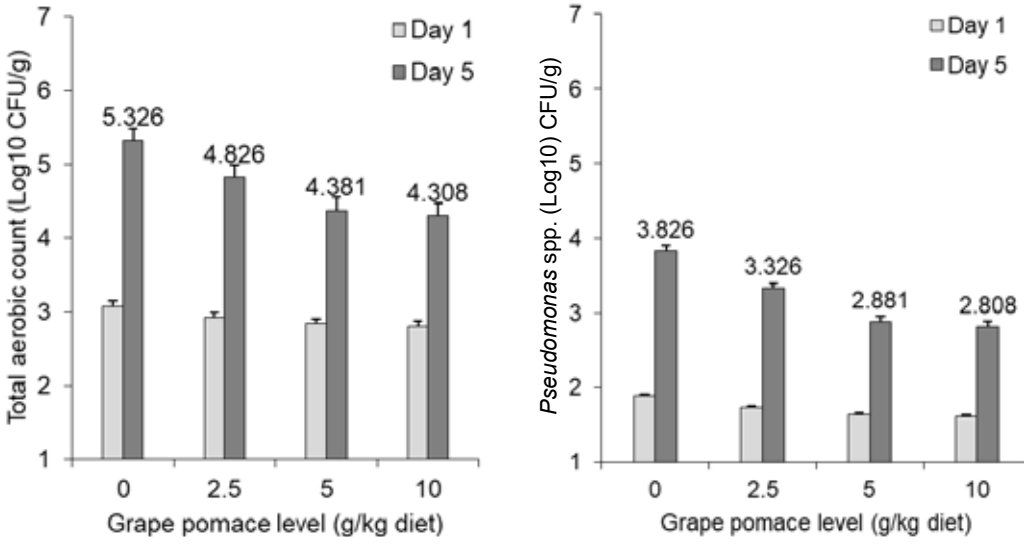

Fig. 2. Effect of grape pomace supplementation on microbiological quality of Japanese quail breast muscles during post-mortem aging periods.(Values with different superscripts differ significantly at p≤0.05; Values are means ± 1 standard error bar)

radical species. This explanation is supported by Goni *et al.* (2007). They claim that consuming feeds high in bioactive chemicals, such as polyphenols, may inhibit intestinal vitamin E breakdown, allowing more of this substance to be absorbed and enhancing oxidative stability in diverse tissues. Chedea *et al.* (2018) investigated grape pomace polyphenols' absorption, and antioxidant activity in monogastric animals, specifically weaned piglets. According to the authors, the potential of grape pomace improves the total antioxidant state in the duodenum and colon, lowering lipid oxidation.

Microbiological analyses: Due to its chemical composition, poultry meat is conducive to developing pathogenic and decomposing bacteria. Therefore, the shelf life of fresh meat during refrigerated storage is restricted to a few days in absence of preservation methods (Javaherzadeh *et al.* 2020). Fig. 2 demonstrates the influence of diet on the microbiological examination of breast muscle preserved at 4°C for the first five days post-mortem. The number of microorganisms on day one did not differ statistically across treatment groups. On day 5 post-mortem, however, the amount of grape pomace altered the bacterial counts for both examined species. The control group demonstrated considerably higher growth of total aerobic counts and *Pseudomonas* spp. than the supplemented groups. The control group's quail samples had the highest counts of all microorganisms considered in this study, and flesh samples from all treatments showed an increase in the development of both microbes over time. Significantly, the examined microorganism levels fell within the reported range and did not surpass the highest allowed limit for poultry flesh (Keener *et al.* 2004). The antibacterial properties of grape polyphenols in meat can explain why bacterial growth was reduced in quail groups whose meals were supplemented with grape by-products (Kasapidou *et al.* 2016).

Sensory evaluation: One of the most important variables in determining whether or not a product will be purchased is its palatability attributes, which are influenced by various factors, including the methods used to manufacture poultry. Panelists frequently emphasize softness, juiciness, and flavour (Escobedo del Bosque *et al.* 2022). When comparing meat samples from quails treated with grape pomace to the control group, the sensory quality values in the quail meat samples were marginally higher. Meanwhile, the distinction was not statistically significant ($p \geq 0.05$) (Table 5). The sensory evaluation of the meat in the current study was unaffected by the addition of grape pomace to the diet, which may be explained by the similarity in technological properties such as *p*H, water holding capacity, and shear force. These findings support the findings of Kasapidouet *et al.* (2016), who discovered no link between nutritional supplementation with grape pomace and perceptions of sensory characteristics of broiler chicken. According to Francesch and Cartaà (2015), grape seed supplementation did not affect the sensory character of chicken flesh.

Overall, it may be concluded that dietary supplementation of grape pomace increased the polyunsaturated fatty acids content as a direct consequence of the marked increase in the concentration of linoleic acid. Furthermore, the improvement in quail meat's oxidative stability and microbial quality must be highlighted. This aspect might justify an extension of the shelf-life with significant potential benefits for consumers' health.

Table 5. Effect of grape pomace supplementation on eating quality of Japanese quail meat

Parameter	Grape pomace level (g/kg diet)				SEM
	0	2.5	5	10	
Tenderness	3.76	3.82	3.88	4.01	0.34
Juiciness	3.71	3.73	3.89	3.92	0.23
Flavour	3.85	3.70	3.69	3.81	0.14
Acceptability	3.93	3.92	3.93	4.05	0.12

SEM, pooled standard error of the mean.

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