How to cite: Güler, H.C., Phenotypic Correlations between Carcass Part Yields and Meat Quality Characteristics in Quails, J. Anim. Prod., 2022, 63 (1): 7-14, https://doi.org/10.29185/hayuretim.1011729

Research Article
(Araştırma Makalesi)

J. Anim. Prod., 2022, 63 (1): 7-14
https://doi.org/10.29185/hayuretim.1011729

Phenotypic Correlations between Carcass Part Yields and Meat Quality Characteristics in Quails

Bıldırcınlarda Karkas Parça Randımanı ve Et Kalite Özellikleri arası Fenotopik Korelasyonlar

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Alınış (Received): 24 10 2021 Kabul tarihi (Accepted): 07 04 2022

Keywords:

Japanese quail, meat quality characteristics, pH, meat color, phenotypic correlation

Anahtar Kelimeler:

Japon bıldırcını, et kalite özellikleri, pH, et rengi, fenotipik korelasyon

ABSTRACT

Objective: This study aimed to determine phenotypic correlations between carcass part yields (breast and thigh yield) and meat quality characteristics (pH_u, lightness, redness, yellowness, chroma, hue, thawing loss, cooking loss, water holding capacity, and texture) in Japanese quails.

Material and Methods: This study was carried out on a total of 130 Japanese quails with mixed sexes. Twenty-four hours after slaughter, pH_u and color measurements were performed in the right breast muscle to determine meat quality characteristics.

Results: Mean breast and thigh muscle yields were determined as 24.19% and 14.41%, respectively. Significant phenotypic correlations were found for carcass part yields and meat quality characteristics in quail meat. While determined negative significant ($p<0.05$) phenotypic correlations for pH_u and lightness (-0.193), yellowness (-0.288), chroma (-0.266), and thawing loss (-0.248); pH_u's relationships with redness, hue, water holding capacity and, texture were insignificant.

Conclusion: In this study, the significant negative phenotypic correlation determined between pH_u and lightness shows that selection for breast meat lightness in quails can affect the ultimate pH and lead to an improvement in quality characteristics, and this situation can be used to reduce meat quality defects.

ÖZ

Amaç: Bu çalışmanın amacı japon bıldırcınlarında karkas parça randımanları (göğüs ve but kası randımanı) ve et kalite özellikleri (pH_u, parlaklık, kırmızılık, sarılık, chroma, hue, çözdürme kaybı, pişirme kaybı, su tutma kapasitesi ve sertlik) arası fenotipik korelasyonları saptamaktır.

Materyal ve Metot: Çalışma toplam 130 adet karışık eşeye sahip japon bıldırcını üzerinde yürütülmüştür. Kesimden 24 saat sonra, et kalite özelliklerini saptamak amacıyla, sağ göğüs kasında pH_u ve renk ölçümleri gerçekleştirilmiştir.

Bulgular: Ortalama göğüs ve but kası randımanları sırası ile %24.19 ve %14.41 olarak saptanmıştır. Bıldırcın göğüs etinde karkas parça randımanları ve et kalite özellikleri için önemli fenotipik korelasyonlar belirlenmiştir. pH_u ile parlaklık (-0.193), sarılık (-0.288), chroma (-0.266) ve çözdürme kaybı (-0.248) için önemli ($p<0.05$) negatif fenotipik korelasyonlar belirlenirken; pH_u'nun kırmızılık, hue, su tutma kapasitesi ve sertlik ile arasındaki ilişkilerin önemsiz olduğu saptanmıştır.

Sonuç: Çalışmada, pH_u ile parlaklık arasında belirlenen önemli negatif fenotipik korelasyon, bıldırcınlarda göğüs eti parlaklığı yönünde yapılacak seleksiyonun son pH'yı etkileyerek kalite özelliklerinde iyileşmeye neden olabileceğini ve bu sonuçların et kalite kusurlarının azaltılmasında kullanılabileceğini göstermektedir.

INTRODUCTION

Animal proteins, which are an indispensable source of human nutrition, it is very important for growth, development, and healthy nutrition. It has been reported that especially the increase in poultry meat production compensates for the decrease in beef and pork production, and poultry meat ranks first with 118 million tons in world total meat production (FAOSTAT, 2021). One of the important reasons for this increase is the consumer perception that poultry meat is healthier against the problem of coronary cardiovascular diseases (WHO, 2015) and obesity due to its lower cholesterol and fat ratio (Wideman et al., 2016).

The reason for this enormous increase in poultry meat production is genetic selection studies that have been going on since the 1950s (Karcher and Mench, 2018). Today's modern broilers consume much less feed and reach almost the same body weight in half the time compared to the 1950s (Havenstein et al., 2003a,b). This rapid development has resulted in significant increases in weight and yield of important carcass parts, especially pectoralis major and thigh muscle. However, due to the rapid development in broiler breeding, metabolic defects, foot-leg problems and muscle abnormalities affecting meat quality have emerged.

Meat quality defines the acceptability of meat by consumers (Wood et al., 2008). Conventionally, the term meat quality includes the natural characteristics of meat such as a taste for eating, suitability for further processing and storage, including a visual selection of meat offered for sale (Andersen et al., 2005). Fletcher (2002) emphasizes that the two most important quality characteristics for poultry meat are appearance and texture. Appearance is critical to both consumers' initial product selection and final product satisfaction. Texture is the most important sensory characteristic that affects the final quality evaluation (Fletcher, 2002).

Today poultry meat is generally consumed as cut upped or processed products rather than whole carcasses (Barbut, 2002). This situation has increased the importance of technological quality (water holding capacity, color, texture, shelf life, and further processing properties) of poultry meat (Le Bihan-Duval, 2004). It has been reported by many researchers that selection can be applied to improve poultry meat quality (Le Bihan-Duval et al., 1999; 2004; 2008; Berri et al., 2005; 2007). Broilers studies showed that the increase in breast muscle mass achieved by genetic selection was mainly related to increased fibre size and did not produce any changes in the breast muscle metabolic profile (Le-Bihan-Duval, 2004). In general, it is known that the genetic correlations between meat quality traits show high heritability (Le Bihan-Duval et al., 1999; 2004; Gaya et al., 2011), while the estimated correlations do not cause any genetic antagonism between carcass yields and meat quality. (Le Bihan-Duval, 2004). These results show that genetic selection to increase meat yield and reduce abdominal fat in poultry will not affect meat quality criteria and that the economic return, which is very important for the producer, can be achieved without a decrease in quality. Many researchers show that the ultimate pH (pH_u) shows strong correlations with color, water holding capacity and texture, therefore it can be an important marker and selection criterion for meat quality (Le Bihan-Duval, 1999; 2001; 2004; Berri et al. 2005). Le Bihan-Duval et al. (1999) reported that selection for high breast muscle yield and low carcass fat can lead to lower L^* value and better water holding capacity. It has been reported that chickens selected for breast muscle development show higher ultimate pH, lower acidic meat and lower glycogen reserve compared to control chickens (Berri et al., 2001). Le Bihan-Duval et al. (2001) reports that the initial pH is not as important as the ultimate pH in the phenotypic relationships between meat quality characteristics. Le Bihan-Duval et al. (2003) found that the rate and the extent of the pH fall exhibited positive and strong phenotypic (rp: 0.26) and genetic (rg: 0.59) correlations, while breast meat lightness was moderately negative (pH_{20} and pH_u; rp: -0.19 and -0.17, respectively) but showed significant phenotypic correlations. Researchers have determined that there are strong negative genetic relationships for redness, yellowness and chroma, while the hue value is insignificant.

Poultry meat color, water holding capacity and appearance affect consumers' choice of purchasing the product (Fletcher, 2002). WHC, which is an important criterion in defining meat quality, determines the visual acceptance of the product, its weight after cooking and the total weight loss that occurs in the meat. The ultimate pH level, on the other hand, affects the water holding capacity and shapes the technological quality characteristics of the meat (Fletcher, 2002; Barbut, 2002). If the ultimate pH remains low, the water holding capacity and technological quality of the meat are reduced. This usually results in pale, soft and exudative (PSE) meat (Kijowski and Niewiarowicz, 1978).

The Japanese quail is the smallest poultry species farmed for meat production. It is one of the alternative poultry meats that is usually preferred by consumers due to its low fat content and high phospholipid content, and production is increasing especially in developing countries (Santhi and Kalaikannan, 2017). In addition, quail is often used as a model animal in genetic studies due to its various advantages (Narinc et al., 2013; Güler et al., 2019). Genetic and phenotypic correlations between performance and meat quality characteristics determine the amount of difference in meat quality due to changes in growth and carcass composition, especially in selected chickens. However, although these characteristics have been extensively studied in broilers, there are limited studies in quail (Oğuz et al., 2004; Gevrekçi et al., 2009; Alkan et al., 2010; Narinc et al., 2013; Zerehdaran et al., 2013; Lukanov et al., 2018; Narinç and Genç, 2021; Nasirifar et al., 2021).

It has been reported that the heritability of the ultimate pH and meat color characteristics in Japanese quails is moderate and high (Oğuz et al., 2004; Gevrekçi et al., 2009; Narinc et al., 2013). This shows that genetics has a dominant role in the control of meat quality criteria in quails as in broilers. Due to the negative moderate phenotypic correlation between pH_u with body weight and breast yield, the ultimate pH was partially dependent on body weight and muscle growth (Oğuz et al., 2004). The phenotypic correlation between ultimate pH and L^* is negative moderate (-0.26) and the high heritability for L^* (0.48) indicates that selection for a lower L^* value will result in higher pH_u and, accordingly, better water holding capacity is obtained. Narinc et al. (2013) reported that similar results the ultimate pH of quail meat could be a selection criterion in genetic selection due to its strong relationship with meat quality characteristics such as water holding capacity and texture or leanness.

The aim of this study was to determine the phenotypic correlations for carcass part yields (BRY and TY) and meat quality characteristics (pH_u, L^*, a^*, b^*, C^*, H^*, TL, CL, WHC and texture) in Japanese quails.

MATERIAL and METHOD

This study was carried out on a total of 130 Japanese (Coturnix coturnix japonica) quails with mixed sexes. For this purpose, carcasses obtained from quails were used in the study that were raised under commercial conditions and slaughtered routinely (Torbalı district of Izmir province). All quails were housed in rearing cages from hatching to slaughter and a 23L:1D lighting program was applied. During the rearing period, quails were fed ad libitum with 24% protein and 2900 kcal/kg ME (NRC, 1994) diet. Feeders were removed 8 hours before slaughter and the live weight of all chicks at 42 days of age was determined. The plucked and eviscerated quails were cooled in an ice water tank. The weights of the pre-cooled carcasses were determined and cut into parts. The breast and thigh muscles were separated from the carcass and weighted. After that they were vacuum packed in polythene bags and stored at +4C° degrees for 24 hours. Breast (BRY%) and thigh (TY%) muscle yields were calculated based on the ratio of relative breast and thigh muscle weight to live weight. At 24 hours after slaughter, breast meat color [lightness (L^*), redness (a^*) and yellowness (b^*); [(Livabond RT 300 portable colorimeter; The Tintometer Limited, UK, CIELAB-Illuminant D65/10°)] and breast meat ultimate pH (pH_u, Hanna, HI99163N, Hanna Instruments, Romania) were determined. Chroma (C^*) and hue (H^*) values were calculated with the following formula using a^* and b^* measurement values in the samples whose color measurements were completed (C^*= (a^*2 + b^*2)1/2; H^*= [arctan (b^*/a^*)]) (MacDougall, 1982). Twenty-four hours after slaughter, approximately 2±0.1 g samples were taken from the cranial part of the pectoral muscle to determine the water holding capacity (WHC). Meat samples were placed between 2 pieces of filter papers on acrylic plates and pressed under a 10 kg weight for 5 minutes. The pressed meat samples were weighed again and the weight of the water removed was calculated with the following formula (100-[(Wi–Wf:Wi)×100]; (Wi: initial weight of the sample, Wf: final weight of the sample) (Carvalho et al., 2014). The samples, whose color and pH measurements were completed, were weighed and placed in vacuum packed in polythene bags and stored at -18˚C until the day of the related analysis. After the thawed meat samples (4˚C for 24 hours) were dried with a paper towel, they were weighed back and the relative TL was calculated with the following formula (TL= [(weight before thawing–weight after thawing):weight before thawing]×100. To calculate the cooking loss, the meat samples were cooked in vacuum packed bags in a +80°C water bath for 25 minutes, and the relative CL was calculated by back-weighing the cooled samples [(weight after thawing–weight after cooking):weight after thawing]×100 (Honikel, 1998). After the same meat samples were rested at +4°C overnight, the texture was calculated using approximately 2 cm^3 meat samples (Hdp/wbv with 2mm/s blade insertion speed, Warner-Bratzler Blade texture analyser) (Papinaho et al., 1996).

Study results were evaluated using SAS package software. Descriptive statistics of characteristics and Shapiro-Wilk normality test were obtained using UNIVARIATE procedure (SAS, 2020). A normality test was performed using the "Shapiro-Wilk Test" for all characteristics. Box-Cox transformation was applied to provide the normal distribution for pH_u, a^*, H^*, TL, CL and texture properties that did not show normal distribution (Sakia, 1992). The correlations between meat color, pH_u, TL, CL, WHC, texture and breast and thigh yield were calculated using Person's correlation (SAS, 2020).

RESULTS and DISCUSSION

The results obtained by using skewness, kurtosis and probability (P) value of Shapiro-Wilk test for meat quality characteristics are presented in Table 1. The Shapiro-Wilk test and skewness and kurtosis based moment tests by Shapiro and Wilk (1965) are some of the most popular tests for univariate normality (Pearson et al., 1977). Measures of skewness and kurtosis are often used to define whether a distribution is normally distributed using shape characteristics and if the skewness is different from 0, the distribution deviates from symmetry. If kurtosis is different from 0, the distribution deviates from normality at tail mass and shoulder (DeCarlo, 1997). In a normal distribution, the expected values for skewness and kurtosis are zero, but pH_u, a^*, H^*, TL, CL and texture did not show the normal distribution in our study. pH_u, H^*, and TL were right-skewed in the untransformed data (before transformation); a^*, CL, and texture were found to be skewed to the left. It was determined that all the characteristics that did not show normal distribution exhibited positive kurtosis in their untransformed form. After Box-Cox transformation, the distribution of pH_u, a^*, H^*, TL, CL and texture characters approached normal distribution (P>0.05) (Table 1). In a way that confirms the results obtained from this study, meat quality characteristics and carcass part yields characteristics obtained from broiler and quails often show a wide variation, and the data obtained diverge from the normal distribution for some characteristics. Characters that do not show normal distribution are provided with various transformations to approach normal (Le Bihan-Duval et al., 2001; Oğuz et al., 2004; Narinc et al., 2013). These results show that although the rearing and slaughtering conditions are standard in the studies, meat quality characteristics are formed under the influence of many factors and the criteria that make up the quality can be significantly affected by the slaughter conditions.

The minimum, maximum, standard deviation (SD) and mean values of carcass yield (BRY and TY) and meat quality characteristics are presented in Table 2. In the study, BRY and TY were determined as 24.19% and 14.41%, respectively, and the results were found to be compatible with the literature. Genchev et al. (2008) reported that the relative ratio of breast meat of quails (male+female) was 20.42%, and 16.30% in thigh meat. Narinc et al. (2013) reported that BRY as 27.45%, while Oğuz et al. (2004) reported it as 27.45%. These results show that breast and thigh muscle yield can differ significantly in quails and genotype, slaughter age and sex may play an important role in the formation of this difference.

Table 1. Skewness and kurtosis values of meat quality characteristics and shapiro wilk normality test results

***Çizelge 1.** Et kalite özelliklerine ait çarpıklık ve basıklık değerleri ile Shapiro Wilk normalite testi sonuçları*

	Skewness		Kurtosis		Shapiro Wilk W Test (Prob<W)	
Variables	Untransformed	Box-Cox	Untransformed	Box-Cox	Untransformed	Box-Cox
pH_u	0.639	0.478	0.431	0.138	0.007	0.0549
a^*	-0.752	-0.152	0.661	-0.434	0.002	0.6048
H^*	1.604	0.109	4.262	0.780	0.000	0.2561
TL	2.910	0.075	16.087	-0.013	0.000	0.5365
CL	-0.666	-0.410	0.420	-0.141	0.005	0.1206
Texture	-0.679	-0.056	1.088	0.194	0.006	0.5009

Untransformed: before transformation; Box-Cox: Box-Cox transformation applied result; pH_u: ultimate pH; a^*: redness; H^*: hue; TL: thawing loss, %; CL: cooking loss, %; texture, kg/cm²

Table 2. Descriptive statistics on breast and thigh yield and meat quality characteristics

Çizelge 2. *Göğüs ve but kası randımanı ile et kalite özelliklerine ait tanımlayıcı istatistikler*

Variables	N	Mean	SD	Min.	Max.
BRY	121	24.19	2.20	16.98	31.86
TY	121	14.41	1.49	10.32	18.83
pH_u	122	5.75	0.10	5.56	6.09
L^*	121	39.29	2.98	31.40	48.81
a^*	122	10.78	2.14	3.63	14.88
b^*	121	11.92	1.90	5.86	17.68
C^*	121	16.18	2.51	7.86	22.45
H^*	121	48.13	5.60	37.71	72.37
TL	122	4.58	2.93	1.12	24.28
CL	122	22.64	2.01	16.01	24.40
WHC	121	14.38	3.48	6.36	21.85
Texture	121	1.34	0.36	0.65	2.63

N: Number of observations; SD: standard deviation; Min: minimum; Max: maximum; BRY: breast yield, %; TY: thigh yield, %; pH_u: ultimate pH; L^*: lightness; a^*: redness; b^*: yellowness; C^*: chroma; H^*: hue; TL: thawing loss, %; CL: cooking loss, %; WHC: water holding capacity, %; texture, kg/cm^2

The mean values of the ultimate pH, color (L^*, a^*, b^*, C^* and H^*), TL, CL, WHC and texture properties of meat quality criteria are presented in Table 2. Mean values for pH_u, L^*, a^*, b^*, C^*, H^*, TL, CL, WHC and texture were determined as 5.75, 39.29, 10.78, 11.92, 16.18, 48.13, 4.58, 22.64, 14.38 and 1.34, respectively. Oğuz et al. (2004) found 5.92, 54.92, 9.70, 2.59, 15.78 and 28.83 for pH_u, L^*, a^*, b^*, C^* and H^* traits in their study on Japanese quails; Narinc et al. (2013) reported pH_u, L^*, a^*, b^*, TL, CL, and texture values as 5.94, 43.09, 19.24, 7.74, 9.09, 24.02 and 7.75, respectively. Although the findings obtained from the studies on the quality characteristics of quail (Gevrekçi et al., 2009; Zerehdaran et al., 2012; Nasr et al., 2017) and broiler meat (Le Bihan-Duval et al., 1999; 2001; 2008; Berri et al., 2005; 2007) are generally compatible with our study, it was found that the lightness of breast meat (39.29) was lower in our study. Similarly, while the lightness of quail breast meat was reported lower by Remington et al. (1998) (L^*: 44.08-45.37), Narinc et al. (2013) (L^*: 43.09) and Nasr et al. (2017) (L^*: 46.40); Oğuz et al. (2004), Gevrekci et al. (2009) and Zerehdaran et al. (2013) found a higher L^* value. While the color of raw poultry meat is of critical importance in the consumer's initial selection of the product, the color of cooked meat is very important in the final product evaluation. Meat color, which can range from pale to pink in raw meat, can range from pale to grey in cooked meat, and the color of cooked meat causes the consumer to accept or reject the product (Fletcher, 2002). Pale fillets are reported to have significantly higher lightness (L^*) and yellowness (b^*), lower redness (a^*), total pigment, myoglobin, and iron content. On the other hand, higher total pigment, myoglobin, iron, a^* and pH in dark fillets; lower L^* and b^* values are reported (Boulianne and King, 1995). Meats with a high L^* cause PSE meat formation. This type of poultry meat exhibits pale color, lower water holding capacity and soft gel form. The reason for the high L^* and poor WHC is protein denaturation as a result of rapid pH drop due to intense glycolysis while body temperature is still high immediately after slaughter (Woelfel et al., 2002). The fact that the L^* can be determined more easily and quickly than pH shows that it can be easily used in commercial companies for the classification of poultry meat and sorting of defective meat (Woelfel et al., 2002).

The lower lightness in our study might have been caused by the high ultimate pH (5.75). Differences in the amount of glycogen stored in the muscles are closely related to the formation and variation of the ultimate pH, which is an important determinant of poultry meat quality (Beauclercq et al., 2016). The amount of glycogen and pH_u are the main determinants for the sensory quality and processing properties of poultry meat. Although the main reason for variation in ultimate pH is muscle glycogen content, many factors such as pre-slaughter stress, feeding, transport and slaughter conditions are associated with metabolism, which affects the shear force and tenderness of meat by affecting pH_u (Obanor, 2002). More than half of the variation in pH_u cannot be explained by a single factor. Therefore, changes in meat quality due to differences in pH_u will continue to pose a problem for the meat industry until the precise relationships between all factors are understood (Li et al., 2014). Although the normal pH for broiler breast meat is between 5.7-6.1, below 5.7 meat is called acidic (PSE), and above 6.1 is called DFD (dark, firm and dry) (Barbut et al, 2005). In meat quality studies carried out in quails (Remington et al., 1998; Narinc et al., 2013; Nasr et al., 2017; Oğuz et al., 2004; Gevrekçi et al. 2009; Zerehdaran et al., 2013), it was found that pH_u varied between 5.59-6.36 and was consistent with the findings of our study.

Table 3. Phenotypic correlations and significance of carcass part yields and meat quality characteristics

Çizelge 3. *Karkas parça randımanları ve et kalite özelliklerine ait fenotipik korelasyonlar ve önemlilikleri*

	TY	pH_u	L	a^*	b^*	C^*	H^*	TL	CL	WHC	Texture
BRY	0.365^{**}	0.171	0.122	0.080	0.083	0.104	0.016	0.039	0.054	-0.320^{*}	-0.048
TY		0.013	-0.067	0.117	-0.010	0.035	-0.156	-0.086	0.247^{**}	-0.044	-0.119
pH_u			-0.193^{*}	-0.115	-0.288^{**}	-0.226^{**}	-0.132	-0.248^{**}	-0.155	-0.098	-0.103
L^*				-0.164	0.422^{**}	0.138	0.632^{**}	0.186^{*}	0.327^{**}	0.111	-0.059
a^*					0.588^{**}	0.873^{**}	-0.526^{**}	0.071	0.240^{**}	-0.098	-0.129
b^*						0.891^{**}	0.335^{**}	0.196^{**}	0.385^{**}	-0.051	-0.091
C^*							-0.083	0.169	0.327^{**}	-0.055	-0.108
H^*								0.123	0.138	0.009	0.068
TL									-0.117	0.046	0.051
CL										-0.051	-0.178^{*}
WHC											-0.045

BRY: breast yield, %; TY: thigh yield, %; pH_u: ultimate pH; L^*: lightness; a^*: redness; b^*: yellowness; C^*: chroma; H^*: hue; TL: thawing loss, %; CL: cooking loss, %; WHC: water holding capacity, %; texture, kg/cm^2

* Correlation is statistically significant (*, P<0.05; **, P<0.01)

The estimated phenotypic correlations for carcass part yields (BRY and TY) and meat quality characteristics (pH_u, L^*, a^*, b^*, C^*, H^*, TL, CL, WHC and texture) are presented in Table 3. While BRY exhibited positive phenotypic correlation with TY (0.365, P<0.01), and moderate-poor negative phenotypic correlation with WHC (-0.320, P<0.05); TY showed a significant positive correlation (0.247, P<0.01) only with CL. Alkan et al. (2010) evaluated the phenotypic correlations between carcass part weights in Japanese quails and found significant (P<0.05) negative correlations (-0.383) between breast muscle weight (g) and thigh muscle weight (g); Bohrer et al. (2018) reported that no significant phenotypic relationships (0.08; p>0.05) were observed between BRY and TY, nor between TY and CL (-0.18, P>0.05). In this study, there was a significant poor correlation between pH_u and L^* (-0.193, P<0.05), b^* (-0.288, P<0.01), C^* (-0.226, P<0.01) and TL (-0.248, P<0.01), while negative but insignificant (P>0.05) correlations were determined for a^*, H^*, CL, WHC and texture. Similar to the results of our study, Narinc et al. (2013) reported that there were poorly negative significant (-0.14, P<0.05) phenotypic correlations between pH_u and L^* in quail breast meats. Similar phenotypic correlations in quails, Oğuz et al. (2004) and Bohrer et al. (2018) reported that there were moderately significant phenotypic relationships between pH_u and L^* (respectively; -0.26, P<0.05; -0.42, P<0.01). On the other hand, Berri et al. (2007) reported that the relationship between pH_u and L^* in broilers was medium-strong and negative (-0.61, P<0.0001), while Qiao et al. (2002) reported that the correlation was negative but very strong (-0,836, P<0.01). Oğuz et al. (2004) reported that pH_u was negatively correlated with a^* (-0.15), b^* (-0.12) and C^* (-0.18), but poorly positively correlated with H^* (0.05). Narinc et al. (2013) reported negative and significant correlations with ultimate pH for a^* (-0.22), TL (-0.24), CL (-0.19) and shear force (-0.43), while very poor for b^* and insignificant relationships. These reported results are in agreement with the findings of our study.

The negative and significant correlation found between pH_u and L^* in the results of this study actually shows an expected situation. Although the correlation is poor, it is seen that the ultimate pH has a significant effect on the determination of quail breast meat color. In the findings, even though the relationship between pH_u and WHC is insignificant, it is known that a high L^* value and low pH_u will cause higher drip loss and higher CL. This situation in meat can be explained by the mechanism of PSE meat, which is caused by the rapid pH drop causing protein denaturation, pale color and WHC reduction (Woelfel et al., 2002). It is reported that there may be significant correlations between meats with higher lightness (L^*) and WHC, pH, color and toughness properties (Barbut et al., 2008).

In conclusion, the significant negative correlation between pH_u and L^* in this study shows that selection for breast meat lightness in quails can improve quality characteristics by affecting the ultimate pH, and reducing the incidence of meat quality defects. In the results of this study, although the relationships between L^* with WHC and texture of the meat are insignificant, moderately significant positive correlations (0.327, P<0.01) between breast meat L^* and CL indicate that an improvement for L^* can reduce breast meat cooking losses.

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How to cite: Güler, H.C., Phenotypic Correlations between Carcass Part Yields and Meat Quality Characteristics in Quails, J. Anim. Prod., 2022, 63 (1): 7-14, https://doi.org/10.29185/hayuretim.1011729