Relationships between technological and nutritional meat quality traits in native Mexican *Meleagris gallopavo gallopavo* L.

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ABSTRACT

Objective: To evaluate the relationships between some technological and nutritional meat quality traits in native Mexican Guajolote (*M. g. gallopavo*).

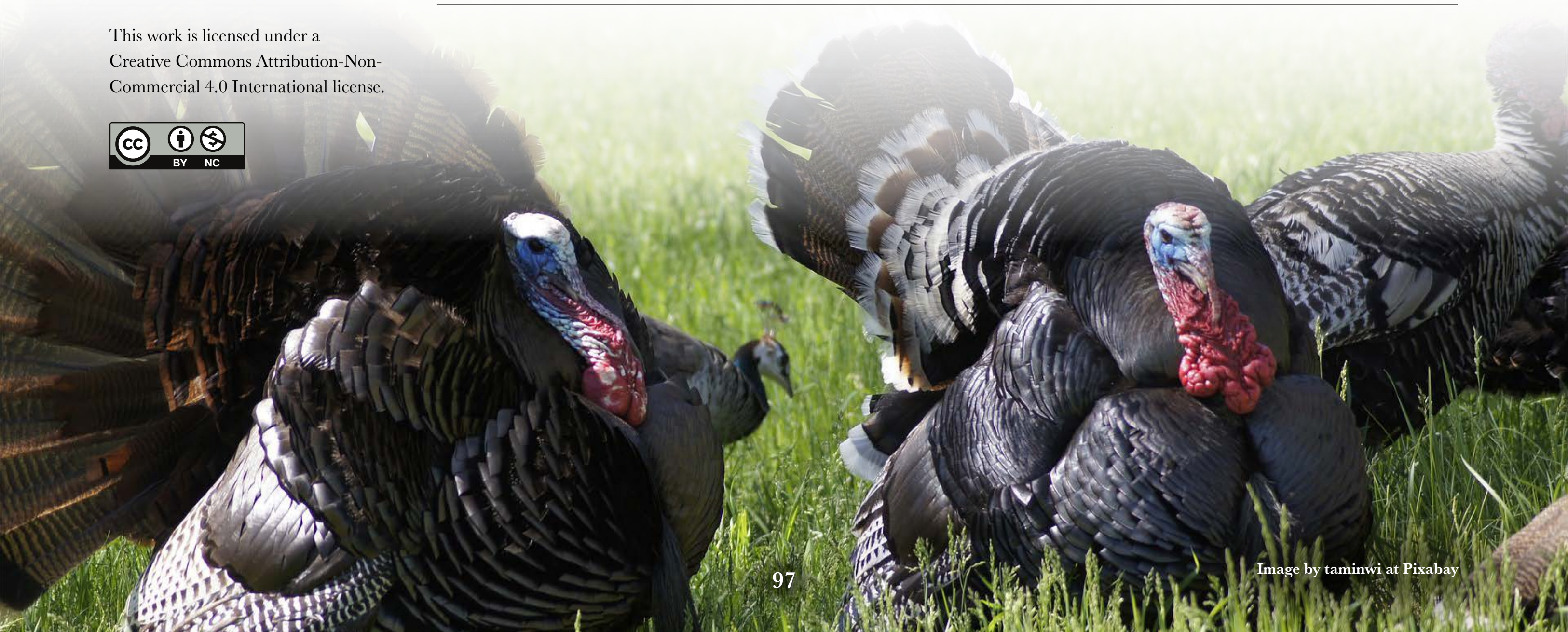
Design/methodology/approach: In the study, a total of 35 carcasses from male native guajolotes (32-40 weeks old; approximately 2.9 kg carcass weight) were used. Some technological [pH, colour (*L**, *a**, *b**), water-holding capacity (WHC), drip loss (DP), and cooking loss (CL)] and nutritional [dry matter (DM), crude protein (CP), crude fat (CF), crude ash (CA) and energy content (EC)] properties of breast and leg meat were evaluated. Pearson correlation of SAS software was used for data analysis.

Results: In breast meat, moderate to high positive correlations ($P<0.01$; 0.35 [pH_{45min} *vs* pH_{24h}]$\leq r<0.82$ [DM *vs* EC]) were observed, but highly and negatively correlations ($P<0.01$; -0.36 [CF *vs* CA]$\leq r<-0.77$ [*b** *vs* DL]) also were found. Similarly, technological and nutritional quality traits in leg meat also showed moderate to high positive correlations ($P<0.01$; 0.38 [pH_{24h} *vs* *L**]$\leq r<0.74$ [DM *vs* CF]); however, high negative correlations ($P<0.01$; -0.42 [pH_{24h} *vs* CL]$\leq r<-0.69$ [*a** *vs* *b**]) were observed.

Limitations on study/implications: Studies on the factors that affect the technological and nutritional characteristics of meat quality in this poultry species should be carried out

Findings/conclusions: The results could be used as an important benchmark of the current state of Guajolote meat quality to develop selection and breeding programs in its genetic improvement.

Keywords: *M. g. gallopavo*, Meat quality, Poultry genetic resource, Technological properties.



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INTRODUCTION

In recent years, consumers are more and more interested in the sustainability, health and nutritional aspects of meat poultry products. They are willing to pay higher price for meat that they perceived as naturally produced and with high standard of animal welfare (Cygan-Szczegielniak *et al.*, 2019). In this way, the interest exhibited by the consumers for poultry products deriving from free-range or organic systems encourages the use of native or local genotypes (Cassandro *et al.*, 2015; Dalle-Zotte *et al.*, 2019). Several studies demonstrated differences in meat quality between native and commercial poultry breeds, particularly in terms of physical traits and chemical composition (Cassandro *et al.*, 2015; Uhlířová *et al.*, 2018; Katemala *et al.*, 2022). Additionally, native poultry meat has a unique taste and texture that draws the attention of consumers (Ali *et al.*, 2021).

Meat quality can be characterized through the technological, chemical and nutritional attributes presented (Hiscock *et al.*, 2022). However, meat quality characteristics in poultry may be influenced by many factors such as species and breed, environment, feeding, and care conditions (Uhlířová *et al.*, 2018; Onk *et al.*, 2019). Meat can be classified with traits such as meat colour, pH, and water-holding capacity and therefore these parameters represent important indicators for meat quality. Due to the relationships between these traits, it is possible that directional selection for some of these traits will improve meat quality (Hiscock *et al.*, 2022).

The native Guajolote (*M. g. gallopavo*) is the second poultry species more abundant and important in backyard poultry in rural and suburban communities of Mexico (Romero-López, 2021). Constitutes a poultry genetic resource of great biological and productive value. Also, has a good capacity for adaptation and high rusticity that allows it to reproduce under different environmental and management conditions (Portillo-Salgado *et al.*, 2022a). Recently, Portillo-Salgado *et al.* (2022b) reported that native Guajolote raised traditionally under extensive conditions can achieve relatively high carcase weights and yields, particularly in males, as well as meat of good nutritional quality, making them preferable for meat production. However, no studies are currently available investigating the possible relationships between meat quality traits. Therefore, the aim of this study was to evaluate the relationships between some technological and nutritional meat quality traits in native Mexican Guajolote. A good understanding of the relationship between these meat quality traits should aid in future breeding strategies to improve overall meat quality of this poultry genetic resource.

MATERIALS AND METHODS

Ethics statement

The experimental protocol was approved by the Animal Welfare Committee of the Colegio de Postgraduados and they complied with the standards for the care and use of animals used for research (Approval folio: COBIAN 002/21).

Sample preparation

For the study, carcases of 35 males native guajolotes (32-40 weeks old; approximately 2.9 kg carcase weight) which were raised traditionally under extensive conditions and fed a mixed diet (Portillo-Salgado *et al.*, 2022b), were used. The birds were humanely slaughtered by exsanguination following the Official Mexican Standards (NOM-008-ZOO-1994, NOM-009-ZOO-1994, and NOM-033-ZOO-1995) established for the humane slaughter of animals intended for meat production. The carcases were scalded in hot water to facilitate manual plucking. Later, carcases were eviscerated and dissected as described by Hahn and Spindler (2002). The right breast (*Pectoralis major*) and leg (thigh and drumstick) meat without skin of each bird were ground for evaluate technological properties and proximate composition.

Evaluation of meat technological properties

The meat pH was measured at 45 min (pH_{45min}) and 24 h (pH_{24h}) *post-mortem* using a portable digital pH-meter (Model HI 99161, Hanna Instruments®, USA). Before measurement, the pH-meter was calibrated using buffers of pH 4.0 and 7.0 at room temperature according to the manufacturer's instructions. The pH was evaluated at three different points, adopting the average value of these three readings. The colour parameters were measured using a colorimeter (Model CR-400, Konica Minolta®, Tokyo, Japan), and were expressed in terms of CIELab colour coordinates reporting values for lightness (L^*), redness (a^*) and yellowness (b^*).

Water-holding capacity (WHC; %) was evaluated by the filter paper press method (Biesek *et al.*, 2021). For this, ground meat samples (3 g) were placed between two sheets of filter paper (Whatman® No. 1) and were pressed with standard weight of 2 kg for 5 min. WHC was calculated as the difference between the initial sample weight and the final weight. Cooking loss (CL; %) was determined by placing ground meat samples (20 g) on a absorbent gauze inside sealed plastic bags, and they cooked in a water bath at 85 °C for 10 min (Kokoszyński *et al.*, 2020). CL was expressed as the ratio between the weight before and after cooking. Drip loss (DL; %) was determined by placing ground meat samples (20 g) in two sealable bags (one of the bags was perforated to allow dripping) and storing them at +4 °C for 24 h (Kokoszyński *et al.*, 2020). DL was expressed as the percentage of weight loss of the sample concerning its weight recorded before the refrigeration period.

Proximate composition of meat

Proximate analysis was performed to determine dry matter (DM; %), crude protein (CP; %), crude fat (CF; %), crude ash (CA; %) and energy content (EC; cal/g) according to the methods approved by the AOAC (1990).

Statistical analysis

Data were analysed using the SAS software, version 9.4 (SAS Institute Inc., Cary, NC). Normal distribution of the variables was analyzed according to the Shapiro-Wilk test. The results are presented as least square means ± standard deviation (SD). Pearson correlation coefficients (r) were evaluated using the PROC CORR procedure to determine relationships between technological and nutritional meat quality traits. Significance was determined when $P \leq 0.05$. Each bird was considered as the experimental unit.

RESULTS AND DISCUSSION

Table 1 shows the technological properties and nutritional meat quality traits of breast and leg meat from native Mexican Guajolote. The pH values obtained in this study (5.71-6.05) varied within the pH range accepted for commercial poultry meat (5.7-6.4) (Gálvez *et al.*, 2018). The decrease in pH_{24h} compared to pH_{45min} *postmortem* indicates normal biochemical changes in muscles (Biesek *et al.*, 2021). Sarica *et al.* (2011) found pH values that varied from 5.9 to 6.1 and 6.1 to 6.4 for breast and thigh meat in turkeys of different genotypes. According to Chumngoen and Tan (2015), the lower pH levels observed in native poultry meat resulted from the effects of more aggressive behavior in native poultry. The authors evidenced that the greater stresses experienced by native chicken caused more glycogens to be metabolized, consequently affected post-mortem glycolysis, lead to lactic acid accumulation, and thus resulted in lower pH values in meat.

Meat colour is the first trait used by the consumer when buying meat, this due used to assess the freshness and quality of meat and is closely related to the ultimate pH (Sujiwo *et al.*, 2018; Uhlířová *et al.*, 2018). Our results showed that leg meat is darker (lower *L** value) and redder (high *a** value) than breast meat. The difference in redness among muscles could be due to a difference in muscle fiber type and histological muscle structure (Sarica *et al.*, 2011). Similar results were observed by Gálvez *et al.* (2018) in commercial turkeys. Myoglobin content is a major factor contributing to meat colour and is dependent on the species, muscle, and age of the bird (Sarica *et al.*, 2011).

WHC is the ability of meat to retain its juice during application of external forces (cutting, heating, grinding, or pressing), and if it is poor, meat will lack juiciness (Sarica *et al.*, 2011; Cygan-Szczegielniak *et al.*, 2019). In this study, the breast and leg meat had WHC values of 59 and 41%, respectively, indicating that breast meat was more suitable for potential further processing. Biesek *et al.* (2021) argued that the mechanism of WHC in the muscles of the breast and legs may differ, as the levels of individual chemical components (protein) are different in both types of muscles. Also, fiber types differ in their ability shrinkage, so the more muscle fibers shrinks, the larger the leakage of water from the muscle tissue would be obtained. Our results regarding WHC are comparable with those reported by Sarica *et al.* (2011) in the breast (46-47%) and thigh (41-46%) meat of turkeys of different genotypes. The CL values observed in the present study were high compared to those reported in commercial turkeys (Damaziak *et al.*, 2016). Differences in cooking loss with respect to genotype might be attributed to different proteins solubility (collagen) and to different fat content. Cooking temperature and ultimate pH could also play a role (Uhlířová *et al.*, 2018).

The proximate composition of breast and leg meat of native Mexican Guajolote is reported in Table 1. Few data were found in the literature about the nutritional composition of native Guajolote. The dry matter, protein, and ash contents were consistent to those reported in breast and thigh meat of native mexican guajolotes (López *et al.*, 2011) and commercial turkeys genotypes (Sarica *et al.*, 2011). However, the latter presented higher fat contents compared to those observed in this study. Therefore, the Guajolote meat may be a better choice for a lower fat diet because of their low fat contents. According to Dalle-Zotte *et al.* (2019), the discrepancies in terms of meat proximate composition in poultry might be

Table 1. Mean ± standard deviation (SD) for technological and nutritional quality traits in breast and leg meat of native Mexican Guajolote.

Traits	Breast meat	Leg meat
	Mean±SD	Mean±SD
pH_{45min}	5.78±0.20	6.05±0.23
pH_{24h}	5.71±0.18	5.75±0.15
*L**	45.60±5.10	42.13±6.43
*a**	1.85±1.00	6.07±2.71
*b**	1.80±1.27	2.79±1.90
Water-holding capacity; % (WHC)	59.09±19.00	40.90±12.69
Drip loss; % (DP)	2.92±1.51	2.97±1.19
Cooking loss; % (CL)	24.82±5.49	25.93±5.88
Dry matter; % (DM)	26.16±0.86	24.66±0.84
Crude protein; % (CP)	22.34±1.00	20.14±0.79
Crude fat; % (CF)	1.47±1.03	1.93±0.71
Crude ash; % (CA)	1.05±0.07	1.02±0.07
Energy content; cal/g (EC)	1291.10±79.09	1199.56±62.00

explained by the lack of standardisation in the productive performances and meat quality traits of these animals.

Analysis of correlations

Tables 2 and 3 show the Pearson correlation matrices between technological and nutritional quality traits in breast and leg meat of native Mexican Guajolote. For breast meat, the pH values were positively correlated with *b** (r = 0.66), and negatively correlated

Table 2. Pearson correlations between technological and nutritional quality traits in breast meat of native Mexican Guajolote.

	pH_{45min}	pH_{24h}	*L**	*a**	*b**	WHC	DL	CL	DM	CP	CF	CA	EC
pH_{45min}	1.00												
pH_{24h}	0.35^{*}	1.00											
*L**	-0.20^{ns}	0.04^{ns}	1.00										
*a**	-0.29^{ns}	-0.21^{ns}	0.04^{ns}	1.00									
*b**	0.27^{ns}	0.66^{***}	0.07^{ns}	-0.21^{ns}	1.00								
WHC	-0.26^{ns}	-0.68^{**}	0.14^{ns}	0.20^{ns}	-0.70^{**}	1.00							
DL	-0.28^{ns}	-0.74^{***}	0.22^{ns}	0.32^{ns}	-0.77^{***}	0.65^{**}	1.00						
CL	-0.40^{*}	-0.56^{**}	0.47^{*}	0.35^{ns}	-0.61^{**}	0.52^{**}	0.59^{**}	1.00					
DM	-0.19^{ns}	-0.22^{ns}	0.05^{ns}	-0.04^{ns}	-0.11^{ns}	0.05^{ns}	-0.03^{ns}	-0.18^{ns}	1.00				
CP	0.01^{ns}	-0.15^{ns}	-0.00^{ns}	0.24^{ns}	-0.25^{ns}	-0.17^{ns}	0.25^{ns}	-0.01^{ns}	0.14^{ns}	1.00			
CF	-0.18^{ns}	-0.10^{ns}	0.03^{ns}	-0.13^{ns}	0.08^{ns}	0.09^{ns}	-0.29^{ns}	-0.02^{ns}	0.63^{**}	-0.53^{*}	1.00		
CA	-0.03^{ns}	-0.17^{ns}	0.50^{*}	-0.16^{ns}	-0.27^{ns}	0.00^{ns}	0.35^{ns}	0.17^{ns}	0.21^{ns}	0.18^{ns}	-0.36^{*}	1.00	
EC	-0.09^{ns}	-0.25^{ns}	0.04^{ns}	0.15^{ns}	-0.17^{ns}	0.26^{ns}	0.03^{ns}	0.08^{ns}	0.82^{***}	-0.03^{ns}	0.78^{***}	-0.08^{ns}	1.00

^{ns} Non Significant; * $P<0.05$; ** $P<0.01$; *** $P<0.001$.

with WHC (r=−0.68), DL (r=−0.74) and CL (r=−0.40 and −0.56) (P<0.01). This result indicated that an increase in pH led to significant increase meat yellowness, but to significant decrease the ability of meat to retain water (Biesek *et al.*, 2021). It is well known that the ultimate pH is of importance when considering meat preservation and stability; high muscle pH affects meat moistness, while a low pH is associated with poor WHC and meat colour (Cygan-Szczegielniak *et al.*, 2019).

The *L** value was found to be positively correlated with CL (r=0.47) and CA (r=0.50) (P<0.05), while *b** was negatively correlated with WHC (r=−0.70), DL (r=−0.77) and CL (r=−0.61) (P<0.01). Similarly, Hiscock *et al.* (2022) found that *L** value was also significantly positively correlated with drip loss (r=0.127-0.166) and cooking loss (r=0.130-0.164) of turkey meat. The authors suggested that lightness (*L**) could be an appropriate indicator trait for overall poultry meat quality that could be included as a phenotype in a breeding program.

In this study, the WHC was significantly positively correlated with DL (r=0.65) and CL (r=0.52), and DL was significantly positively correlated with CL (r=0.59) (P<0.01). These findings confirm the close relationship between these meat technological traits, since the WHC also can be evaluated by drip or cook losses (Sarica *et al.*, 2022). The DM was positively correlated with CF and EC with correlation coefficients of 0.63 and 0.82, respectively (P<0.01). Likewise, CF showed a positive correlation with EC (r=0.78) (P<0.001). Instead, CP was negatively correlated with CF (r=−0.53) (P<0.05). In Holli chickens, dry matter content was positively correlated with protein and ash contents, and fat content was positively correlated with the meat texture, pH values and *a**, but negatively correlated with the protein content (Tougan *et al.*, 2013).

Regarding the leg meat (Table 3), pH_{45min} value was positively correlated with *a** (r=0.59), but negatively correlated with *L** (r=−0.65) and b* (r=−0.48) (P<0.01). For

Table 3. Pearson correlations between technological and nutritional quality traits in leg meat of native Mexican Guajolote.

	pH_{45min}	pH_{24h}	L*	a*	b*	WHC	DL	CL	DM	CP	CF	CA	EC
pH_{45min}	1.00												
pH_{24h}	-0.22^{ns}	1.00											
L*	-0.65^{***}	0.38^{*}	1.00										
a*	0.59^{**}	-0.46^{**}	-0.75^{***}	1.00									
b*	-0.48^{**}	0.49^{**}	0.44^{*}	-0.69^{***}	1.00								
WHC	0.23^{ns}	-0.57^{**}	-0.15^{ns}	0.45^{*}	-0.56^{**}	1.00							
DL	0.37^{ns}	-0.22^{ns}	-0.57^{**}	0.66^{**}	-0.46^{*}	0.42*	1.00						
CL	-0.12^{ns}	-0.42^{*}	0.06^{ns}	0.22^{ns}	-0.36^{ns}	0.39^{ns}	0.17^{ns}	1.00					
DM	0.04^{ns}	-0.08^{ns}	-0.11^{ns}	0.25^{ns}	-0.31^{ns}	0.17^{ns}	-0.16^{ns}	-0.05^{ns}	1.00				
CP	0.15^{ns}	0.08^{ns}	-0.29^{ns}	0.14^{ns}	-0.27^{ns}	0.26^{ns}	0.09^{ns}	0.07^{ns}	0.08^{ns}	1.00			
CF	-0.00^{ns}	-0.07^{ns}	0.06^{ns}	0.18^{ns}	-0.15^{ns}	-0.05^{ns}	-0.00^{ns}	-0.12^{ns}	0.74^{**}	-0.50^{*}	1.00		
CA	-0.00^{ns}	0.16^{ns}	0.10^{ns}	-0.38^{ns}	0.53^{*}	-0.14^{ns}	-0.38^{ns}	-0.24^{ns}	0.13^{ns}	-0.25^{ns}	0.07^{ns}	1.00	
EC	0.04^{ns}	-0.07^{ns}	0.07^{ns}	0.24^{ns}	-0.34^{ns}	0.13^{ns}	0.22^{ns}	0.08^{ns}	0.72^{**}	0.06^{ns}	0.71^{**}	-0.11^{ns}	1.00

^{ns} Non Significant; * P<0.05; ** P<0.01; *** P<0.001.

pH_{24h}, positive correlations with *L** (r=0.38) and *b** (r=0.49) were observed; however, it was negatively correlated with *a** (r=−0.46), WHC (r=−0.57) and CL (r=−0.42) (P<0.05, P<0.01). The above results can be explained by fast acidification of meat and degradation of muscle protein and pigments, this refers to the colour fading (higher *L**, higher *b**, lower *a**), and decreased WHC (increased drip and cooking loss) (Hiscock *et al.*, 2022). Similarly, Barbut (1993) reported high negatives correlations between pH with lightness (r=−0.36) and redness (r=0.38) values.

Meat lightness (*L**) was negatively correlated with *a** (r=−0.75) and DL (r=−0.57) (P<0.01); while positively correlated with *b** (r=0.44) (P<0.05). The results indicate that poultry meat with higher redness tends to present higher levels of lightness and yellowness (Tougan *et al.*, 2013). Positively correlations between reddnes (*a**) and WHC (r=0.45) and DL (r=0.66) (P<0.05, P<0.01) were observed. Yellowness (*b**) was also negatively correlated with WHC (r=−0.56) and DL (r=−0.46) (P<0.05). Interestingly, *b** was significantly correlated with CA (r=0.53) (P<0.05). Finally, DM was positively correlated with CF (r=0.74) and EC (r=0.72) (P<0.01). Instead, a negative correlation (P<0.05) was found between CP and CF (r=−0.50). The latter had a positive correlation with EC (r=0.71) (P<0.01). It is important to examine the relationships between fat content and other nutritional traits of poultry meat closely because low-fat meat is beneficial in a health-driven market (Sarica *et al.*, 2011).

CONCLUSIONS

This study provides an preliminary description of phenotypic correlations between important quality traits of breast and leg meat from native Mexican Guajolotes. The results could be used as an im-portant benchmark of the current state of Guajolote meat quality to develop selection and breeding programs in its genetic improvement. Future work might address the main factors affecting these meat quality traits (*e.g.*, genetics, management, environmental, ante-mortem behavior, among others).

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