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Evaluating the Suitability of Orange Pulp Meal as a Partial Substitute of Corn on the Chemical and Sensorial Properties of Broiler Meat (*Pectoralis major*)

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ABSTRACT

Background: The study aimed to assess the effect of a partial dietary substitution of corn with dried orange pulp (DOP) powder in broiler diets and their effect on *Pectoralis major* meat quality. Furthermore, the study investigated the relationship between physicochemical parameters and sensory characteristics of breast meat even of control and experimental broilers groups.

Methods: Four dietary treatments namely basal diet (control), 5, 10 and 15% DOP were given to 200 broilers 16 days-old for 49 days. Throughout all breeding periods, the control group was fed a diet primarily composed of corn, soybean meal and wheat bran. The experimental groups were given the same initial diet as the control group, but their grower and finisher diets contained 5%, 10% and 15% of orange pulp powder respectively. Physicochemical parameters, proximate composition, lipid oxidation index and sensory characteristics of broiler breast muscle were determined.

Result: Significant decreases in moisture and fats were observed in the experimental groups ($P<0.0001$). However, the experimental diets positively affected the lipid oxidation of breast meat samples, as indicated by the lower malondialdehyde content ($P<0.05$). The partial substitution with orange pulp powder did not show an effect ($P>0.05$) on sensory attributes of breast meat except for overall acceptability by the degustation panel. According to the panel degustation results, the flavor in experimental diets breast meat had a significant correlation on some sensory characteristic like juiciness and color of experimental breast samples ($P<0.001$). Pearson's correlation revealed that flavor of control breast meat was negatively correlated with 2 physicochemical parameters (pH and lipid peroxidation). Similarly, the flavor of experimental groups was negatively correlated with the sensory attributes (juiciness and color). Additionally, a significant positive correlation was found between juiciness and the parameters (color and pH) of experimental meat.

Key words: Broilers, Dried orange pulp, Lipid oxidation, Malondialdehyde, Pectoralis major.

INTRODUCTION

A significant increase in the demand for meat proteins can be attributed to the expansion of the world's population, which is anticipated to reach about 10 billion people by the year 2050 (Zampiga *et al*., 2021). Feeding represents the major cost in raising of broiler chickens and has important implications for environmental impact, either directly or indirectly. Due to the rapid rearing period and its quick response to changes released in diets composition of broiler chickens, the high nutritional value, affordable price of their meat is the best food in the majority of nations. Chicken meat is easier to digest than other types of meat due to its relatively low collagen level (Kralik *et al*., 2018). However, polyunsaturated fatty acids (PUFA) are highly susceptible to oxidation, which affects meat's nutritional value, sensory qualities and shelf life (Kralik *et al*., 2018). There is an increasing interest in utilizing natural feed additives or substitute to improve animal performance and the quality of meat intended for human consumption.

Recently, citrus fruit residues have the potential to serve as valuable natural sources of antioxidants, containing a significant amount of ascorbic acid (Hassan *et al*., 2021).

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The nutritional composition and organoleptic properties of meat hold significant importance for consumers and are essential considerations for the meat industry

(Jung *et al*., 2014). The contents of chicken meat, including moisture, crude protein, crude fat, crude ash and crude fiber are important to show the nutritional profile. Juiciness, appearance, tenderness, flavor are the most important attributes for humans' consummation (Kishawy *et al*., 2019). Although there are texture and appearance that can affect meat quality, consumers place a high value on appearance, particularly the color, as it is a key factor in both the initial decision to purchase a product and the level of satisfaction.

The aim of the current study was to determine how the substitution corn with dried orange pulp at graded levels of 5, 10 and 15% in the diet influenced the physicochemical, sensory and antioxidant status of broilers *Pectorails Major* muscles.

MATERIALS AND METHODS

Experimental animals and management

This investigation utilized a sample size of 200 Arbor Acres broiler chicks that were one day old. Upon arrival, the chicks were subjected to an anti-stress treatment, which was supplied via clean drinking water at a concentration of 100 g/50 L. The aforementioned actions were undertaken in order to alleviate the stress commonly associated with transportation, stimulate them appetite and offer a supplementary source of energy (Chaib eddour *et al*., 2023).

After 16 days of rearing period, the chicks were individually weighed and randomly assigned to four dietary treatments, with five replications of 10 birds per replicate. The temperature of the broiler house was initially established at 35°C at the beginning of the feeding trial. Subsequently, it was systematically reduced by 2-3°C on a weekly basis until it reached 22°C by the fifth week.

To promote feeding and drinking of the chicks, an initial 24-hour illumination schedule was implemented for a duration of 72 hours. Following this, the lighting duration was decreased to 23 hours per day by the end of the initial period (day 15) of postnatal. Subsequently, the lighting duration was further reduced to 22 hours per day and sustained until the animals reached the day of slaughter. The compositional details of distinct dietary formulations are delineated in Table 1 (Chaib eddour *et al*., 2023).

Animal welfare and slaughtering procedures

All chicken breast meat used in this study were purchased directly from our experiment released in Higher School of Agronomy, Mostaganem, Algeria, immediately after slaughter. Broiler chickens of different diets (Control, 5, 10 and 15% DOP) were slaughtered at 49 days of age. Ten broilers were selected for the slaughtering process in accordance with an 8-hour fasting regimen for each feeding treatment. The chickens underwent scalding at the recommended water temperature of 55°C. Following defeathering, the carcasses were eviscerated, washed and placed in airtight plastic bags.

After the completion of the slaughtering process, the breast muscles, notably the Pectoralis Major, were carefully removed from each carcass in a methodical manner in order to facilitate subsequent chemical analysis. The carcasses were packed in transparent storage bags and hung in cold storage at 4°C for 24 h to determine the pH. The breast muscles were dissected from the whole carcass sample of meat chicken minced, placed in plastic bags and stored frozen (-20°C) until used for chemical analyses.

The breast samples (n= 2 per repetition; and total of 10 per group) were randomly evaluated for chemical composition, pH, moisture, percentage of lipids, dry matter and mineral matter.

Physical characteristics of broiler chickens breast meat

1-Meat pH measurements

Ten samples from each group were stored at 4°C until used to determine the pH within 24 h. The pH of the breast fillet samples were analyzed using a portable pH meter with a meat penetrating probe (model STARTER 2100 PH BENCH-ST2100-F), according to (Olivo *et al*., 2001).

Ten breast muscle meat from each treatment were measured. Three measurements were obtained from the cranial region of the *Pectoralis major* muscle. The pH meter was calibrated using pH 4, pH 7 and pH 9 standard solutions. The probe was then inserted into the *Pectoralis major* meat on the left side of the breast at 45° angle.

Table 1: Feed ingredients of different diets (Chaib Eddour *et al*., 2023).

Ingredients (%)	Grower and finisher (15 to 49 days of age)			
	Control	5% DOP	10% DOP	15% DOP
Corn	67%	62 %	57%	52%
Soybean meal	27%	27%	27%	27%
Wheat bran	5%	5%	5%	5%
Dried orange pulp	0%	5%	10%	15%
Phos+Cal	1%	1%	1%	1%
Vit- premix	1%	1%	1%	1%

*Phos+Cal: Phosphorus and Calcium.

*Vitamin-mineral premix: Provided (in mg kgG1 of diet), Vitamin E: 6, Vitamin K3: 0.80, Vitamin B1: 1, Vitamin B2: 3, Pantothenate of Ca: 6, Vitamin B6: 1.5, Vitamin B12: 0.006, Folic acid: 0.2, Nicotinic acid: 12, Copper: 5, Cobalt: 0.65, Manganese: 65, Zinc: 65, Selenium: 0.25, Iron: 50, Iode: 0.8, Magnesium: 100.

The probe was washed with deionized water between each sample.

2-Proximate composition

The proximate composition (moisture, crude fat and total ash) was analyzed using standard protocols (AFNOR, 1985). The analysis of all parameters was conducted in ten replicates in order to confirm the accuracy of the results. In order to ascertain the moisture content, the utilization of an oven-drying technique at a temperature of 105°C for a duration of 24 hours was implemented. The ash content was determined by exposing the samples to a process of ashing at a temperature of 550°C in a muffle furnace for a duration of 3 hours, until the ash reached a light gray or white color.

3-Lipids

The lipid extracts were obtained using a chloroform-methanol mixture according to (Folch *et al*., 1957) method.

Briefly, a meat sample was homogenized with Folch reagent (chloroform/methanol 2:1) using an Ultra Turrax for 3 minutes. Following this, the filtrate was mixed with a sodium chloride (NaCl) solution of 0.73% concentration, with a volume ratio of 1-part NaCl solution to 4 parts of the filtrate. The mixture was let to undergo a settling process for a duration of two hours. The bottom phase, comprising lipids, was isolated by filtration using anhydrous sodium sulfate.

The top phase underwent a further extraction process employing a 50 ml solution consisting of 20% (0.58% NaCl) and 80% (methanol + chloroform). The objective of this stage was to extract any residual lipid residue. The mixture was permitted to undergo a settling process lasting approximately 30 minutes. The lower phase (chloroform + residual lipids) is then collected and added to the initial filtrate.

After chloroform evaporation, the dry lipid residues are weighed. The lipid content is determined by the following formula:

$$\% LT = \frac{\text{Weight of filled balloon - Weight of empty balloon}}{\text{Sample weight}} \times 100$$

4-Measurement of oxidative stability (TBARS)

Thiobarbituric acid reactive substances (TBARS) were measured on the breast meat of the bird 20 days after slaughter, with the samples kept at (-20°C) during the storage period.

Thiobarbituric acid (TBA) reacts with malondialdehyde (MDA) to generate a pink and yellow complex exhibiting maximal absorption at a wavelength of 532 nm. The assessment of lipid peroxidation in breast muscle meat followed the method outlined by Genot (1996).

In this process, a meat sample is placed within a tube containing trichloroacetic acid and ascorbic acid (Vitamin C). The mixture is homogenized using an Ultra-Turrax at approximately 20,000 rpm. The resulting filtrate is subsequently combined with thiobarbituric acid. Sealed tubes are immersed in a water bath set at 70°C for a duration of 30 minutes and then transferred to a cold-water bath.

The results are expressed in mg equivalent of malondialdehyde (MDA) per kg of fresh weight and calculated using the following formula:

$$\text{Mg equivalent MDA/kg} = \frac{(0.72/1.56) * (A532 * V\ solvent * Vf)}{PE}$$

Where:
A532: Represents the corrected absorbance value.
V solvent: Volume of the TAC dilution solution in milliliters.
PE: Weight of the test sample in grams.
Vf: Volume of the collected filtrate.

The absorbance of the sample was detected at 532 nm using a spectrophotometer UV-SPECTORD 210 PLUS (analytikjena, Germany).

5-Sensory evaluation

Sensory analysis of chicken breast meat was conducted after two weeks of storage at (-20°C) to assess meat quality based on specific sensory criteria, including color, juiciness, tenderness, flavor, overall acceptability and a calculated Sensory Index (SI). The sensory index (SI) was calculated with the following equation:

$$SI = \frac{(2.\ O + 2.\ C + T)}{5}$$

Where:
SI= Sensory Index.
O= Odor.
C= Color
T= Texture.

The sensory evaluation was conducted in the Laboratory of Biotechnology Applied to Agriculture and Environmental Preservation, located at the Higher School of Agronomy “Mohamed El Amjed Ben Abdel Malek” in Mostaganem, Algeria.

After the slaughter of the animals, ten chicken carcasses were randomly selected from: the control group (C), 5, 10 and 15% DOP groups. The carcasses were subjected to the process of oven roasting, with a cooking duration of 1 hour and 30 minutes for every kilogram of carcass, without additional seasoning.

Subsequently, the meat samples were wrapped in aluminum foil and designated with codes. The cooked samples were presented to the taster in a plate divided into four coded sections, each corresponding to meat derived from broiler chickens fed with different diets: a control group and diets containing 5%, 10% and 15% of Dried Orange Pulp (DOP). A 16 semi trained panel of assessors consisting of Professors, staff and students.

The assessors received training on the sensory protocol and instructions regarding parameters such as tenderness, juiciness, flavor, cooked color and overall acceptability, assessed using a 9-point hedonic scale. The room was

maintained at 21°C and illuminated with fluorescent light. The panelists sat on a long table two meters apart.

Statistical analysis methods

Physicochemical and sensory properties of broiler chicken *Pectoralis major* meat were examined in relation to the impacts of substitute corn by dried orange pulp powder in diets using the Analysis of Variance (ANOVA). The correlations between the physicochemical parameters of meat and its sensory attributes were studied by the Pearson correlation.

Version 26.0 of Statistical Package for the Social Sciences (SPSS) software was used to analyze the data.

RESULTS AND DISCUSSION

In Table 2 the physicochemical properties of broiler chicken breast meat have been presented.

1-Physical characteristics of broiler chickens breast meat

The pH values of the chicken breast meat samples examined in this investigation exhibited a range 165 between 6.03 and 6.12. The results of the statistical analysis revealed that there were no statistically significant differences observed among the chicken breast meat samples from the different treatment groups (P= 0.51).

During the process of animal slaughter, glycogen is enzymatically hydrolyzed into glucose, which subsequently undergoes glycolysis. In the absense of oxygen, the process of anaerobic glycolysis occurs, resulting in the production of lactic acid. This accumulation of lactic acid is responsible for the decrease in muscle pH, which in turn contributes to the conversion of muscle tissue into meat (Qwele *et al*., 2013).

Typically, the pH range for *Pectoralis major* meat 24 hours after slaughter is between 5.6 and 5.9 (Garcia *et al*., 2010; Salwani *et al*., 2016), although it can go up to 6.02 (Bruckner *et al*., 2012). However, in partial relation with our results (Zoidis *et al*., 2022 and Mourao *et al*., 2008), concluded that the pH values were lower in the breast muscles from the birds fed with DOP, in comparison with the controls. According to Xiong *et al*. (2011), the addition of pine needle powder, which is recognized for its high phenolic component concentration, did not lead to notable changes in the pH levels of fresh breast and thigh meats across the different experimental groups.

2-Meat proximate composition of different chicken

The breast meat derived from the different dietary regimens exhibited statistically significant variations in moisture and ash content (P<0.05). The moisture content findings found in our investigation are consistent with the range previously documented by Brunel *et al*. (2006) for breast muscle, which varied from 71.5% to 78.4%.

The current investigation has revealed a significant decrease in fat content within the pectoral muscle tissue of broiler chickens fed with dietary regimen containing dehydrated orange pulp (DOP) compared to the control group (P<0.0001). Broilers fed a diet containing 5% dried orange pulp had fat content reduced by 47.43% compared to *Pectoralis major* meat from the control diet. Crude ash content was the lowest in control *Pectoralis major* meat among all treatments (P<0.02).

Bostami *et al*. (2017) reported that supplementation with plant by-products may decrease fat concentrations due to the presence of phenolic compounds.

The results shown in this study agree with previous study results conducted by (Kralik *et al*., 2018; Benamirouche *et al*., 2020). These studies used phytochemical extracts and demonstrated a notable decrease in the fat content of the thigh muscle. Similarly, a study showed about 10% lower total lipids in broilers offered polyphenol rich grape seed at 10 to 40 g/kg diets (Mahfuz *et al*., 2021). The phenolic compounds have the potential to impact the enzymatic processes associated with the assimilation and use of dietary fats. The modulation of these processes by phenolic compounds has the potential to result in a reduction in fat formation in meat (Diaz-Vargas *et al*., 2018). Also, the incorporation of orange pulp into the diet results in a reduction in fat content, which may have an indirect effect on the moisture level of meat. The inclusion of high-fiber components such as orange pulp in broiler diets have the potential to decrease the overall calorie density of the diet, hence potentially resulting in a decrease of fat accumulation. A reduction in fat content of meat has the potential to decrease the total moisture percentage.

Fig 1 illustrates the influence of integrating dehydrated orange pulp into the diets of broiler chickens on the levels of malondialdehyde (MDA). A noteworthy decrease in malondialdehyde (MDA) levels was observed in the breast muscle of broiler chickens across all analyzed samples of *Pectoralis major*, which were fed diets containing dried

Table 2: Results of the compositional analysis of *Pectoralis major* meat of broiler chickens.

Proximate composition	Treatments				SEM	P value
	Control	DOP 5%	DOP 10%	DOP 15%		
pH	6.12^{a}	6.03^{a}	6.06^{a}	6.09^{a}	0.06	0.51
Fat (%)	2.07^{b}	0.98^{a}	1.07^{a}	1.11^{a}	0.23	P < 0.0001
Crude ash (%)	1.24^{a}	1.25^{a}	1.60^{b}	1.55^{b}	0.11	P = 0.02
Moisture (%)	74.51^{bc}	74.76^{c}	73.39^{a}	72.60^{ab}	0.45	P < 0,0001

a-c Mean values with a different superscript letter within the same row are significantly different (P<0.05).
The presented values constitute the mean of triplicate measurements±standard error (SE).

orange pulp, in comparison to the control group. In particular, broiler chickens that were fed a meal containing 10% dried orange pulp had a significant reduction of 65.3% in malondialdehyde (MDA) concentrations in their *Pectoralis major* meat in comparison to those chickens that were fed the control diet.

Similarly, it has been suggested that inclusion of orange pulp in broiler diets could potentially reduce MDA levels in broiler meat (Mavrommatis *et al*., 2022). Moreover, our results are related to those presented by (Petru Alexandru Vlaicu *et al*., 2020), where broiler diet supplemented with orange pulp had a lower level of TBARS compared to the control group. Finally, it was proved that Dried Citrus Pulp inclusion rates of up to 10% in broiler diets favorably decreased oxidation rate in chicken meat (Diaz-Vargas *et al*., 2018 and Zoidis *et al*., 2022). Faiz *et al*. (2017) reported similar results in their study on the impact of citrus peels in reducing TBARS levels. Based on the findings of this study, it can be concluded that the inclusion of antioxidants in broiler feed effectively inhibits the formation of malondialdehyde (MDA) in breast meat and retards the process of lipid oxidation. A group of natural antioxidants serves to protect fats against oxidative damage by deactivating nitrogen dioxide (without decomposition) and reacting with hydroxyl, superoxide and peroxyl radicals (Johnson-Dahl *et al*., 2017).

Sensory analysis of *Pectoralis major* meat

The sensory characteristics of breast meat from each chicken treatment are presented in Table 3. The inclusion of orange pulp in the diets led to an increase in flavor intensity, tenderness and juiciness scores of the meat, although the effect was not statistically significant. Notably, during the tasting session, the overall acceptability score of broiler samples fed with 15% dried orange diets exhibited a significant ($P<0.05$) increase of over 23% compared to the control group.

Numerous studies have explored the influence of diet composition on the sensory attributes of chicken meat (Kim *et al*., 2009; Escobedo del Bosque *et al*., 2020). Extracts derived from plants can introduce variations in color and flavor, potentially impacting meat quality characteristics (Jin *et al*., 2015).

Despite the lack of statistical significance, observable differences in meat color among the supplemented birds may be attributed to the higher phenolic contents in their diets. These phenolic compounds likely transferred to the meat and prevented the oxidation of myoglobin (Ouyang *et al*., 2016). According to Jiang and Xiong (2016), the addition of flavonoids to meat could have a beneficial impact on its sensory qualities.

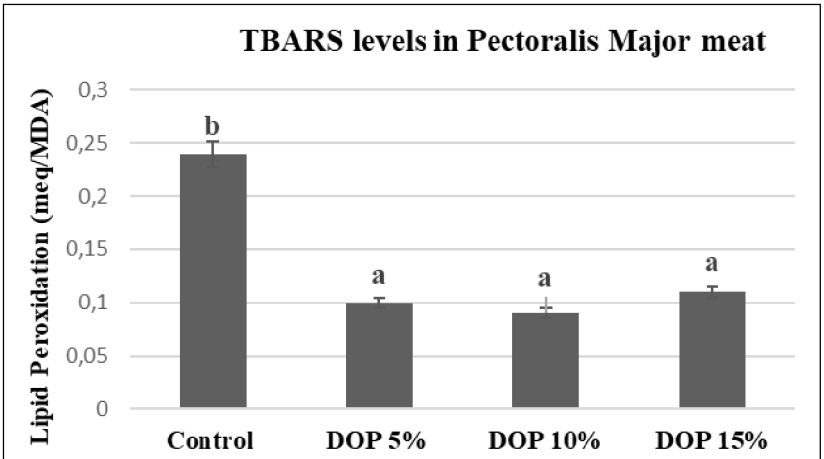


Fig 1: TBARS levels in *Pectoralis major* meat of broiler chickens.

Table 3: Sensory characteristics of *Pectoralis major* chicken's meat.

	Control	DOP 5%	DOP 10%	DOP 15%	SEM	P value
Flavor intensity	3.91[a]	3.97[a]	4.06[a]	4.41[a]	0.76	0.91
Juiciness	3.47[a]	2.97[a]	3.34[a]	2.78[a]	0.66	0.64
Tenderness	6.72[a]	6.28[a]	6.91[a]	5.47[a]	0.64	0.13
Color	2.69[a]	3.16[a]	3.41[a]	3.56[a]	0.54	0.51
Acceptability	5.44[a]	5.22[a]	5.28[a]	7.00[b]	0.72	0.048
Sensorial index	4.37[a]	4.48[a]	4.39[a]	4.86[a]	0.60	0.84

Control, DOP5, 10 and 15% graded levels of dried orange pulp.

[ab]Means in the same row with different superscript are significantly different.

Table 4: Relationship between sensory attributes and meat guality in the *Pectoralis major* of broiler chickens fed control and varying levels (5%, 10% and 15%) of dried orange pulp (GDOP) diets.

	Régime	Sensory attributes		Physicochemical parameters		
		FLAV	JUI	COL	pH	PL
FLAV	Control	1	-0.23	-0.23	-0.63*	-0.81**
	GDOP	1	-0.38**	-0.38**	0.25	0.08
JUI	Control		1	1.00**	-0.58	-0.83**
	GDOP		1	1.00**	0.36*	0.13
COL	Control			1	-0.58	-0.83**
	GDOP			1	0.36*	0.13
pH	Control				1	0.48
	GDOP				1	-0.18
PL	Control					1
	GDOP					1

L.P: Lipid peroxidation (meq Malondialdehyde); FLA: Flavor; JUI: Juiciness; COL: Color.

The results are presented in the form of correlation coefficient, r.

*Correlation is significant at 0.05 level. **Correlation is significant at 0.01 level.

Correlations between sensory aspects and breast meat quality of broiler chickens

The analysis of data using Pearson correlation coefficient revealed a relationship between sensory characteristics and quality parameters of the *Pectoralis major* meat in broiler chickens from different treatments in the study (Table 4). Sensory evaluations included tenderness, juiciness, flavor, texture, color and sensorial index. The measured quality parameters are muscle pH, fat content, mineral content, water content and lipid peroxidation.

Control group

Firstly, a statistically significant positive correlation was observed between color and juiciness (r= 1.00; P<0.0001). Additionally, we identified a moderate negative correlation between flavor and the pH of meat obtained from chickens fed a control diet (r= -0.63; P<0.05).

Moreover, the flavor was negatively correlated with lipid peroxidation (r= -0.81; P= 0.004). Further, the concentrations of MDA in *Pectoralis major* meat presented a negative correlation with juiciness (r= -0.83; P= 0.03) and color (r= -0.83; P= 0.03). According to Lindsay (1985), many of the flavor components of poultry are fat-soluble. The presence of fat also contributes to the juiciness characteristics of meat. Our correlations in the control group meat were consistent with the findings of (Basmacioglu *et al*., 2004), confirming that meat exposed to unfavorable storage conditions and an increase in the content of polyunsaturated fatty acids (PUFA) can impact the process of lipid oxidation, which in turn affects color and flavor. These changes can also lead to a reduction in water-binding capacity, resulting in decreased juiciness and a tougher texture in the meat (Sohaib *et al*., 2017).

Dried orange pulp groups

Flavor exhibited strong negative correlations with both Juiciness (r= -0.38; P= 0.009) and Color (r= 0.38; P= 0.009). Furthermore, Juiciness showed a strong positive correlation with Color (r= 1.00; P<0.0001) and a moderate correlation with pH (r= 0.36; P= 0.001). Similarly, a moderate positive correlation was identified between the color and pH of breast meat obtained from chickens fed a diet that included a substitution of corn for graded levels of dried orange pulp (r= 0.36; P<0.05).

The development of flavor has been ascribed to the presence of phenolic chemicals and flavonoids. For example, the quercetin dihydrate addition decreased the aldehydes volatiles particular hexanal and pentanal (Sohaib *et al*., 2017). Meat color is closely related to protein denaturation, pH and oxidation state (Bostami *et al*., 2018).

Moreover, the improved meat redness could be attributed to the lower drip loss because myoglobin is soluble in water and could be lost during drip loss or purge (Barbut *et al*., 2008; Hernandez *et al*., 2016).

Color value of the meat reduced as the concentration of orange waste was increased in the feed of the broilers. The orange waste phenolic deposit in meat act as antioxidant and result in reduction of color values judged by assessors. These findings are in line with the study of Mourao *et al*. (2008) in which a reduction in color redness of broiler chickens' meat was observed with higher level of citrus pulp supplementation.

The presence of hesperidin and naringin in dried orange peel (DOP) has been observed to have the ability to mitigate radical chain reactions within the lipid component. This is achieved through the donation of hydrogen atoms to free radicals (Hager-Theodorides *et al*., 2021).

CONCLUSION

Dried orange byproducts are a valuable source of fiber and bioactive compounds having possible health-stimulating benefits and enhancing the quality of broiler chicken's pectoral muscle. Furthermore, the current study suggests that adding orange pulp powder to broiler feed has the

potential to improve broiler breast meat quality by reducing lipid oxidation during the whole storage time.

Sensory evaluation indicated that broiler *Pectoralis major* obtained from the group fed with 15% dried orange pulp were preferred by the sensory panel, suggesting potential benefits in flovor and overall acceptability.

Conflict of interest statement

The authors declare that there are no conflicts of interest related to this article.

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