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Effect of dietary turmeric powder (*Curcuma longa* L.) on cooked pig meat quality

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Abstract

The study was carried out on raw meat samples derived from pigs fed with a control diet and a diet supplemented with daily 4.5 g of turmeric powder per pig. After slaughter raw meat was stored for 7 days at 4°C. At Day 0 and Day 7 samples were cooked in a preheated oven at 163°C to the internal temperature of 71°C. Colour parameters, Warner Bratzler shear force, TBARS and antioxidant capacity (ABTS, DPPH and FRAP) were determined at Day 0 and Day 7. Dietary turmeric powder induced an increase in cooked meat of L^* value ($P<0.001$) and reductions in a^*, b^* indexes and in C^* value ($P<0.01$, $P<0.001$ and $P<0.001$, respectively). Colour modifications in cooked meat were correlated with colour parameters of raw samples. The *Curcuma longa* powder dietary supplementation did not affect lipid oxidation, Warner Bratzler shear force and antioxidant capacity of cooked meat ($P>0.05$).

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Introduction

Meat and meat products are susceptible to variation in quality parameters and deterioration of their nutritional component (Shah *et al*., 2014). Pig meat, is characterized by a high content of unsaturated fatty acids that tends to rapidly oxidize and degrade (Wood *et al*., 2004). Pig meat is consumed worldwide after processing (such as fermentation, seasoning, curing) or cooking (such as boiling, roasting, baking). Cooking of raw meat is necessary to eliminate any associated foodborne pathogens (Gill *et al*., 2005; Mataragas *et al*., 2008). Cooking technique can influence quality, odour and flavour of cooked meat obtained from the same raw meat, moreover quality of cooked meat can be influenced by pH, meat source, fat content, added ingredients, storage conditions and preservation treatments (Aaslyng *et al*., 2003; Bejerholm and Aaslyng 2004; King and Whyte 2006). Dietary natural antioxidant can improve raw meat quality and extend shelf-life of products, and lead modifications after consumption (Velasco and Williams 2011; Shah *et al*., 2014; Mancini *et al*., 2016). *Curcuma longa* and its derived powder (turmeric) might be a useful natural antioxidant dietary supplementation. Turmeric has anti-inflammatory, anti-infectious and anti-tumours properties partly deriving from curcumin (Jain *et al*., 2007). Curcumin has the ability to inhibit lipid peroxidation and scavenge the superoxide anion and hydroxyl radicals (Ruby et al., 1995; Motterlini *et al*., 2000) and its concentration in turmeric may vary and, in general, was attested in the percentage of 3% (Jayaprakasha *et al*., 2002; Sasikumar *et al*., 2004; Tayyem *et al*., 2006; Kim and Jang, 2009). The effect of turmeric on raw meat samples was reported in few articles (Daneshyar, 2012; Sharma *et al*., 2012; Mancini *et al*., 2015) but, at the best of our knowledge, no research was carried out to evaluate its antioxidant capacities after cooking procession in meat matrix. The aim of this study was to investigate the effect a supplemented diet with turmeric powder on pig meat colour, Warner Bratzler shear force, lipid oxidation and antioxidant capacity after storage and cooking.

Material and Methods

Animals and diets

Eighteen female pigs of Cinta Senese breed (15 months, 122 ± 2 kg) were reared in a pasture system for experimental period of 30 days as reported in our previous study (Mancini *et al*., 2016). Pigs fed a daily supplementation of 2 kg of cereal feed per pig (barley

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50%, wheat 25%, beans 15%, and oats 10%) with free access to water. At the age of fifteen months pigs were randomly allocated into 2 diet treatments (Control, C, and Turmeric, Tu). Each diet treatment was formed by three groups (3 pens of 3 animals for each diet treatment, pens were analysed as block factor, B). Diet treatments were performed as follow: C only basal diet, Tu basal diet with a daily supplementation with 4.5 g of turmeric powder per pig. Turmeric powder was mixed with fresh feed every day. At the end of the experimental period all the animals were electrically stunned and slaughtered at a local commercial slaughterhouse. After 24h at 4°C the left longissimus lumborum muscles were removed from carcasses and transported to the laboratory.

Meat quality

Longissimus lumborum muscles were cut into 25 mm thick chops perpendicular to the fiber direction. Raw chops were stored at 4°C for 0 and 7 days (3 chops from each pig for each retail displays, for a total of 108 chops) on Styrofoam trays with polyethylene overwrap film. At day 0 and 7 raw chops were cooked for analyse cook meat quality. Chops were cooked in a ventilated oven at 163°C to the internal temperature of 71°C. Cooked meat samples were analysed, after reached the room temperature, for colour, Warner Bratzler shear force, lipid oxidation (TBARS, thiobarbituric acid reactive substances) and antioxidant capacity (2,2'-azino-bis(3-ethylbenzthiazoline-6-sulphonic acid) - ABTS reducing activity, 2,2-diphenyl-1-picrylhydrazyl - DPPH radical scavenging activity and ferric reducing ability - FRAP).

Colour measurements were performed using a Minolta CR300 colorimeter (Minolta, Osaka, Japan, illuminant D65 and incidence angle of 0°). Before each session the colorimeter was calibrated on a white tile, according to the CIE colour space system. Colour parameters (L^*, a^* and b^*) were used to calculate the total colour differences (ΔE) as reported in Sharma (2003). A higher value of ΔE than 2.3 units corresponds to a just-noticeable difference (JND) for the human eye, and it is considered discernable. Warner Bratzler shear force was measured as shear force (kg cm^{-2}) using Warner-Bratzler Shears applied to an Instron 1011 (Instron Ltd, High Wycombe, UK). Cylinders of cooked meat were cut from each sample (2.54 cm diameter) and placed inside the Warner-Bratzler, to be sheared perpendicularly to the long axis of the muscle fibers with a 50 kg tension-compression load cell using a crosshead speed of 100 mm min^{-1}. Lipid oxidation was measured by TBARS method using the colorimetric method described by Dal Bosco *et al.* (2009), and results were expressed as mg MDA on kilogram of cooked sample.

Samples were extracted with ethanol and the antioxidant capacity was assessed using the following methods: ABTS reduction activity (Re *et al*., 1999), DPPH radical scavenging activity (Jung *et al*., 2010) and FRAP reduction ability (Descalzo *et al*., 2007) as modified in Mancini *et al.* (2015).

Colour indexes and pH of raw samples, previously reported in Mancini et al. (2016), were used to calculate correlation with colour indexes of cooked samples. Colour parameters of raw samples were also used to calculate ΔE between raw and cooked samples.

Statistical analysis

Data obtained from colour, Warner Bratzler shear force, lipid oxidation and antioxidant capacity were analysed using R free statistical software (R Core Team 2013). The significance level was set at 5 % (statistically significant for $P<0.05$).

Data were analysed with the following linear model:

$$Y_{ijkz} = \mu + \alpha_i + \beta_j + \gamma_k + \alpha\beta_{ij} + e_{ijkz}$$

where Y_{ijkz} is the dependent variable of the z^{th} observation; μ is the overall mean; αi is the effect of the diet (i = C, Tu); β_j is the effect of the storage time (j = 0, 7 days); γ_k is the effect of the block B (k = 1, 2, 3, 4, 5, 6); $\alpha\beta_{ij}$ is the effect of the interaction between diet and storage time, and eijkz is the random error. No block B significant difference was found and B was removed from the final model. Interaction between main factors was not significant and thus was not reported in tables.

Two-ways ANOVA was conducted and data are reported as mean of the fixed effects Diet (D) and Storage time (ST), the variability was expressed as Root Mean Square Error (RMSE).

Probabilities and correlation coefficients between pH, colour indexes and the cooking loss of raw samples and colour indexes of cooked samples were calculated. The normality of residuals was tested with Shapiro-Wilk test.

Results and Discussion

The effects of D and ST on meat colour and Warner Bratzler shear force are reported in Table 1. Warner Bratzler shear force did not differ among the experimental factors considered. L^*, a^*, b^* and C^* colour parameters were significantly affected by diet ($P<0.001$ for L^*, b^* and C^* and $P<0.01$ for a^*) and

Table 1. Physical characteristics of meat cooked samples.

	Diet (D)		Storage time (day, ST)		P-value		RMSE[1]
	C	Tu	0	7	D	ST	
Samples n.	9	9	18	18			
L*	64.15	67.77	63.53	68.40	***	***	2.282
*a**	9.25	8.15	10.10	7.31	**	***	0.913
*b**	14.24	13.15	14.04	13.35	***	*	0.834
C*	17.04	15.53	17.32	15.24	***	***	1.006
H*	57.20	58.61	54.42	61.39	ns	***	2.482
WB [2]	11.03	10.72	11.46	10.29	ns	ns	1.787

C = Control diet; Tu = Control diet + Turmeric powder.
ns = not significant; * = P<0.05; ** = P<0.01; *** = P<0.001.
[1] root mean square error.
[2] Warner Bratzler shear force, expressed as kg cm^{-2}.

storage time (P<0.001 for L^*, a^* C^* and P<0.05 for b^*). Cooked meat samples derived for Tu diet showed higher value of L* and lower levels for a*, b* and C* than C diet samples. King and Whyte (2006) reported that pH of raw meat could affect colour parameter of cooked meat as it has a central role in the formation of ferrihemochrome from myoglobin. As pH of raw samples was not statistical different (Mancini *et al.*, 2016) the differences observed in colour indexes of cooked samples depended on feeding regime. At day 7 cooked meat samples appeared more grey and pale in colour than at day 0, as showed by the higher value of L^* and the lower values of a^* and b^*. In literature no data are available to compare our results since all reported data consider the quality evaluation of refrigerated cooked meat samples. Ranucci *et al.*, (2014) reported the same trend of L^* in cooked meat derived from pigs fed with oregano essential oil and sweet chestnut wood extract, conversely to our results a^* was higher than control diet. O'Grady *et al*. (2008) reported that L^* and a^* parameters were unaffected by diet in cooked meat of pig supplemented with grape seed extract or bearberry.

H^* was influenced by only ST (P<0.001) and showed higher level after 7 days and inversely proportional with a^* values. At Day 7 the difference between a^* and b^* indexes was higher than at Day 0, this induced lower values of b^*/a^* ratio (used for calculate H^*) at Day 0 than Day 7. To better understand the relationship between colour indexes of cooked samples and pH, colour indexes and cooking loss of raw samples pairwise comparison correlations were calculated (Table 2). No correlation between pH and cooking loss of raw samples and colour parameters of cooked samples was detected, these results confirmed that the colour differences could be related to the different diets rather than pH and water holding capatiy.

An absence of correlations were also showed between colour indexes of raw and cooked samples at Day 0 and Day 7. Both the diet treatments showed positive relationships between L^* of cooked samples with L^* and b^* of raw meat samples (P<0.01 and P<0.001, respectively). Redness indexes of both cooked meat diet treatments were significantly negative large associate with raw meat b^* indexes (P<0.001). Different correlations were found between the diet treatments for redness indexes of cooked samples; indeed a^* of Tu samples was significantly negative large correlated with L^* of raw samples, while no significant statistical correlation was found for C diet. The variation of colour indexes of cooked meat samples might be related to different diets; as reported by Andrés-Bello *et al*. (2013) the colour of cooked meat might depend on not only the pH but also on the colour of raw meat.

The significant differences of L^*, a^* and b^* parameters between diets or storage times influenced the total colour difference (ΔE) values and all the combination reported an appreciable colour variation. The ΔEs of cooked samples were higher than JND threshold with a human's eyes discernable differences between samples of the two different D at the same ST (3.48 and 4.44, ΔE between C and Tu samples at Day 0 and 7, respectively) or between the same D as a function of ST (5.21 and 6.13, ΔE between Day 0 and Day 7 within C and Tu, respectively). The changes of colour after cooking (ΔEs calculated between raw and cooked samples) at Day 0 for C and Tu were 17.43 and 18.97 respectively; at Day 7 were 21.23 for C and 21.79 for Tu diet treatments. In both the considerate days Tu samples reported a greatest variation of colour after cooking, with a highest variation of all the colour parameters (L^*, a^* and b^*).

Cooked meat derived from the pig fed the Tu diet presented a hue colour more pale and grey-like than

Table 2. Pairwise comparison correlation coefficients and the significance between colour indexes of cooked samples and pH, colour indexes and cooking loss of raw samples.

		Cooked samples parameters		
	Raw samples parameters[1]	L*	a*	b*
Day 0	pH	0.0902	-0.0767	0.0566
	L*	0.4468	-0.0457	0.2261
	a*	-0.3363	0.1785	0.3254
	b*	0.0567	0.0970	0.3693
	Cooking loss	-0.2599	-0.1643	-0.2754
Day 7	pH	0.1200	-0.0805	-0.2747
	L*	0.3345	-0.2857	0.1508
	a*	-0.4559	0.3569	0.2677
	b*	-0.1094	0.0837	0.3933
	Cooking loss	0.3052	-0.2843	-0.1258
C	pH	-0.1871	0.1361	0.0938
	L*	0.6959**	-0.3613	0.2153
	a*	0.2898	-0.4082	-0.1743
	b*	0.7599***	-0.7156***	-0.0056
	Cooking loss	-0.2575	-0.0080	-0.1258
Tu	pH	0.2680	-0.4346	-0.3778
	L*	0.6175**	-0.6064**	-0.2243
	a*	0.2706	-0.3833	-0.1195
	b*	0.7662***	-0.8435***	-0.4472
	Cooking loss	-0.2688	0.2787	-0.0642

C = Control diet; Tu = Control diet + Turmeric powder.
[1] Mancini *et al.* (2016).
** = P<0.01; *** = P<0.001.

Table 3. Lipid peroxidation (TBARS) and antioxidant capacity (ABTS, DPPH and FRAP) of meat cooked samples

	Diet (D)		Storage time (day, ST)		P-value		RMSE[1]
	C	Tu	0	7	D	ST	
Samples n.	9	9	18	18			
TBARS	0.09	0.09	0.08	0.10	ns	ns	0.049
FRAP	0.08	0.08	0.08	0.08	ns	ns	0.025
ABTS	0.70	0.64	0.64	0.70	ns	ns	0.122
DPPH	0.13	0.12	0.12	0.13	ns	ns	0.026

C = Control diet; Tu = Control diet + Turmeric powder.
TBARS are expressed in mg of MDA per kilogram of cooked meat.
ABTS and DPPH are expressed in mmol of Trolox equivalent per kilogram of fresh meat.
FRAP are expressed in mmol of Fe^{II} equivalent per kilogram of fresh meat.
ns = not significant.
[1] root mean square error.

the cooked meat derived from C diet.

Pink hue in cooked pork is reported to be unlike by the consumers as correlated with the idea of not well cooked meat (i.e. safety against trichinosis) (Heymann *et al.*, 1990; Mancini *et al.*, 2005). Therefore a more pale-grey colour might be more attractive for the consumers. Anyway no general-international conclusions could be formulated on the preferences of meat pork, as reported by Ngapo, Martin and, Dransfield (2007) for raw pork chops acceptability. No statistical differences of D and ST were found for the lipid oxidation and the antioxidant

capacity (Table 3).

Very few researches have considered TBARS values and antioxidant capacity in cooked meat derived from animals fed different diets. Guillevic *et al*. (2009) and Dalle Zotte *et al*. (2014) observed the same trend in TBARS in smoked bellies from pigs fed extruded linseed and in cooked rabbit meat from animals fed spirulina and thyme. Botsoglou *et al.* (2002, 2003) evaluated dietary oregano essential oil on lipid oxidation on cooked meat of broiler and turkey during refrigerated storage, the initial TBARS values (days 0 of the trial, i.e. fresh cooked meat) did not show variation between control and treated samples.

In our study the lack of statistical difference in antioxidant capacity of raw samples (Mancini *et al*., 2016) might have influenced the results of the cooked samples. Sáyago-Ayerdi *et al.* (2009) reported significantly higher ABTS values of raw and cooked hamburgers made of meat from chicken fed red grape pomace than control diet. Also Fasseas *et al*. (2008), Jo *et al.* (2003) and Mancini, Paci and, Preziuso (2016) observed the same intrinsically correlation in antioxidant capacity of raw and cooked meat samples added with natural antioxidants.

Pig dietary turmeric powder produced modifications in colour of the cooked samples, strongly correlated with colour of raw samples. Also lipid oxidation and antioxidant capacity of cooked samples seem to be linked with the raw meat values. Since the bioavailability of the turmeric powder and of their components is not well known no general conclusion could be formulated. Authors suggested a variation in doses of *C. longa* powder in future researches in order to probably obtain variations in raw meat parameters and in cooked sample values.

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