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Ginger (*Zingiber officinale* Roscoe) powder as dietary supplementation in rabbit: life performances, carcass characteristics and meat quality

Simone Mancini^a , Giulia Secci^b, Giovanna Preziuso^{a,c}, Giuliana Parisi^b  and Gisella Paci^{a,c}

^aDipartimento di Scienze Veterinarie, University of Pisa, Pisa, Italy; ^bDipartimento di Scienze delle Produzioni Agroalimentari e dell'Ambiente (DISPAA), University of Florence, Firenze, Italy; ^cCentro Interdipartimentale di Ricerca "Nutraceutica e Alimentazione per la Salute", University of Pisa, Pisa, Italy

ABSTRACT

The aim of this study was to evaluate the effect of dietary *Zingiber officinale* Roscoe (ginger) powder on rabbit productive performances, meat quality and shelf-life of raw and cooked meat. Ninety hybrid rabbits of 60 days old were fed three different diets: basal diet (control, C), basal diet supplemented by 4 g of ginger powder on 100 g of feed (G4) and basal diet supplemented by 8 g of ginger powder on 100 g of feed (G8) (3.6 and 7.2 g/100 g of dry matter for G4 and G8, respectively). Live weight, average daily gain and feed intake were recorded. Ten rabbits of each group were slaughtered at 90 days of age and meat quality was assessed during seven days of storage at 4 °C. Live performance and slaughter traits did not show any significant differences. Dietary ginger powder induced modification in pH of raw samples and in colour indexes of both raw and cooked meat. Lipid oxidation of raw samples was delayed in time by ginger feed addition even if no modification was highlighted in antioxidant capacity. Ginger powder could be a potential supplementation in diet of rabbits for increasing meat shelf-life.

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Rabbit; ginger; meat quality; antioxidant; diet

Introduction

In the last decades, much attention has been given in rabbit farming in order to increase productions without negatively affecting meat quality and animal well-being. In recent years, studies have been carried out on the addition of natural antioxidants as nutritional supplements in animal feeding to improve performance, health, meat quality and shelf-life of raw or cooked meat products (Jiang and Xiong 2016).

Dietary supplementation with natural antioxidant can improve the oxidative stability of rabbit meat which is susceptible to the deterioration because of its nutritional composition (Dalle Zotte 2002). To improve the performance, healthy conditions and meat quality, different aromatic herbs and essential oils have been used in rabbit feed (Dal Bosco et al. 2012; Peiretti et al. 2013; Gerencsér et al. 2014).

Ginger powder and extracts have been studied for their antioxidant and antimicrobial properties both in dietary supplementation and in food preservation (Zomrawi et al. 2012; Mancini, Paci, Fratini, et al. 2017; Mancini, Preziuso, et al. 2017). Hence, ginger could play an important role in rabbit feeding strategy. The

aim of this study was to assess in rabbit the effects of two different concentrations of ginger powder as supplement in feed on the productive performances and meat quality.

Materials and methods

Ninety hybrid rabbits of 60 days old were randomly allotted into three groups and housed in cages. Groups were fed *ad libitum*, one with a commercial pellet (control diet, C; proximate composition as g/100 g of dry matter: crude protein 18.5, ether extract 3.0, crude fibre 17.8, ash 9.0) and the other two with the same pellet supplemented by ginger powder at the concentration of 4% (G4) or 8% (G8) of the feed (3.6 g/100 g and 7.2 g/100 g of dry matter, respectively). Water was available *ad libitum* from nipple drinkers. Body weights and feed intake were registered weekly, anyhow only initial and final weights and total feed intake were considered for statistical analyses. The experimental protocol was designed according to the guidelines of the current European and Italian laws on the care and use of experimental animals (European

directive 2010/63/UE, put into law in Italy with D.Lgs. 26/2014).

Ten rabbits from each experimental group were slaughtered at 90 days of age. Rabbits were electro-stunned and slaughtered by cutting carotid and jugular veins. The dissection procedures of warm and chilled carcasses followed the WRSA recommendations (Blasco and Ouhayoun 1996). The pH after 45 minutes and 24 h of chilling was recorded on the *Longissimus thoracis et lumborum* (measured between sixth and seventh lumbar vertebrae) and in *Biceps femoris* muscle (pHmeter pH80 equipped with a S7 2 PORE SLIM electrode; XS instruments, Carpi, MO, Italy). At 1 day *post mortem*, left and right *Longissimus thoracis et lumborum* muscles were dissected and used for meat quality assessments.

Longissimus thoracis et lumborum muscle of each animal was individually packaged in Styrofoam trays overwrapped with polyethylene film and stored at 4 °C up to seven days (namely eight *post mortem* days) after been divided in sub-samples. Meat was analysed at days 2, 5 and 8 (T2, T5 and T8) *post mortem* days for water holding capacity, pH, colour, lipid oxidation and antioxidant capacity. Moreover, pH, colour, lipid oxidation and antioxidant capacity were also analysed on meat cooked at T2, T5 and T8. Right and left muscles of each animal were analysed as raw and cooked meat respectively. Water holding capacity was quantified as drip loss between T2 and T5 or T2 and T8 (Lundström and Malmfors 1985) and as cooking loss after cooking in a preheated oven at 163 °C to an internal temperature of 71 °C (AMSA 1995).

pH was recorded via electrode injection in three different points for each sample; colour (L^* = lightness, a^* = redness, b^* = yellowness; CIE 1976) was measured using a Chroma metre Minolta CR300 (Minolta, Osaka, Japan) with an aperture size of 8 mm (illuminant D65, incidence angle of 0°). Hue (H^*) and chroma (C^*) parameters were calculated as reported by CIE (1976) and the numerical total colour difference (ΔE) was calculated as proposed by Sharma and Bala (2002) among samples of the same diet at different storage times (effect of storage time), among samples of two different diets at a fixed storage time (effect of diet) and among raw and cooked samples of the same diet at the same storage time (effect of cooking).

Lipid oxidation and antioxidant capacity were evaluated via thiobarbituric acid reactive substances (TBARS), ABTS (2,2'-azinobis(3-ethylbenzothiazoline-6-sulphonic acid) reducing activity, DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging activity and FRAP ferric reducing ability on both raw and cooked samples. TBARS were evaluated spectrophotometrically

according to Ke et al. (1977) method, as modified by Dal Bosco et al. (2009). The absorbance of TBARS was measured at 532 nm with a V-530 spectrophotometer (Jasco International, Milan, Italy). Results were expressed in mg of malondialdehyde on 100 g of sample via a calibration curve plotted with 1,1,3,3-tetraethoxypropane (0–15 μ M).

Antioxidant capacity was measured on meat ethanol extracts as reported by Mancini et al. (2015) using the radical probes of ABTS and DPPH, as reported respectively by Re et al. (1999) and Blois (1958), and the FRAP method as reported by Descalzo et al. (2007) for meat samples. The effect of the diet on the rabbit performances (initial and final weights, feed intake) and the carcasses characteristics were statistically analysed via one-way ANOVA. A two-way ANOVA repeated measured was applied on the raw and cooked meat quality parameters in order to evaluate the effects of the diet (D), of the storage time (T) and of their interaction ($D \times T$). Tukey's test was used to determine the differences when the p value was under .05. When the interaction $D \times T$ was not significant, the results were reported as the mean of the fixed effects D and T; the variability was expressed as root mean square error (RMSE). R software (R Core Team 2015) was used.

Results and discussion

Live performances and carcass characteristics did not show any significant differences between the three experimental groups (Tables 1 and 2). In literature studies on natural antioxidant supplementation in rabbit diet reported a wide range of effect (Abdel-Khalek 2013). Celia et al. (2016) and Abd-El-Hady (2014) reported that live performances of rabbits fed an herbal mixture (Digestarom®) were variable as affected also by other not-diet related parameters because animal age or rearing technique.

Few differences were found in meat quality of both raw and cooked samples (Table 3). In raw samples, diet affected pH, lightness, yellowness and chroma

Table 1. Productive performance of rabbits.

	Diet (D)			p Value	RMSE
	C	G4	G8		
Initial BW, g	1365	1390	1417	.246	163.2
Final BW, g	2438	2481	2557	.061	225.6
ADG, g/head d	35.8	36.4	38.0	.166	4.92
ADFI, g/head d	126.1	129.5	133.2	.410	18.89
FCR	4.2	4.0	4.0	.352	0.87

C: control diet; G4: control diet +4% ginger powder; G8: control diet +8% ginger powder; BW: body weight; ADG: average daily weight gain; ADFI: average daily feed intake; FCR: feed conversion ratio (kg feed ingested/kg of body weight gain).

($p < .05$ for pH and L^* ; $p < .001$ for b^* and C^*). G8 samples showed lower value of pH and higher values of L^* , b^* and C^* than C and G4 samples. Modifications in pH values could affect lightness of meat (Swatland 2000), and G8 raw samples showed, as consequence of dietary regimen, a higher value than C samples as at a more acid matrix a lighter meat corresponds. This correlation was found in several studies in which rabbit meat physical characteristics were evaluated (Dal Bosco et al. 2014; Mancini et al. 2015).

Interestingly b^* and C^* indexes showed statistical differences due to the diet also on cooked samples, with higher values of G8 than other diet groups ($p < .01$) as influenced by the natural colour of ginger. Storage time affected pH, L^* , b^* , H^* and C^* in raw samples ($p < .01$ for pH, b^* , H^* and C^* ; $p < .01$ for L^*) and pH and L^* in the cooked samples ($p < .001$ and $p < .01$ for pH and L^* , respectively). pH of raw samples decreased between T5 and T8, while pH of cooked

samples reported a constant decrease from T2 to T8. Lightness of raw samples increased progressively during the storage time, whilst an opposite trend was shown by cooked samples. Raw samples showed to increase yellowness index between T5 and T8, and this modification in colour affected the values of H^* and C^* that consequently increased their value between T5 and T8.

Numerical colour differences (ΔE s) are reported in Table 4. ΔE s between raw samples of the same diet at different storage times reported that G8 samples appeared different between T5 and T8 and in the overall evaluation (T2–T8), whereas C samples modified their colour in a perceptible way only if compared T2–T8. No colour discernible differences were shown by cooked samples during storage time. Moreover, cooked samples of C and ginger diet groups (G4 and G8) showed to be not recognisable for difference in colour as the ΔE s calculated

Table 2. Effect of diets on slaughter traits.

	Diet (D)			p Value	RMSE
	C	G4	G8		
Slaughter weight (SW), g	2334	2355	2383	.218	96.5
Warm carcass, g	1304	1321	1338	.112	51.3
Chilled carcass, g	1281	1300	1315	.118	50.5
Reference carcass, g	1066	1096	1091	.191	46.3
Chilled carcass yield, % SW	54.9	55.2	55.2	.635	1.48
Skin and paws, g	405.9	412.8	420.0	.255	29.51
Full gastrointestinal tract weight, g	448.0	450.2	451.2	.816	32.94
Hind leg, g	184.0	186.2	188.8	.199	8.93
<i>Longissimus thoracis et lumborum</i> , g	236.7	232.4	227.8	.207	16.79
pH 45 min					
<i>Longissimus lumborum</i>	7.02	7.04	7.08	.311	0.134
<i>Biceps femoris</i>	6.89	6.93	6.97	.350	0.190
pH 24 h					
<i>Longissimus lumborum</i>	5.62	5.65	5.66	.412	0.107
<i>Biceps femoris</i>	5.78	5.79	5.82	.268	0.086

C: control diet; G4: control diet +4% ginger powder; G8: control diet +8% ginger powder.

Table 3. Effects of diets and storage times on meat quality.

	Diet (D)			Storage time (T)			p Value			RMSE
	C	G4	G8	T2	T5	T8	D	T	D × T	
Raw										
Drip loss	1.33	1.25	1.18	1.51	1.14	1.11	.785	.813	.670	2.053
Cook loss	31.38	31.47	31.97	31.69	31.64	31.54	.171	.972	.058	1.827
pH	5.60 ^a	5.63 ^a	5.55 ^b	5.66 ^x	5.69 ^x	5.37 ^y	.016	<.001	.055	0.069
L^*	60.83 ^b	60.85 ^b	62.10 ^a	60.21 ^y	61.01 ^{xy}	62.57 ^x	.028	.002	.239	2.045
a^*	1.11	1.13	1.26	1.31	1.2	1.04	.360	.407	.473	0.603
b^*	2.81 ^b	2.91 ^b	3.82 ^a	2.52 ^y	2.98 ^y	4.05 ^x	<.001	<.001	.065	0.711
H^*	68.25	69.03	70.53	63.25 ^z	67.99 ^y	76.69 ^x	.061	<.001	.742	4.686
C^*	3.10 ^b	3.15 ^b	4.06 ^a	2.90 ^y	3.06 ^y	4.49 ^x	<.001	<.001	.062	0.752
Cooked										
pH	5.94	5.94	5.92	6.08 ^x	6.01 ^y	5.71 ^z	.274	<.001	.862	0.066
L^*	85.06	85.35	85.47	85.74 ^x	85.18 ^{xy}	84.89 ^y	.146	.048	.389	1.022
a^*	2.61	2.63	2.63	2.48	2.65	2.74	.848	.111	.141	0.365
b^*	7.70 ^b	7.65 ^b	8.24 ^a	7.9	7.92	7.92	.001	.990	.056	0.563
H^*	71.34	71.98	72.33	72.76	71.69	71.06	.082	.079	.078	2.041
C^*	8.14 ^b	8.17 ^b	8.65 ^a	8.34	8.35	8.42	.003	.874	.122	0.601

C: control diet; G4: control diet +4% ginger powder; G8: control diet +8% ginger powder.

^{a,b}Different letters in the same row indicate significant differences for D at $p < .05$.

^{x,y,z}Different letters in the same row indicate significant differences for T at $p < .05$.

between the two diets in function of the storage time did not show values over 2.30 points (threshold value for a noticeable difference). Instead, raw C and G8 samples at T2 and T8 were slightly over the threshold leading to a partial difference in colour. As expected, cooking strongly modified the colours of samples, as showed by ΔE s calculated between raw and cooked samples of each diet's samples as function of the storage time.

Lipid oxidation (TBARS) of raw samples showed a significant interaction $D \times T$ ($p < .01$, Figure 1). Samples

Table 4. Total colour difference (ΔE) between diets, storage times and between raw and cooked samples.

Sample	Diet (D)	Storage time (T)		
		T2–T5	T5–T8	T2–T8
<i>ΔE Storage time</i>				
Raw	C	2.15	1.20	3.19*
	G4	1.34	1.56	3.26*
	G8	0.44	3.24*	3.25*
Cooked	C	0.51	0.65	0.86
	G4	0.56	0.24	0.99
	G8	1.15	0.20	1.09
<i>ΔE Diet</i>				
		T2	T5	T8
Raw	C–G4	1.15	0.54	1.69
	C–G8	2.38*	0.48	2.36*
	G4–G8	2.33*	0.65	2.40*
Cooked	C–G4	0.66	0.84	0.95
	G4–G8	0.80	0.96	0.94
	C–G8	0.88	0.98	0.80
<i>ΔE Raw-cooked</i>				
		T2	T5	T8
Raw	C	26.76*	24.46*	23.10*
	G4	25.54*	24.53*	23.84*
	G8	25.31*	24.56*	21.67*

C: control diet; G4: control diet +4% ginger powder; G8: control diet +8% ginger powder.

*Value over the threshold (2.3 points) with a noticeable difference in colour between the samples.

showed lowest values of oxidation at T2 with a constant increase during storage time. Anyhow, at T8, G4 and G8 samples showed to maintain their level of lipid oxidation at least comparable to T5 of the C samples, proving an enhancement of meat shelf life due to ginger addition in the diets. At T5, G8 samples showed lower value than C and G4 samples, delaying lipid oxidation in time. A different resistance to lipid oxidation in samples from groups differently fed was not shown in cooked samples as only storage time significantly affected TBARS values ($p < .001$, Table 5), that increased with storage time with statistical differences among all the tested times. Similarly, Lo Fiego et al. (2004) reported that dietary vitamin E (300 ppm) and vitamin C (500 ppm) negatively affected the lipid oxidation in rabbit meat stored at 2.0°C for eight days, as well as Eid et al. (2011) reported that also dietary green tea significantly decreased TBARS of thigh and loin meat stored for two months. Even if TBARS were affected by dietary antioxidant supplementation no modifications were highlighted in antioxidant capacity of raw and cooked samples (Table 5). This lack of correlation between antioxidant characteristics and lipid oxidation in rabbit meat was reported by other Authors (Dal Bosco et al. 2014; Dalle Zotte et al. 2014) and in other meats from different animal species (Hernández-López et al. 2016; Mancini, Paci, Pisseri, et al. 2017) fed antioxidant products. On the other hand, few research articles on dietary supplementation report a decrease in lipid oxidation as consequence of a modification in antioxidant characteristics (Jung et al. 2010; Qwele et al. 2013; Mancini et al. 2016). These lack of coherence between studies lead to

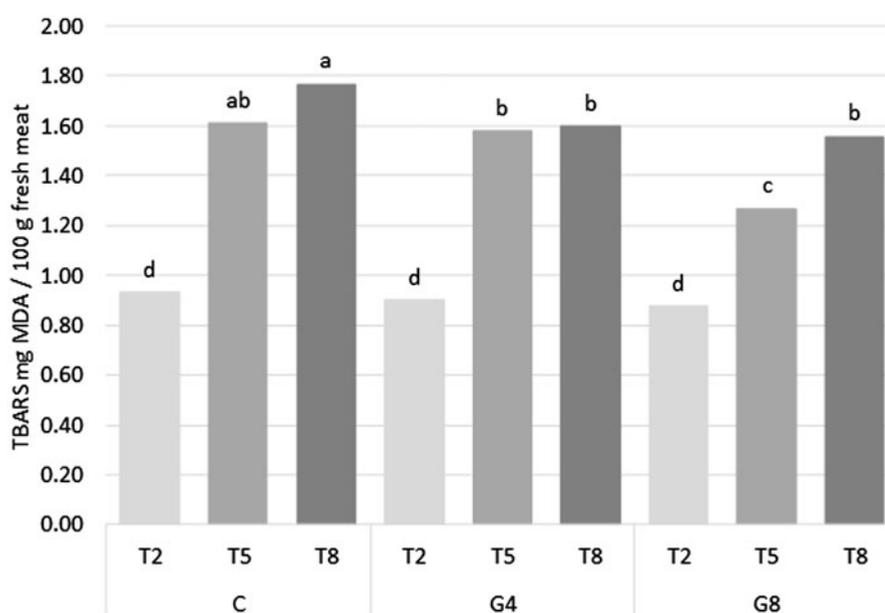


Figure 1. Effect of the interaction of diet (D) and storage time (T) on lipid oxidation (TBARS) of raw rabbit meat. C: control diet; G4: control diet +4% ginger powder; G8: control diet +8% ginger powder.

^{a,b,c,d}Different letters indicate significant differences for $D \times T$ at $p < .05$.

Table 5. Effects of diet and storage time on lipid oxidation and antioxidant capacity of rabbit meat.

	Diet (D)			Storage time (T)			p Value			RMSE
	C	G4	G8	T2	T5	T8	D	T	D × T	
Raw										
ABTS	2.55	2.55	2.56	2.58	2.54	2.55	.664	.628	.168	0.117
DPPH	0.57	0.57	0.57	0.57	0.57	0.57	.396	.766	.617	0.031
FRAP	0.36	0.36	0.36	0.37	0.36	0.36	.963	.299	.792	0.019
Cooked										
TBARS	3.10	3.05	2.98	2.17 ^z	3.03 ^y	3.91 ^x	.680	<.001	.166	1.063
ABTS	2.06	2.05	2.03	2.01	2.05	2.07	.336	.156	.260	0.098
DPPH	0.34	0.33	0.33	0.34	0.33	0.33	.156	.145	.491	0.334
FRAP	0.35	0.34	0.35	0.35	0.35	0.34	.818	.430	.485	0.017

C: control diet; G4: control diet +4% ginger powder; G8: control diet +8% ginger powder.

TBARS expressed in mg of MDA per 100 g of fresh meat; ABTS and DPPH in mmol of Trolox equivalent per kg of fresh meat; FRAP in mmol of Fe^{II} equivalent per kg of fresh meat.

^{x,y,z}Different letters in the same row indicate significant differences for T at $p < .05$.

hypothesise that different mechanisms of action could be related to different antioxidants and no consistent results could be expected.

Conclusions

Dietary supplementation with ginger powder represents a good opportunity to ameliorate meat quality of rabbits, resulting in a lowering of lipid oxidation susceptibility without any interference with productive performances of animals. Modifications were also highlighted in pH values and colour parameters of both raw and cooked samples.

Disclosure statement

No potential conflict of interest was reported by the authors.

ORCID

Simone Mancini  <http://orcid.org/0000-0001-8643-507X>

Giuliana Parisi  <http://orcid.org/0000-0003-4646-6036>

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