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Original article

Quality characteristics of cured ham produced from Landrace and Duroc pigs fed restricted energy diets with and without α-tocopheryl acetate or green tea catechins

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Abstract – The effects of compensatory growth diets with and without antioxidant (α-tocopheryl acetate (α-TA) or green tea catechin (GTC)) inclusion on the quality characteristics of cured hams were examined. Compensatory growth diets combined periods of restricted dietary energy intake (incorporating grassmeal as a source of low metabolisable energy) followed by periods of high energy intake. Landrace or Duroc pigs (n = 72) were allocated to one of six experimental diets from 21 days post-weaning to 105 kg live weight. Dietary treatment did not influence any of the ham characteristics examined (ham weight, cook loss, lipid oxidation or CIE colour values). Lipid oxidation, determined as 2-thiobarbituric acid reactive substances (TBARS values), and CIE colour (L*, a* and b*) values remained stable throughout refrigerated storage. Brine solution additives may have contributed to oxidative stability and masked any dietary effects. In contrast, breed significantly affected ham quality. Lipid oxidation was lower in hams from Duroc pigs. Redness (a* values) was more intense in Landrace hams than equivalent Duroc samples. No differences were observed between breeds for CIE L* and b* values or percentage cook loss. The quality characteristics of cured hams were influenced to a greater extent by breed than by dietary intervention through compensatory growth. Inclusion of α-TA or GTC did not affect the quality or storage stability of cured hams.

compensatory growth / ham / breed / pork quality / α-tocopheryl acetate / tea catechins / grass

Résumé – Les critères qualités du jambon saumuré produit à partir de porcs Landrace et Duroc ayant subit un régime restreint en énergie avec ou sans ajout d'acétate d'alpha-tocophérol ou catéchines de thé vert. Les effets de régimes visant une croissance compensatrice avec ou sans

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ajout d'antioxydants (acétate d'alpha-tocophérol ou catéchines de thé vert) sur les critères de qualité de jambon saumuré ont été examinés. Les régimes alimentaires visant une croissance compensatrice comprenaient une période de distribution d'aliments restreints en énergie (incorporation de farine d'herbe comme source d'énergie faiblement assimilable) suivie d'une période de distribution d'un régime riche en énergie. Les porcs Duroc et Landrace (n = 72) ont été nourris avec un des six régimes expérimentaux 21 jours après leur sevrage jusqu'à ce qu'ils atteignent un poids vif de 105 kg. Le régime appliqué n'avait aucune influence sur les critères examinés (poids du jambon, perte d'eau à la cuisson, oxydation des lipides ou couleur). Les mesures de l'oxydation des lipides, déterminées par les valeurs de substances réactives à l'acide 2-thiobarbiturique (TBARS) et les mesures de couleur (L*, a* et b*) sont restées stables jusqu'à la fin du stockage réfrigéré. L'injection de saumure a probablement contribué à la stabilité de l'oxydation et masqué tous les effets du régime. Au contraire, la race influence significativement la qualité du jambon. Le poids de muscles du jambon était significativement plus élevé pour les porcs de race Landrace comparé au Duroc. L'oxydation des lipides était plus faible pour la race Duroc. La couleur rouge (la valeur a*) était plus intense pour les jambons issus de la race Landrace que sur les échantillons équivalents de Duroc. Aucune différence n'a été observée entre les races en ce qui concerne les valeurs de L* et b* ou le pourcentage de perte d'eau pendant la cuisson. En conclusion, les critères de qualité des jambons saumurés étaient plus influencés par la race que par le régime. L'ajout d'acétate d'alpha-tocophérol ou de catéchines de thé vert n'a pas affecté la qualité ou la stabilité des jambons saumurés lors de leur stockage.

jambon / race / qualité de la viande de porc / acétate d'alpha-tocophérol / catéchines de thé / herbe

1. INTRODUCTION

Recent years have seen a growth in demand for meat products with reduced fat contents. Production strategies incorporating a period of restricted energy feeding followed by a subsequent compensatory growth response may result in an increase in carcass lean meat percentage [3]. Compensatory growth may be defined as a physiological process whereby growth is accelerated after a period of nutritional energy restriction, such that the animal's weight equals or approaches that of animals whose growth was never reduced [7]. Such an effect is dependent on the timing, duration and intensity of energy restriction and re-alimentation. Restricted energy feeding has been shown to increase leanness in pigs [3] although any effects on processed meat quality have not been demonstrated. Increased lean meat yield may impact negatively on meat quality.

The major properties by which consumers judge meat quality are colour, texture and flavour. Of these, colour strongly influences the decision to purchase. Nitrosylmyochrome, the pigment responsible for the desirable pink colour of cured cooked meat, oxidises to metmyogloblin on exposure to light and oxygen, giving a dull greyness to the meat surface [17]. Pigment oxidation has been positively correlated with lipid oxidation, a process that impacts negatively on flavour, texture and nutritive value [2]. Supplementing diets with α-tocopheryl acetate (α-TA) is an established means of decreasing the susceptibility of fresh pork to oxidation [9, 18]. Data on such benefits in cured pork are less extensive, although improved oxidative stability in cured products enriched with α-TA has been reported [5, 8]. Catechins are polyphenolic flavanols derived from green tea and are a group of compounds whose exogenous antioxidant activity is established in muscle foods [16]. Any antioxidant activity in cured pork through dietary inclusion has not yet been examined. Diets were assessed in two breeds of pig known to differ in intramuscular fat (IMF) content: Landrace sired

pigs representing a lean type and Duroc sired pigs representing a less meaty (fatter) type. Previously, we reported the effects of the present dietary strategy on the quality of fresh pork using the same animals as those in this study [15]. The objective of this work was to evaluate the quality of cured ham from pigs fed restricted-energy diets based on grassmeal with or without supplementation with dietary antioxidants (α-TA or GTC).

2. MATERIALS AND METHODS

2.1. Animals, diets and sampling

Pigs were reared at the Pig Production Unit, Moorepark Research Centre, Cork, Ireland. Large White × Landrace sows were served using semen (Hermitage AI, Kilkenny, Ireland) from a composite dose of either Landrace (n = 80) or Duroc (n = 80) boars. Piglets of similar weight were penned in same breed, single sex groups of 12 pigs. Weaner diets were fed from 21 days post-weaning up to 35 kg live weight followed by finisher diets to slaughter. Experimental treatments and dietary compositions are shown in Tables I and II, respectively. Pigs were weighed on a regular basis and pigs were slaughtered when they reached 105 kg. A total of 72 female pigs (n = 36, Landrace, n = 36 Duroc) were used in this study. Pigs were transported 14 km to the abattoir (Galtee, Mitchelstown, Cork, Ireland) and killed by bleeding after CO_2 stunning. Carcasses were subsequently stored at ~ 3 °C for 24 h in a chilling room. Backfat and lean thickness was measured 6 cm from the edge of the split back at the level of the 3rd–4th rib using a Hennessy Grading Probe (Hennessy and Chong, Auckland, New Zealand) and the lean meat content (g per kg) was calculated [4]. Carcass weight was estimated by multiplying the weight of the hot eviscerated carcass, (minus tongue, bristles, genital organs, kidneys, flare fat and diaphragm) 45 min after slaughter by 0.98. Kill-out proportion (g per kg) was calculated as carcass weight/slaughter weight. pH measurements were taken at the last thoracic vertebra 45 min and 24 h after slaughter using a WTW 320 pH meter (WTW GmbH, Weilheim, Germany). The right side of each carcass was delivered under refrigerated conditions to the Meat Processing Facility, University College Cork, Ireland and subsequently partitioned into shoulder, middle part and ham by two perpendicular cuts.

2.2. Ingredients and reagents

All chemicals used were 'AnalaR' grade, obtained from Sigma Chemical Co. Ltd, Poole, Dorset, UK. Green tea catechins (GTC) (86% purity) extracted from green tea (*Camellia sinensis* L. variety *assamica*) were supplied by Kinglong Natural Plant Products and contained 40% epigallo-catechingallate, 24% epigallocatechin, 12% epicatechingallate and 10% epicatechin. α-TA was supplied by Roche Products Ltd., Welwyn Garden City, Hertfordshire, UK. Brine ingredients were obtained from 'All 'n All Ingredients Ltd.', Park West, Dublin 12, Ireland.

2.3. Ham production

Hams were de-boned and membranes, tendons, fatty tissue and rind were removed. Care was taken to ensure that all muscles between the hipbone and the hind foot remained intact. Brine was injected into the ham muscles using an Inject Star patent multi-needle injector (Machine Factory Hollstein and Fuhrmann, Vienna, Austria) such that ham weight increased by 17%. Brine composition (% w/w) was salt 12.0, sugar 3.5, potassium phosphate 2.5, sodium nitrite 0.15, sodium nitrate 0.15, sodium ascorbate 0.5 and water 81.2. Hams were subsequently stored overnight

Table I. Experimental dietary treatments fed to Landrace and Duroc pigs[1].

	Dietary Treatments
Control	Pigs fed high-energy concentrate diets (weaner, finisher) to slaughter (Diets 1 and 3 respectively).[2]
GM105	Pigs fed low-energy concentrate diets with grass-meal (GM) (100 g per kg GM – weaner, 200 g per kg GM – finisher) to slaughter (Diets 2 and 4).
GM50	Pigs fed low-energy concentrate diets with GM to 50 kg live weight (Diets 2 and 4). From 50 kg to slaughter fed high nutrient dense finisher diet (Diet 3).
GM80	Pigs fed concentrate diets with GM to 80 kg live weight (Diets 2 and 4). From 80 kg to slaughter fed high nutrient dense finisher diet (Diet 3).
α-TA	Pigs fed concentrate diets with GM to 80 kg live weight (Diets 2 and 4). From 80 kg to slaughter fed a vitamin E enriched (200 mg α-TA per kg) diet with fat inclusion from rapeseed oil (50 g per kg) (Diet 5).
GTC	Pigs fed concentrate diets with GM to 80 kg live weight (Diet 2 and 4). From 80 kg to slaughter fed a green tea catechin enriched (200 mg tea extracts per kg) diet with fat inclusion from rapeseed oil (50 g per kg) (Diet 6).

[1] [15].
[2] Feed composition and nutrient content of diets 1 to 6 are detailed in Table II.

Table II. Feed ingredients and nutrient content of experimental diets (g per kg feed)[1].

Diet number	1	2	3	4	5	6
Diet type	Weaner	Weaner	Finisher	Finisher	Finisher	Finisher
Duration	~ 33 days	~ 33 days	*	**	~ 33 days	~ 33 days
			Ingredients			
Barley	225	202.5	540	432.4	522	522
Wheat	312	280.7	214	172	204	204
Maize	100	90	0	0	0	0
Soya Hi-Pro.	290	261	215	171	204	204
Fat (lard)	50	45	10	8	0	0
Rapeseed oil	0	0	0	0	50	50
Grassmeal	0	100	0	200	0	0
Vit./Mineral Mix	3.0	2.7	1.0	0.8	0.95	0.95
α–TA added (mg per kg)	0	0	0	0	200	0
α–TA (mg per kg)	109	71	55	35	178	45
GTC (mg per kg)	0	0	0	0	0	200
			Nutrient Content			
Protein	202	200	175	175	167	167
Fat	68	64	29	29	68	68
Crude fibre	32	48	37	63	36	36
Lysine[2]	13.1	12.5	11.0	10.2	10.5	10.5
DE (MJ per kg)	14.8	13.3	13.5	10.8	14.4	14.4

[1] [15].
[2] Levels of methionine, methionine plus cysteine and threonine were 0.3, 0.6 and 0.65 respectively of the lysine content.
* ~ 96, 73 and 33 days for Control, GM50 and GM80 diets, respectively.
** ~ 96, 23, 63, 63 and 63 days for GM105, GM50, GM80, α-TOH and GTC diets, respectively.

in brine solution at 4 °C to allow for cure colour development. Hams were then tumbled in a vacuum tumbler (Inject Star) at 26" Hg for 1 h at 10 rpm and 0 °C, netted and packed into heat shrinkable cooking bags and cooked in a SuMann oven (Linden Mann GmbH, Halzbachtal 2, Germany) at a temperature of 80 °C (until a ham core temperature of 72 °C was reached) and relative humidity of 99%. Total cooking time was approximately 8 h. Cooked hams were allowed to cool (4 °C × 6 h) before vacuum packaging and storage at –20 °C until analysis. Hams were thawed overnight at room temperature and sliced to a thickness of 10 mm (Meat Slicer, Avery Berkel, West Midlands, England) before modified atmosphere packaging (MAP) in low O_2 permeable (8–12 cm^3 per m^2 per 24 h) trays with a gas atmosphere of 70% N_2/30% CO_2. Gas compositions in the modified atmosphere packages were analysed each test day using a Checkmate 9900 gas-analyser (PBI Dansensor, Ringsted, Denmark). A neoprene septum was placed on the lid of each pack and a gas aliquot from the headspace was withdrawn for analysis of oxygen (± 1%) and carbon dioxide (± 2%) contents. Samples for lipid oxidation and colour determination were held in refrigerated (4 °C) display cabinets under fluorescent lighting (616 lux) for the duration of the 20 day trial.

2.4. Ham measurements

De-boned hams were weighed prior to injection of brine. Cooking loss was determined gravimetrically by weight difference before and after cooking and expressed as a percentage of the original ham muscle weight.

Lipid oxidation was assessed by the 2-thiobarbituric acid (TBA) distillation method of Tarladgis et al. [23] as modified by Ke et al. [13]. TBA reactive substances (TBARS) were calculated by multiplying the absorbance readings by a factor of 7.8 and expressed as mg malondialdehyde per kg sample. TBARS were measured every fourth day from d0 to d20.

A Minolta CR-300 (Minolta Camera Co., Chou-Ku, Osaka 541, Japan) was used for colour determination. Commission Internationale de l'Éclairage (CIE) L*, a* and b* values were measured on the surface of the ham slices, through the transparent MAP lid material. Calibration was carried out against a white tile covered with a MAP lid. CIELAB colour values were recorded every fourth day from d0 to d20 using illuminant D65 (light source).

2.5. Statistical analysis

For ham weight, % cooking loss and gas composition 2 × 6 ANOVA were performed to investigate the effects of breed, diet and breed × diet interaction. For TBARS and colour (CIE L*, a* and b* values), a full repeated measures ANOVA was conducted to investigate the effects of breed, diet, day, two-way and three-way interactions between these factors. Breed and diet represent the "between-subjects" factors where pigs are subjects in this case. The effect of day was measured "within-subjects" and multiple measurements were made on the same animal. All breed × diet × day interactions were statistically non-significant. Thus all subsequent analyses were performed omitting this term. The Tukey-Kramers test was used to adjust for multiple comparisons. Statistical analyses were carried out using the SPSS 11.0 software package for Windows (SPSS, Chicago, IL, USA).

3. RESULTS

3.1. Effect of breed and diet on pig production and carcass traits

Breed did not significantly affect feed intake, average daily gain (ADG), kill-out

Table III. Effects of breed and dietary treatment on pig performance and ham properties.

	Breed			*Diet*					
Pig performance[1]	Landrace (n = 36)	Duroc (n = 36)	Significance	Control (n = 12)	GM105 (n = 12)	GM50 (n = 12)	GM80 (n = 12)	α–TOH (n = 12)	GTC (n = 12)
Feed/day (g)	1843	1881	ns	1818^{b}	1885^{ab}	1820^{b}	1900^{a}	1877^{ab}	1870^{ab}
Average daily gain (g per d)	707	694	ns	730^{a}	675^{c}	710^{ab}	686^{bc}	698^{abc}	704^{ab}
Kill-out (g per kg)	771	773	ns	779^{a}	763^{c}	775^{ab}	772^{b}	777^{b}	771^{b}
Carcass lean (g per kg)	596	592	ns	594	596	594	596	592	593
Backfat (3rd-4th rib) (mm)	11.5	11.6	ns	12.2^{a}	10.6^{c}	11.9^{ab}	11.2^{bc}	11.7^{ab}	11.7^{ab}
Days to Slaughter	147.7	150.9	ns	147.3	153.5	148.9	151.0	148.2	147.1
Ham properties									
Ham weight (%)[2]	9.41	8.94	ns	8.87	9.39	9.44	9.12	8.74	9.45
Cook loss (%)	15.0	15.4	ns	16.0	15.0	14.7	15.2	15.1	15.2

[1] [15].

[2] Ham weights expressed as % of cold carcass weight.

[a, b, c] Mean values in the same row with different superscripts are significantly different ($P < 0.05$). Same or no superscripts = ns.

Significance: ns = non significant.

No significant Breed × Diet interactions were detected.

proportion, carcass leanness, backfat thickness or days to slaughter (Tab. III). Carcass traits were most affected in pigs fed restricted energy diets for the duration of the trial (GM105) and from weaning to 80 kg (GM80) (Tab. III). Dietary treatments affected backfat thickness, ADG and kill-out proportion similarly and these indicators were lowest in animals fed GM105 and GM80 diets.

3.2. Effect of breed and diet on ham weight and percentage cooking loss

The effect of breed and diet on ham weight and percentage cooking loss is shown in Table III. Ham muscle weight (expressed as a percentage of cold carcass weight) was not affected by breed or dietary treatment. No significant differences were detected between breeds for % cooking loss although ham from Duroc sires had somewhat higher values (15.4 vs. 15.0; $P > 0.05$). Pigs fed control and GM50 diets had the highest and lowest percentage cooking loss respectively, although no significant differences were detected between dietary treatments.

3.3. Effect of breed and diet on lipid oxidation in cured ham

Hams from Duroc sires were more stable to lipid oxidation than those from Landrace animals (Tab. IV). Although, with the exception of d1 (values were equal), TBARS values were greater in Landrace samples than Duroc although such differences were significant only on days 4 and 16 ($P < 0.001$ and $P < 0.05$ respectively). Both breeds exhibited similar trends for the development of lipid oxidation with respect to time.

There was no significant dietary effect on TBARS values in cured pork (Tab. IV). Cured pork was not susceptible to lipid oxidation during the 20-day storage period and all values remained below 0.15 mg malondialdehyde MDA per kg sample. At the end of storage, hams from pigs supplemented with α-TA had the lowest (though non-significant) levels of lipid oxidation (0.06 mg MDA per kg sample).

Oxygen levels in the packages remained below 0.5% for the duration of the trial and no significant differences between breeds or diets were detected. Oxygen levels on

Table IV. Effects of breed and dietary treatment on lipid oxidation in cured ham stored in retail display units at 4 °C for 20 days.

	Breed			*Diet*						
Day	Landrace	Duroc	Significance	Control	GM105	GM50	GM80	α–TOH	GTC	Significance
0	0.09[1]	0.08	ns	0.11	0.10	0.09	0.07	0.08	0.08	ns
4	0.12	0.09	**	0.11	0.12	0.10	0.11	0.11	0.08	ns
8	0.12	0.11	ns	0.11	0.12	0.11	0.13	0.14	0.10	ns
12	0.08	0.07	ns	0.06	0.08	0.08	0.07	0.07	0.09	ns
16	0.09	0.06	*	0.08	0.07	0.07	0.08	0.07	0.06	ns
20	0.11	0.11	ns	0.11	0.11	0.09	0.13	0.10	0.10	ns

[1] T BARS values (mg malondialdehyde per kg).
Significance: *** $P < 0.001$, ** $P < 0.01$, * $P < 0.05$, ns = non significant.
Breed × Day and Diet × Day interactions were significant ($P < 0.01$ and $P < 0.05$ respectively).
No significant Breed × Diet, or Breed × Diet × Day interactions were detected.

Table V. Effects of breed and dietary treatment on redness of cured ham stored in retail display units at 4 °C for 20 days[1].

	Breed			*Diet*						
Day	Landrace	Duroc	Significance	Control	GM105	GM50	GM80	α–TOH	GTC	Significance
0	8.20[1]	5.99	***	7.81	6.42	7.52	6.51	7.57	6.71	ns
4	4.52	3.22	***	3.63	3.57	4.18	3.19	4.37	4.25	ns
8	3.76	2.25	***	2.94	2.90	3.13	2.48	3.77	2.78	ns
12	3.19	2.41	**	2.64	2.68	2.51	2.62	3.67	2.67	ns
16	3.40	2.34	***	2.66	3.31	2.68	2.97	3.25	2.28	ns
20	3.10	2.46	*	2.62	2.80	2.46	2.27	3.84	2.59	ns

[1] CIE a* values.
Significance: *** $P < 0.001$, ** $P < 0.01$, * $P < 0.05$, ns = non significant.
Breed × Day and Diet × Day interactions were significant ($P < 0.001$).
No significant Breed × Diet or Breed × Diet × Day interactions were detected.

d20 ranged from 0.02–0.4%. Carbon dioxide levels declined during storage to ~23% on d20 and were comparable for all packages regardless of breed or diet (data not shown).

3.4. Effect of breed and diet on colour stability in cured ham

Breed had a significant effect on the redness (CIE a* values) of cured ham (Tab. V) but did not significantly affect CIE L* or b* values (data not shown). Dietary treatments did not influence CIE a* (Tab. V), L* or b* values (data not shown). CIE a* values decreased during storage for both breeds and all dietary treatments.

4. DISCUSSION

4.1. Effect of breed and diet on pig production and carcass traits

The performance of Landrace and Duroc pigs in response to dietary treatments was very similar. The relationships between indicators of pig performance found here are supported by findings that although Landrace pigs grew faster than Durocs, neither ADG nor slaughter

weights were affected by breed [1]. In general, indicators of pig performance were poorest in animals fed diets with lowest metabolisable energies. ADG, kill-out proportion and backfat thickness were significantly lower ($P < 0.05$) in pigs fed GM105 and GM80 diets compared to Control diet animals, despite higher daily feed intakes. A compensatory growth effect was observed in pigs fed restricted diets to 50 kg as these animals (GM50) had higher ADG and backfat thickness compared to pigs restricted until slaughter. Although the time required for pigs to reach a slaughter weight of 105 kg was greatest in pigs fed low energy diets (147.3 days for Control vs. 153.5 and 151.0 days for GM 105 and GM80 diets respectively), these differences were not significant.

4.2. Effect of breed and diet on cured ham weight

Despite the lower intramuscular fat levels associated with Landrace pigs resulting from intensive selection for lean meat content [1], hams from this breed were not proportionally heavier than those from Duroc animals. Differences in ADG between diets were not reflected in ham weights. It is possible that the severity of dietary energy restriction from grassmeal diets needs to be greater in order to significantly affect ham muscle mass. Given that dietary treatment did not significantly affect days to slaughter, dietary energy restriction may provide a means of reducing production costs without comprising ham muscle weight. No comparable studies on dietary energy restriction and ham weight are available for comparison.

4.3. Effect of breed and diet on cooking loss in cured ham

Percentage cooking loss of cured hams was not affected by breed or diet. Post-mortem pH fall influences muscle shortening and proteolysis and consequently meat tenderness, water-holding capacity and cooking losses [21]. All pigs used in this study had 'normal' ultimate pH values, *ca*. 5.8. No indication of PSE (pale, soft and exudative) or DFD (dark, dry and firm) meat was observed. Previous investigators [20] reported cooking losses in 'normal' cured ham (pH 5.4–6.2) of 16.9% which is similar to the values obtained in the present study (14.7–16.0%). A previous study has shown that cooking loss does not differ between Landrace and Duroc pigs [10]. It has also been reported that outdoor rearing of pigs, which included access to fresh pasture, did not influence the cooking yield of ham muscle (m. *biceps femoris*) when compared to pigs reared indoors on conventional feed [11]. Brine ingredients, such as sodium chloride and phosphates, used to enhance water and fat binding and hence stabilise cooking losses in hams, may also have masked any potential dietary effects.

4.4. Effect of breed and diet on lipid oxidation in cured ham

Hams from Duroc sired pigs had improved oxidative stability compared with hams from Landrace sired pigs. This is similar to the oxidative response observed in fresh *longissimus dorsi* from pigs fed the same experimental diets as those in the present study [15]. This effect was attributed to the lower levels of PUFA in the muscle of Duroc pigs. Lipid oxidation in cured ham remained stable throughout the storage period and below the detectable threshold level for malondialdehyde of 0.5 mg MDA per kg by trained sensory panelists [14, 24]. Such minimal oxidation levels were probably due to the presence of nitrites, ascorbates and phosphates in the brine solution, the antioxidant properties of which are well established [5, 12]. The combined effects of these brine

components along with exclusion of oxygen in MAP packs prevented any significant oxidation during the period examined and are typical of processing conditions used in the retail industry. The decrease in MAP headspace CO_2 concentrations (from 30 to 23%) was likely due to the dissolution of CO_2 into the aqueous phase of the product [17].

TBARS values increased from d0 to d8 before decreasing in value from d8 to d16. This trend may reflect an increase and maximisation of TBARS values prior to a subsequent decline due to further reactions of MDA with amino groups [22]. Dietary intervention did not influence lipid oxidation in cured ham. It has been reported that oxidative stability of cured ham was not affected by dietary enrichment with α-TA in meat with low levels of oxidation [2]. Dietary supplementation with 200 ppm α-TA for 42 days prior to slaughter reduced lipid oxidation in dry–cured Iberian hams [7]. However, oxidation of the control group was more extensive than that in the present study. Further masking of potential α-TA or GTC effects may have resulted from the levels of nitrate and nitrite used, since a positive effect of dietary α-TA has been previously demonstrated in low nitrite cured pork [5].

4.5. Effect of breed and diet on colour stability in cured ham

Ham from Landrace sired pigs had improved muscle redness in comparison to ham from Duroc sired pigs. A previous study showed the red colour of hams from Duroc sires to be the least intense of all pig crosses examined and this was attributed to high IMF content [1]. The IMF content of m. *LD* from the pigs used in the present study was significantly higher in Duroc than in Landrace sired pigs [15] and it may be presumed that the IMF content of Duroc ham muscle was also higher. Variations in pigment content between pork breeds have been reported. Higher myoglobin levels have been reported in Duroc pigs compared to Landrace [19]. In contrast, Terra and Fries found that Landrace pigs have more pigment than Duroc pigs [24] and that higher pigment levels generate more hemochrome (nitrosylmyochrome) thereby enhancing the colour of cured pork products. Such an effect may explain the increased a* values in this study, as no significant differences were detected in ultimate pH values (5.87 vs. 5.84 for Landrace and Duroc, respectively). A decrease in muscle redness was noted in both breeds from d0 to d4, as nitrosylmyochrome faded slightly. This was possibly due to the exposure of hams to oxygen and light during sample preparation. Neither breed nor diet significantly affected L* or b* values in cured hams. This may have been due to the increased stability of hams resulting from brine additives as outlined previously. Evidence for enhanced redness in hams from pigs supplemented with α-TA at higher levels and for longer durations than in the present study has been shown [6, 25]. No published research on the potential effects of dietary GTC supplementation on cured ham colour is available for comparison with the present data.

Restricting dietary energy content with grassmeal had no effect on colour stability and it is possible that dietary energy restrictions were insufficient to result in any observable effects. Meat from cattle raised on grass has been reported to be darker in colour than meat from animals raised on conventional, concentrate based diets [6]. In contrast, the present study used pelleted grassmeal and some degradation in nutritional status is likely to have occurred. Grassmeal finisher diets contained lower levels of α-tocopherol compared to the Control finisher diet with 35 and 55 mg α-tocopherol per kg respectively (Tab. II). It is possible that the antioxidant and chelating action of curing

additives may have stabilised ham colour during refrigerated storage thereby resulting in the limited dietary effects observed.

5. CONCLUSION

In general, the effects of breed on ham quality were greater than those due to dietary treatment. Lean ham weight did not differ between breeds and was not affected by compensatory growth feeding strategy. No differences were detected in ham cooking yields for either breed or diet. Hams from Duroc sired pigs had improved lipid stability. In contrast, hams from Landrace sired pigs had improved colour stability (a* values). Brine ingredients were the probable cause of oxidative stability and may have masked any dietary effects on ham quality. Dietary energy restriction may offer potential as a cost-effective production strategy for high-value pork products. Cured hams produced in this way were not susceptible to lipid or colour deterioration during prolonged refrigerated storage.

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