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Relationships of genotype and slaughter time with the appearance and texture of dry-cured hams

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Abstract

The influence of genetics and slaughter time on the sensory characteristics of dry-cured hams was studied. To this end, 341 dry-cured hams, selected from 1257 pigs from five different crosses, including Duroc, Landrace and Large White, in five slaughters distributed over a year (namely, December 2000, March, April, July and November 2001) were sensorially evaluated according to the ISO 8586-2:1994. The sensory parameters assessed were pastiness, softness, colour, ring colour, crusting and marbling. Analysis of the results revealed that both the genetics and slaughter time had a significant effect on the dry-cured ham quality. Thus, warmest months provide dry-cured hams of the highest quality, but with a higher incidence of crusting. Dry-cured hams with the best sensory evaluation for texture and colour were from crossbreed A [(LR × LW) × DU]; while crossbreed D [(LR × LW × DU) × DU] provided the highest percentage of faulty dry-cured hams, except for incidence of crusting. Other parameters, such as the ham weight, relationship between salting days and ham weight, pH before salting and total weight loss, also influenced the properties of the end-product.

Keywords: Dry-cured ham; Genetics; Slaughter time; Sensory parameters

1. Introduction

One of the most appreciated Spanish food products is dry-cured ham. Parameters, such as texture, colour, intramuscular fat (marbling or veined), are used as indicators of dry-cured ham quality (Rovira, Ordóñez, & Jaime, 1996). Defective texture of the final product involves softness, adhesiveness, lack of elasticity and usually extraneous aroma and flavour (Parolari, Virgili, & Schivazappa, 1994). Colour influences the appearance and attractiveness of dry-cured ham because a defective colour, similar to raw meat, is rejected by consumers as they associate it with unripeness. Concerning intramuscular fat, several authors consider the veined grade as reflecting quality of the pig meat (Wood, Warriss, & Enser, 1992), although an excessive fat content could have a negative effect on the acceptance of the product by consumers (Kempster, Dilworth, Evans, & Fisher, 1986; Rovira et al., 1996; Wood, Jones, Francombe, & Whelehan, 1986). Marbling is influenced by many factors, such as the characteristics of the fresh matter employed, breed, weight, sex and diet (Arnau, Guerrero, & Gou, 1993; Coma, 1999; Diestre, 1992; Timón, Barnadiaran, De la Vega, & Ventanas, 1995), and the biochemical changes that occur during the curing process (time of the salting stage, temperature, humidity and total time of the process). Recently, most pig producers have included genetic selection in their production programmes for improving meat quality (Tarrant, 1998; Visscher, Pong-Wong, Whittemore, & Haley,

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2000) as cross-breeding drastically influences this. Oliver et al. (1994) studied meat quality and aptitude for the production of dry-cured ham using different male lines (Duroc, Large White and Belgian Landrace) and only one female line. They found that the cross-bred Duroc × (Landrace × Large White) was characterized by a major intramuscular fat content. In this way, purebred Duroc or Duroc crossed with animals of Iberian, Landrace or Large White breed are used as a terminal sire to produce high quality dry-cured ham because of their high fat content (Alves, Castellanos, Ovilo, Silió, & Rodríguez, 2002; Barton-Gade, 1988; Cameron, Warris, Porter, & Enser, 1990; Gispert, Díaz, Oliver, Tibau, & Diestre, 1990; Gispert, Gou, & Diestre, 2000; Oliver, Gispert, Gou, Blasco, & Diestre, 1992).

The research here presented belongs to the research guideline on the influence of raw meat quality on the sensory characteristics of dry-cured ham. Thus, García-Garrido (2001) studied the ability of two cross-breeds, Landrace × Duroc – LR × DU – and (Landrace × Duroc) × Penerland – (LR × DU) × PN – to produce dry-cured ham and the effect of seasonality. One result of this research was that the presence of some defects, such as pastiness, poor colour, colour rings or crusting in Spanish serrano dry-cured ham is related to raw material, and the hams from (LR × DU) × PN cross-breed exhibit a higher incidence of these defects than those from the LR × DU breed. Another influential variable on dry-cured ham quality is the seasonality or time of year when the slaughter takes place; so it must also be taken into account. Thus, the hams that began the curing process in February and June most frequently exhibit a soft texture, while, pastiness is more common in hams from raw material obtained in December and February. Soriano-Pérez (2001) compared productive parameters and raw ham quality between white pigs from three cross-breeds, including Duroc breed. The genetics providing the best results in the work García-Garrido (2001) was a female line crossbred with three male lines, namely, Duroc, supplied by two different companies, and Duroc × Large White; two of the genetics had 75% DU and 25% LR, and the third genetics with 50% DU, 25% LD and 25% LW. The two genetics with the same crossbreed provided hams with similar characteristics except for the fat thickness and size. A variation of 25% in blood Duroc, substituted by Large White, resulted in dry-cured hams with the most favourable sensory values and the most homogeneous quality.

The improvement of cured ham quality makes a better knowledge of the raw material characteristics mandatory. Thus, the aim of this research was to study the influence of genetics, as well as seasonality, on the sensory properties of dry-cured ham. Based on the above previous research, the present study involved specimens from five commercial crossbreeds (mixed Duroc, Landrace and Large-White genotypes), including the genetics with the best results in the research by Soriano-Pérez (2001) and collected at five different times over a year.

2. Materials and methods

2.1. Sampling

The ham samples were obtained from 1257 entire and castrated pigs, and females, from five different crosses including Duroc (DU), Landrace (LR) and Large White (LW). The crosses were [♀ × ♂]: A, (LR × LW) × DU; B, (LR × LW) × DU; C, (LR × LW) × DU; D, (LR × LW × DU) × DU; E, (DU × LR) × (DU × LW). A, B and C belonged to the same synthetic sire but were provided by different suppliers. The hams were collected in five slaughters performed in the same slaughterhouse and distributed over a year (namely, December 2000, March, April, July, and November 2001, -Dec00, March01, April01, July01 and Nov01-) in order to investigate the effect of seasonality on the raw material.

The duration of the *post-mortem* period was 3–5 days and, then, hams were subject to the traditional process for producing Spanish dry-cured ham that involves over 13 months divided into the following steps: salting (the specimens were salt-coated with curing salts – 5:5:90, $NaNO_2$, KNO_3 and NaCl ratio – and stood for about 0.78 ± 0.15 days per kg of ham, that is, from 8 to 10 days, depending on ham weight); resting time or post-salting (3–5 °C and 80% of relative humidity for 45 days); cold-drying (the salted hams were subject to temperatures gradually increased from 3 to 22 °C, with strict control of the relative humidity, decreased from 80% to 70%, for 5 months); warm-drying (the pieces were subject to temperatures from 22 to 30 °C and 70–80% of relative humidity for 4 months); and ripening (the hams were protected with a layer of liquid fat manually applied by a brush and stored for 2–3 months at temperatures from 12 to 15 °C and 80% of relative humidity). Hams were produced in the same industry and in a common process plant.

Seventy five hams (between 9 and 19 were random selected from each slaughter) were weighed at the end of the curing period for monitoring the total weight loss.

2.2. Sensory evaluation

The sensory evaluation of the product, at the end of the curing process, was aimed at detecting the incidence of quality defects. Ten to fifteen samples of each genetics were selected from each of the five sacrifices in order to obtain a number of samples sufficient for a statistical study with costs acceptable by the industry. Thus, 341 hams were boned and cross-sectioned about 5 cm below the hip bone. Two technicians from the ham manufacturing industry, specializing both in the curing process and detection of anomalous sensory properties in dry-cured ham, in accordance with the ISO 8586-2:1994 (1995), assessed the sensory properties of dry-cured ham on the cross-sectioned surfaces. Sensory parameters were scored on a scale from 1 to 10: values lower than or equal to 7 were attributed to the presence of defects that are detected by the consumers and/or to poor quality of the final product, and higher than 7 to defects either absent or not detected by the consumers. The final score was the average value of the scores by both expert judges.

The specific parameters assessed included:

(a) *Pastiness*. The presence of pasty texture occurs mainly in *Biceps femoris* muscle, although this defect can also be detected in *Semitendinosus*, *Vastus intermedius*, *Vastus lateralis* and *Vastus medialis* muscles, and reflects a lack of elasticity on pressing gently on the zone concerned and also gives intense adhesiveness. Hams with this textural defect also possess other unwanted properties, such as a somewhat bitter, piquant flavour and a lack of the aroma of cured ham.
(b) *Softness*. The presence of soft texture results from a lack of firmness from the slice, which can be readily deformed simply by pressing gently with a finger. Unlike pasty ham, elasticity and adhesiveness are not affected.
(c) *Colour*. The zone, exposed after a slice is cut, must exhibit the typical red colour of the cured product (Arnau, 1998). A defective colour, similar to raw meat, is rejected by consumers because it is associated with unripeness.
(d) *Colour rings*. This defect consists of zones that lack the typical colour of cured ham as they likely result from an uneven distribution of the nitrifying agent (Arnau, 1998).
(e) *Crusting*. An excessive hardness on the zone close to the fat-free surface characterizes this phenomenon, which mainly affects *Gracilis*, *Semimembranosus* and *Abductor* muscles.
(f) *Marbling or intramuscular fat*. This is related to the smell-gustatory characteristics, and to other sensory features, such as hardness and juiciness (Guerrero, Gou, Alonso, & Arnau, 1996; Ruiz, 1996; Virgili, Porta, & Schivazappa, 1998).

2.3. pH measurement

The pH before salting (pH BS) was monitored at 48 h *post-mortem* in *Semimembranosus* (SM) muscle due to both easy accessibility and non-destructive measurement. A portable pH meter, pH Star from Matthäus, equipped with a penetration electrode Crison cat. 52-32, was used.

2.4. Statistical analysis

The experimental data were statistically processed using the SPSS v. 10.0 software suite.

3. Results and discussion

3.1. General

The results from the sensory evaluation are given in Table 1. Frecuencies are expressed as percentages relative to the total number of specimens in each group formed by combining the two factors studied: genetics and time of the year when the animals were slaughtered. In regard to pastiness and softness, pasty hams could not be distinguished from hams that are both pasty and soft at the same time and the last type of hams were considered as pasty hams. Normal hams were those that did not present either of these texture defects.

In order to check the influence of the slaughter time and genetics on the appearance of faulty dry-cured hams, the data from the evaluation of the hams processed were analyzed by the Kruskall–Wallis non-parametric test.

Based on previous research, parameters, such as ham weight, salting days:ham weight ratio, pH BS and total loss of weight, were included in this study due to their influence on dry-cured ham quality. García-Garrido (2001) found that the appearance of defective dry-cured ham is related to both high ham weight before salting and duration of the salting step, depending on the ham weight. Another factor that influences the dry-cured ham quality is the pH in *Semimembranosus* muscle before salting (García-Rey, García-Garrido, Quiles-Zafra, Tapiador, & Luque de Castro, 2004), so it must be taken into account. As regards the total loss of weight once the curing process is finished, the results obtained are of paramount importance both (a) from the research point of view (in order to check if all the hams evolve similarly and, if not, to know the influence of the dissimilarity on the features of the final product) and (b) from the industry point of view, as the genetics with smaller weight losses yield the greatest benefits.

3.2. Pastiness

The Kruskall–Wallis test (Table 2) revealed that both the slaughter time and genetics have significant effects on the incidence of pasty texture ($p < 0.01$). Hams obtained in Dec00 and Nov01 and from genetics D showed the highest percentage of pastiness dry-cured hams; while, genetics A and warmest months provided dry-cured hams with the lowest incidence of pasty texture.

There were significant differences between pasty and normal hams with regard to ham weight and pH BS, but not with regard to salting days:ham weight ratio

Table 1
Percent frequencies of the quality of the sensory parameters for the groups established in terms of the slaughter time and genetics

Slaughter time	Genetics	Pastiness		Softness		Colour		Ring colour		Crusting		Marbling	
		1	2	1	2	1	2	1	2	1	2	1	2
Dec00	A	11.1	88.9	33.3	66.7	30.8	69.2	7.7	92.3	23.1	76.9	84.6	15.4
	B	22.2	77.8	30.0	70.0	25.0	75.0	8.3	91.7	33.3	66.7	50.0	50.0
	C	16.7	83.3	64.3	35.7	53.3	46.7	26.7	73.3	33.3	66.7	86.7	13.3
	D	71.4	28.6	83.3	16.7	52.9	47.1	11.8	88.2	41.2	58.8	88.2	11.8
	E	50.0	50.0	57.1	42.9	60.0	40.0	50.0	50.0	50.0	50.0	100.0	
March01	A	12.5	87.5		100.0	37.5	62.5	37.5	62.5	75.0	25.0	93.8	6.3
	B	23.1	76.9	9.1	90.9	28.6	71.4	14.3	85.7	57.1	42.9	71.4	28.6
	C	9.5	90.5	13.6	86.4	40.0	60.0	13.3	86.7	66.7	33.3	100.0	
	D	29.4	70.6	14.3	85.7	36.8	63.2	26.3	73.7	63.2	36.8	84.2	15.8
	E	8.3	91.7		100.0	16.7	83.3	8.3	91.7	91.7	8.3	100.0	
April01	A		100.0	18.2	81.8	9.1	90.9		100.0	45.5	54.5	63.6	36.4
	B	12.5	87.5	6.7	93.3	23.5	76.5	5.9	94.1	52.9	47.1	88.2	11.8
	C	16.7	83.3		100.0	25.0	75.0		100.0	83.3	16.7	91.7	8.3
	D	16.7	83.3		100.0		100.0		100.0	50.0	50.0	83.3	16.7
	E	46.2	53.8	12.5	87.5	35.7	64.3	21.4	78.6	57.1	42.9	92.9	7.1
July01	A		100.0	44.4	55.6	11.1	88.9	22.2	77.8	66.7	33.3	66.7	33.3
	B		100.0		100.0		100.0	12.5	87.5	87.5	12.5	62.5	37.5
	C	12.5	87.5		100.0	12.5	87.5	12.5	87.5	75.0	25.0	75.0	25.0
	D	55.6	44.4	50.0	50.0	61.5	38.5	38.5	61.5	61.5	38.5	76.9	23.1
	E		100.0		100.0	12.5	87.5	25.0	75.0	87.5	12.5	75.0	25.0
Nov01	A	9.1	90.9	9.1	90.9	16.7	83.3	8.3	91.7	75.0	25.0	100.0	
	B	36.4	63.6	12.5	87.5	58.3	41.7	25.0	75.0	75.0	25.0	100.0	
	C	54.5	45.5	16.7	83.3	58.3	41.7	25.0	75.0	75.0	25.0	100.0	
	D	66.7	33.3	62.5	37.5	50.0	50.0	7.1	92.9	28.6	71.4	85.7	14.3
	E	38.5	61.5	20.0	80.0	53.3	46.7	40.0	60.0	86.7	13.3	100.0	

1: Hams with sensory value lower than or equal to 7.
2: Hams with sensory value higher than 7.

Table 2
Results of the non-parametric test of Kruskall–Wallis

Sensory parameters	Slaughter time		Genetics	
	Chi-squared	Significance	Chi-squared	Significance
Pastiness	13.19	0.010	15.77	0.003
Softness	46.10	0.000	9.72	0.045
Colour	11.92	0.018	9.77	0.045
Ring colour	3.99	0.408	6.93	0.140
Crusting	29.46	0.000	10.92	0.027
Marbling	16.90	0.002	12.47	0.014

and total weight loss. Thus, pasty hams yielded higher weight and lower pH BS than normal hams, which was in agreement with previous research (García-Garrido, 2001; García-Rey et al., 2004). Despite the differences not being statistically significant, salting days:ham weight ratio and total weight loss were lower in pasty hams than in normal hams. The fact that the pasty texture was not influenced by the salting time coincides with the results obtained by Arnau, Guerrero, and Pere (1997). According to these authors, hams with the highest duration of salting stage yielded better results in pastiness and softness than the rest. Arnau et al. (1997) did not find significant differences with the salting time; however García Garrido concluded that softness is significatively influenced by the salting time.

3.3. Softness

Concerning the appearance of soft texture, there were significant differences, depending on both the slaughter time and genetics (Table 2). Soft texture was more common in the specimens obtained in Dec00 and Nov01, and from genetics D. The best score for softness was achieved by hams from the warmest month and genetics B and E; nevertheless, genetics A and D give a higher percentage of soft hams in July01.

Table 3
Descriptive analysis of ham weight, salting days:kg green ham ratio, pH before salting and total loss of weight in the two groups formed according to the evaluation of each parameter

Parameter	Ham weight		Salting days:ham weight		pH BS		Total of weight loss	
	1	2	1	2	1	2	1	2
Pastiness								
N	67	217	67	217	67	217	15	43
Mean	12.01	11.62	0.784	0.791	5.54	5.73	37.13	38.21
S.D.	0.87	0.89	0.040	0.046	0.11	0.22	1.64	3.29
p-Value	0.002		0.220		0.000		0.232	
Softness								
N	57	217	57	217	57	217	17	43
Mean	12.39	11.62	0.774	0.791	5.69	5.73	35.33	38.21
S.D.	0.77	0.89	0.030	0.046	0.22	0.22	2.28	3.29
p-Value	0.000		0.009		0.162		0.001	
Colour								
N	119	222	119	222	119	222	23	52
Mean	11.89	11.79	0.789	0.786	5.57	5.75	37.39	37.25
S.D.	0.97	0.88	0.045	0.042	0.14	0.23	2.46	3.28
p-Value	0.303		0.523		0.000		0.854	
Ring colour								
N	63	278	63	278	63	278	15	60
Mean	11.91	11.80	0.789	0.787	5.53	5.72	37.67	37.20
S.D.	0.90	0.91	0.044	0.043	0.11	0.22	2.09	3.24
p-Value	0.423		0.696		0.000		0.598	
Crusting								
N	209	132	209	132	209	132	31	44
Mean	11.64	12.11	0.794	0.776	5.70	5.67	38.87	36.18
S.D.	0.89	0.88	0.045	0.038	0.21	0.23	3.56	2.00
p-Value	0.000		0.000		0.142		0.000	
Marbling								
N	296	45	296	45	296	45	64	11
Mean	11.81	11.90	0.788	0.784	5.67	5.80	37.50	36.09
S.D.	0.92	0.89	0.045	0. 033	0.20	0.29	3.04	2.84
p-Value	0.566		0.618		0.000		0.157	

1: Hams with sensory value lower than or equal to 7.
2: Hams with sensory value higher than 7.
N: Number of samples.
S.D.: Standard deviation.

Soft hams were heavier than normal hams with a statistically significant difference (Table 3). Opposite to the results from hams grouped as a function of pastiness, there were significant differences between soft and normal hams, depending on the days salt:ham weight ratio and total loss of weight, but not on pH BS. The salting days:ham weight ratio and the loss of weight were lower in soft hams than in normal hams; and, in the case of loss of weight, the difference was about 3%. Arnau (1991) showed that low salt concentration seems to produce more softness of the inner muscles.

3.4. Colour and ring colour

The Kruskall–Wallis test shows (Table 2) that both the slaughter time and genetics exert a significant effect on the incidence of defective colour, but not on the ring colour of dry-cured hams. The typical colour of cured ham was poorer, in general, for hams made from raw material obtained in Dec00 and worse for hams from genetics D and E. July01 and genetics A and B provided hams with the most desirable colour. Nevertheless, hams from genetics D obtained in July01 yielded the highest percentage of defective colour (>60%).

Despite the non-significant differences, the incidence of colour rings was higher in hams made from specimens obtained from genetics E, and especially in those from the coldest months. However, genetics A and D yielded hams with high ring colour incidence, but in July01. All hams obtained in April01 has the lowest ring colour incidence. Genetics B provided hams with the best behaviour, in this characteristic, over the year.

The pH BS established significant differences between hams: those with both colour defects and ring colour exhibited a pH lower than normal hams (Table 3).

3.5. Crusting

There was a significant effect of both the slaughter time and the genetics on crusting appearance (Table 2). Crusting was more marked in specimens obtained in July01 and March01 and from genetics E. The lowest incidence of crusting was in the dry-cured hams obtained in Dec00 and from genetics D and A.

As in the case of softness, there were significant differences between all parameters studied, except for pH BS; but, contrarily to soft hams, those with crusting incidence had a lower weight and higher total loss weight than normal hams.

3.6. Marbling

Table 2 shows that both the slaughter time and genetics exert a significant effect on marbling (intramuscular fat content). Dry-cured hams with the lowest marbling scores were from genetics E and obtained in Nov01. The best evaluation was for hams obtained in July01 and from genetics B and A.

As in the case of defective colour, there was only a significant difference in pH BS, and hams with poor marbling exhibited a pH BS lower than that of hams with adequate marbling (Table 3).

4. Conclusion

The results obtained in this research establish that both the genetics and seasonality exert a significant influence on dry-cured ham quality; therefore, they must be taken into account in order to obtain the best product. Thus, warmest months provide dry-cured hams of the highest quality, but with a higher incidence of crusting. Dry-cured hams with the best sensory evaluation for texture and colour are from genetics A, followed by genetics B, while genetics D provides the highest percentage of faulty dry-cured hams, except for incidence of crusting, followed by genetics E.

The mean and *p*-values of ham weight, salting days: ham weight ratio, pH BS and total weight loss – obtained as a function of different groups formed according to sensory parameters – are in agreement with previous research, as mentioned in the previous section. The fact that hams grouped according to the incidence of softness and crusting have significant differences in the total weight loss means that the appearance of these defects is mainly due to an inadequate curing process and, besides raw material and seasonality, the factors that affect curing process must be taken into account in order to minimize the softness and crusting appearance.

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