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EFFECTS OF SALTING DURATION AND BOAR TAINT LEVEL ON QUALITY OF DRY-CURED HAMS

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ABSTRACT

Meat from entire males (EM) may take an important market share in the EU in case surgical castration is abandoned. The aim of the present study was to assess the effect of salting regime and boar taint level on dry-cured ham quality. Standard (18 days, HS) and shortened salting (6 days, LS) was applied to 16 hams from 8 EM, being also evaluated according to boar taint; low (LBT) or high (HBT). Compared to standard procedure, shorter salting resulted in 40 % lower salt content, higher proteolysis, higher aw, softer texture, accompanied by lower sensorial saltiness and sourness and higher meat colour intensity, sweetness, bitterness, pastiness and off-flavour perception. HBT hams were more proteolysed, with softer texture, higher perception of bitterness, pastiness and juiciness with more pronounced off-flavours and poorer typical cured odour than LBT hams. A significant interaction between boar taint level and salting on perceived off flavours denotes that either salt covers off-flavours or there are additive effects of boar taint substances and proteolysis products when salt content is low.

Key words: pigs, entire male pigs, meat, dry-cured ham quality, boar taint, salting regime

1 INTRODUCTION

Traditional dry-cured ham *Kraški pršut* is the most appreciated dry-cured meat product among Slovenian consumers (Čandek-Potokar and Arh, 2004). Appropriate raw material quality is essential for high quality product. For *Kraški pršut*, the origin of raw material is not prescribed, thus the producers are strongly bound to the supply of green hams from the European markets. Due to the initiative to stop surgical castration of piglets, it is expected that rearing of entire males (EM) will take significant share in European pig production. Besides accumulation of malodorous boar taint substances (skatole and androstenone) in fat tissue, EM deposit less fat (subcutaneous as well as intramuscular – IMF) and exhibit lower water holding capacity (WHC) of meat (Batorek *et al.*, 2012; Pauly *et al.*, 2012) which may reduce dry-cured ham quality. Namely, poor WHC causes lower seasoning yields and higher salt uptake, resulting in dry, firm and salty product with poor aroma (Čandek-Potokar and Škrlep, 2012). Proper amount of fat prevents excessive water loss and serves as a barrier for salt uptake, with IMF improving the development of typical aromatic and textural properties. Furthermore, EM exhibit higher protein deposition capacity, which could affect the proteolytic potential of EM meat and induce changes associated to the process of proteolysis during the lengthy dry-curing process (Toldra, 2002). As the information about the use of EM for dry-cured ham production is scarce, the aim of this study was to investigate the influences of such raw material on ham processing and final quality considering different salting regimes and boar taint levels.

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***Table 1:** Raw material traits and processing losses (LS means) according to salting duration and boar taint*

	Salting		Boar taint		*p*-value			RMSE
	HS	LS	LBT	HBT	Salting	Boar taint	Salting × boar taint	
Green ham traits								
Ham weight (kg)	12.9	12.7	12.9	12.6	0.768	0.688	0.948	1.5
pH SM	5.49	5.47	5.50	5.46	0.664	0.305	0.492	0.07
Fat thickness (mm)	16	13	16	13	0.235	0.108	0.973	4
Processing losses (%)								
Salting 6 days	2.0	1.9	1.8	2.1	0.856	0.182	0.871	0.5
Salting 18 days	3.9	-	-	-	-	-	-	-
Resting	20.1	20.0	19.2	20.9	0.990	0.207	0.976	2.5
Drying	27.6	27.2	26.4	28.3	0.809	0.234	0.944	3.1
Ripening	36.6	36.6	35.2	38.0	0.984	0.237	0.902	4.6

HS – salting 18 days; LS – salting 6 days; HBT – androstenone content in subcutaneous fat > 0.78 μg/g; LBT – androstenone content in subcutaneous fat < 0.78 μg/g; SM – *semimembranosus* muscle; RMSE – root-mean-square error

***Table 2:** Effect of salting duration and boar taint on chemical traits (LS means) of dry-cured hams*

	Salting		Boar taint		*p*-value			RMSE
	HS	LS	LBT	HBT	Salting	Boar taint	Salting × boar taint	
SM muscle								
Salt (g/kg)	67.0	37.8	50.8	54.0	0.000	0.472	0.948	8.7
Dry matter (g/kg)	489.3	471.1	470.5	489.9	0.214	0.186	0.894	27.6
IMF (g/kg)	44.1	39.6	40.8	43.0	0.270	0.574	0.900	7.8
NPN (g/kg)	13.2	15.2	13.6	14.8	0.002	0.045	0.332	1.1
Proteolysis index (%)	22.1	25.3	23.1	24.3	0.003	0.183	0.283	1.8
a_w	0.894	0.940	0.921	0.913	0.0001	0.397	0.919	0.017
BF muscle								
Salt (g/kg)	77.4	45.8	58.9	64.4	0.000	0.217	0.813	8.4
Dry matter (g/kg)	405.5	389.4	390.5	404.4	0.139	0.198	0.895	20.3
IMF (g/kg)	29.1	30.3	29.9	29.5	0.634	0.874	0.874	4.6
NPN (g/kg)	13.7	15.6	13.8	15.5	0.034	0.048	0.659	1.5
Proteolysis index (%)	29.8	33.5	30.0	33.3	0.024	0.042	0.666	2.9
a_w	0.895	0.937	0.920	0.912	0.000	0.227	0.815	0.014
Subcutaneous fat								
Androstenone (μg/g)	0.97	1.01	0.65	1.32	0.846	0.005	0.885	0.39
Skatole (μg/g)	0.17	0.15	0.08	0.24	0.811	0.013	0.838	0.11

HS – salting 18 days; LS – salting 6 days; HBT – androstenone in subcutaneous fat > 0.78 μg/g; LBT – androstenone in subcutaneous fat < 0.78 μg/g; SM – semimembranosus muscle; BF – biceps femoris muscle; IMF – intramuscular fat; NPN – non-protein nitrogen; aw – water activity; RMSE – root-mean-square error

2 MATERIALS AND METHODS

Green hams (n = 16; 12.8 ± 1.4 kg) from 8 crossbred boars fed commercial feed mixture were processed in a commercial facility according to the rules of consortium *Kraški pršut*. Measurements of green ham weight, subcutaneous fat thickness and pH in *semimembranosus* (SM) muscle were recorded prior to salting at 2–4 °C for 6 days (LS – shortened salting, right hams) or 18 days (HS – standard salting regime, left hams). After the salting, the hams were washed and left to rest at 4–6 °C and 70–85 % relative humidity (RH) for 89 and 77 days for LS and HS, respectively. Following resting, the hams were left to dry and ripen (14–20 °C, 60–80 % RH) until reaching the final processing age of 68 weeks. In order to monitor processing losses, ham weight was recorded at the end of each phase. Boar taint substances androstenone and skatole were determined by HPLC (as described by Batorek *et al.*, 2012) in samples of subcutaneous fat taken at the level of the last rib at slaughter and from the central part of the ham at the end of the ripening. Chemical analysis (salt, total nitrogen content, non-protein nitrogen – NPN, proteolysis index – IP, IMF) and rheological measurements (force decay coefficient, texture profile analysis) were performed in SM and *biceps femoris* (BF) muscle samples as described in Pugliese *et al.* (2015). Sensory analysis (quantitative descriptive analysis) was conducted with 11 trained panellists evaluating sensory descriptors on entire ham slice (marbling, colour homogeneity and intensity, typical cured odour), subcutaneous fat (whiteness, rancidity, sweetness, off-flavours) and separately SM and BF muscles (saltiness, acidity, sweetness, bitterness, off-flavours, solubility, juiciness, pastiness). Data was statistically analysed using GLM procedure of the SAS/STAT module (SAS Institute, Cary, NC, USA). The median of androstenone concentration (0.78 µg/g liquid fat) measured in subcutaneous fat of dry-cured hams was used to classify the hams into low (LBT; androstenone < 0.78 µg/g) and high boar taint (HBT; androstenone > 0.78 µg/g). This benchmark agrees with the level considered as threshold for sensorial perception i.e. 0.5–1.0 µg/g fat (Walstra *et al.*, 1999). Salting time, boar taint level, and their interaction were included as fixed effects. Differences between groups were considered significant at $p < 0.05$.

3 RESULTS AND DISCUSSION

Green ham traits were recorded due to their importance for dehydration, salt intake and biochemical changes. No effect ($p > 0.10$) of salting regime or boar

Table 3: *Effect of salting duration and boar taint on rheological traits (LS means) of dry-cured hams*

	Salting		Boar taint		*p*-value			RMSE
	HS	LS	LBT	HBT	Salting	Boar taint	Salting × boar taint	
SM muscle								
Force decay coefficient	0.62	0.67	0.63	0.65	0.005	0.148	0.980	0.03
Hardness (N)	90.1	54.3	69.9	74.5	0.006	0.671	0.433	21.4
Cohesiveness	0.49	0.43	0.49	0.43	0.111	0.119	0.597	0.07
Gumminess (N)	54.2	24.0	35.2	43.0	0.008	0.426	0.143	19.0
Springiness (mm)	3.5	3.1	3.4	3.2	0.190	0.377	0.935	0.5
Chewiness (N)	191.4	77.7	128.3	140.8	0.009	0.737	0.226	72.7
Adhesiveness (N*mm)	−2.4	−3.3	−2.1	−3.5	0.027	0.003	0.267	0.8
BF muscle								
Force decay coefficient	0.68	0.71	0.69	0.70	0.083	0.890	0.980	0.04
Hardness (N)	42.3	25.8	38.7	29.3	0.004	0.067	0.931	9.3
Cohesiveness	0.51	0.41	0.52	0.40	0.029	0.016	0.841	0.08
Gumminess (N)	23.1	11.2	21.4	12.9	0.009	0.047	0.716	7.7
Springiness (mm)	3.6	3.6	3.6	3.6	0.892	0.964	0.102	0.7
Chewiness (N)	87.1	38.5	81.7	43.9	0.016	0.049	0.369	34.6
Adhesiveness (N*mm)	−1.0	−1.5	−0.9	−1.5	0.188	0.127	0.299	0.8

HS – salting 18 days; LS – salting 6 days; HBT – androstenone in subcutaneous fat > 0.78 µg/g; LBT – androstenone in subcutaneous fat < 0.78 µg/g; SM – semimembranosus muscle; BF – biceps femoris muscle; RMSE – root-mean-square error taint level was observed confirming that groups were equilibrated in terms of raw material properties (Table 1).

Reducing salting from 18 to 6 days led to 40 % salt reduction (in BF and SM; Table 2), and resulted in higher a_w and proteolysis index ($p < 0.05$) in LS than HS hams, which corroborates inversely proportional relationship between salt content and protein breakdown (Martín *et al.*, 1998). Proteolysis index in BF muscle of LS hams exceeded (in average) the level of 30 %, which has been associated with flavour and texture defects (Virgili *et al.*, 1995). Substantial salt reduction can be problematic also for product safety. LS hams in our study were microbiologically tested and were proven safe. However, average a_w (SM and BF) was slightly above 0.93, a prescribed limit for dry meat products (UL RS, 59/2012). Salt reduction is positive for lower risk of cardiovascular diseases, but stability of such products may be compromised as high a_w facilitates microbial growth (Bem *et al.*, 2003) and thus lowers product shelf life. Notably higher NPN (both muscles) and IP (BF) ($p < 0.05$) observed in HBT than LBT can be explained with androstenone which reflects higher anabolic potential, higher protein turnover

Table 4: *Effect of salting duration and boar taint on sensory traits (LS means) of dry-cured hams*

	Salting		Boar taint		*p*-value			RMSE
	HS	LS	LBT	HBT	Salting	Boar taint	Salting × boar taint	
Entire slice								
Meat colour uniformity	6.3	6.4	6.3	6.4	0.524	0.647	0.247	0.4
Meat colour intensity	5.0	5.5	5.2	5.3	0.032	0.667	0.205	0.4
Marbling	2.2	2.5	2.4	2.3	0.400	0.783	0.974	0.6
Typical cured odour	5.4	5.2	5.6	5.0	0.384	0.038	0.234	0.5
Subcutaneous fat								
Fat whiteness	5.8	5.3	5.5	5.6	0.298	0.929	0.867	1.0
Fat sweetness	4.1	3.5	3.8	3.7	0.004	0.531	0.808	0.3
Fat off-flavour	1.0	1.3	0.9	1.4	0.254	0.081	0.330	0.4
Fat rancidity	1.6	1.7	1.7	1.6	0.642	0.974	0.822	0.5
SM muscle								
Bitterness	0.6	1.3	0.8	1.1	0.001	0.053	0.114	0.3
Sourness	1.8	1.5	1.6	1.6	0.030	0.822	0.475	0.3
Pastiness	1.1	2.1	1.0	2.2	0.032	0.017	0.143	0.8
Sweetness	0.6	1.3	0.9	1.0	<0.0001	0.662	0.226	0.2
Saltiness	6.0	4.0	5.2	4.8	<0.0001	0.227	0.299	0.6
Juiciness	3.8	4.4	4.3	4.0	0.046	0.357	0.205	0.5
Solubility	4.9	5.2	4.9	5.2	0.251	0.109	0.182	0.4
Off-flavour	0.7	1.7	0.9	1.5	0.0001	0.006	0.071	0.3
BF muscle								
Bitterness	0.7	1.3	0.8	1.2	0.001	0.014	0.227	0.3
Sourness	2.3	2.0	2.1	2.2	0.140	0.438	0.890	0.3
Pastiness	1.5	2.8	1.4	2.9	0.039	0.019	0.504	1.0
Sweetness	0.6	1.2	0.9	1.0	<0.0001	0.138	0.180	0.1
Saltiness	6.8	4.8	5.9	5.7	<0.0001	0.421	0.655	0.5
Juiciness	5.2	5.4	5.3	5.3	0.188	0.856	0.051	0.4
Solubility	5.2	5.2	5.0	5.5	0.952	0.019	0.177	0.4
Off-flavour	0.9	1.9	1.0	1.7	0.0001	0.002	0.014	0.3

HS – salting 18 days; LS – salting 6 days; HBT – androstenone content in subcutaneous fat > 0.78 μg/g; LBT – androstenone content in subcutaneous fat < 0.78 μg/g; SM – semimembranosus muscle; BF – biceps femoris muscle; RMSE – root-mean-square error

Table 5: *Interacting effect of salting and boar taint on off-flavours in different dry-cured ham tissues*

Salting	HS		LS		*p*-value			RMSE
Boar taint	LBT	HBT	LBT	HBT	Salting	Boar taint	Salting × boar taint	
Off-flavour								
BF	0.8[a]	1.0[a]	1.3[a]	2.5[b]	0.0001	0.002	0.014	0.3
SM	0.6[a]	0.8[a]	1.2[a]	2.1[b]	0.001	0.006	0.071	0.3
Fat	0.9	1.1	1.0	1.6	0.254	0.081	0.330	0.4

HS – salting 18 days; LS – salting 6 days; HBT – androstenone content in subcutaneous fat > 0.78 µg/g; LBT – androstenone content in subcutaneous fat < 0.78 µg/g; SM – semimembranosus muscle; BF – biceps femoris muscle; RMSE – root-mean-square error; a,b Means within a row with different superscripts differ at $p < 0.05$

and thus also increased proteolytic activity (Claus *et al.* 1994). There was no effect of salting on the level of boar taint compounds. LBT was in average below and HBT above benchmark considered a threshold for sensory perception (Walstra *et al.*, 1999).

Salting duration affected majority of evaluated rheological parameters (Table 3). Compared to HS, hams of the LS group had softer, less gummy and chewy texture ($p < 0.05$) with higher force decay coefficient ($p < 0.10$) in both investigated muscles, along with reduced cohesiveness ($p < 0.05$) and increased adhesiveness ($p < 0.05$) in BF and SM, respectively. Noted impacts are in line with chemical traits namely the effect of low salt content and higher proteolysis and/or a_w on increased protein breakdown and consequently softer texture (Ruiz-Ramírez *et al.*, 2006). Considering the effect of boar taint, HBT had higher adhesiveness ($p < 0.05$) in SM and lower hardness ($p < 0.10$), cohesiveness, gumminess and chewiness ($p < 0.05$) than LBT hams. As in the case of salting regime, the effect can be related to differences in proteolysis observed between HBT and LBT groups.

Salting duration showed notable effect ($p < 0.05$) on a good number of investigated sensory traits (Table 4). Compared to standard procedure, shorter salting was associated with higher colour intensity (entire ham slice), lower saltiness, higher bitterness, pastiness, sweetness (BF and SM) and higher juiciness (SM) along with lower fat sweetness. In addition, higher degree of off-flavours was perceived in both LS ham muscles. While traits like saltiness and sourness perception can be related to the level of salt i.e. chloride ions (Buscailhon *et al.*, 1995), other effects are most probably related to the differences in proteolysis. More intensive colour of LS hams could be explained by the higher level of stable red pigment, related to the degree of proteolytic degradation (Grossi *et al.*, 2014). Other traits like increased pastiness, higher bitterness and off-flavour presence are indicating excessive protein degradation, resulting in their structural breakdown as well as numerous free amino acids and short peptides, which can negatively affect sensory perception (Virgili and Schivazappa, 2002).

Regarding the association of boar taint level with sensory traits, both muscles of HBT group were evaluated as more pasty and bitter with higher degree of off-flavours in addition to higher BF solubility ($p < 0.05$) and off-flavour presence in ham subcutaneous fat ($p < 0.10$). Despite lipophilic nature of boar taint substances, the difference in off-flavour was much more evident in muscle (with low IMF) than fat tissue indicating that increased protein breakdown could be an important source of the off-flavours in HBT hams. Although a negative effect of boar taint substances on off-flavour perception could be anticipated, the effect of increased proteolysis may play a significant role in this case.

An interaction between salting and boar taint (Table 5) was observed for off-flavours in BF ($p < 0.05$) and SM ($p < 0.10$). In HS hams slightly higher score of off-flavour perception in HBT than LBT was not significant, whereas in LS hams HBT had notably higher off-flavour score than LBT in muscle ($p < 0.05$) and in fat ($p > 0.10$) tissue. This indicates that either salt covers foreign flavours when present in higher amounts (Breslin and Beauchamp, 1997) or there are additive effects of boar taint and proteolysis on products when the amount of salt is low.

4 CONCLUSIONS

Substantial reduction of salting duration considerably reduced salt content and affected other dry-cured ham properties, but not always in a favourable manner. Interestingly, higher boar taint level was associated with increased proteolytic activity, pointing out an additional issue for dry-cured hams, processed from EM meat, especially in combination with lower salt content.

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