Meat Science 222 (2025) 109762

Contents lists available at ScienceDirect

Meat Science

journal homepage: www.elsevier.com/locate/meatsci

Quality of Slovenian dry-cured ham from Krškopolje and hybrid pigs: Influence of skin trimming methods

Bojana Savić [a], Martin Škrlep [a], Nives Marušić Radovčić [b], Sandra Petričević [c], Marjeta Čandek-Potokar [a,d,*]

[a] Agricultural Institute of Slovenia, Hacquetova ulica 17, 1000 Ljubljana, Slovenia
[b] University of Zagreb, Faculty of Food Technology and Biotechnology, Pierottijeva 6, 10000 Zagreb, Croatia
[c] Croatian Veterinary Institute, Regional Institute Split, Poljanička cesta 33, 21000 Split, Croatia
[d] University of Maribor, Faculty of Agriculture and Life Sciences, Pivola 10, 2311 Hoče, Slovenia

ARTICLE INFO

Keywords:
Dry-cured ham
Krškopolje pig
"Kraški pršut"
"Istrski pršut"
Physico-chemical properties
Volatile profile

ABSTRACT

This study examined the quality of dry-cured hams produced from local pig breed and modern hybrids using two trimming methods. Hams (n = 24) of similar weight were harvested from local breed *"Krškopolje pig"* (KKP) and conventional hybrid pigs (CON). The left and right hams from KKP were trimmed according to "*Kraški pršut*" (K) and "*Istrski pršut*" (I), respectively, while the hams from CON were trimmed as "*Kraški pršut*", yielding 8 hams per treatment (K-KKP, I-KKP, K-CON). After processing, the samples of dry-cured hams (part with biceps femoris, semimembranosus and semitendinosus muscles) were collected and analysed for chemical composition, texture, sensory analysis and volatile profile. Dry-cured hams of local breed (K-KKP) had lower dehydration loss (due to thicker fat cover), moisture content and a_w, softer and more plastic texture, with sensory analysis showing more marbling, softer, pastier texture, more pronounced herbal aroma and sweetness than K-CON. Trimming type was associated with higher dehydration loss (due to removed skin), lower moisture content and a_w, higher salt content and harder texture, with sensory analysis showing more marbling, more surface moisture and herbal odour, harder and pastier texture, and sweeter and less bitter taste in I-KKP than K-KKP. The analysis of volatile compounds clearly distinguished the types of dry-cured hams, with each exhibiting a unique volatile profile that enabled differentiation based on breed or trimming. Overall, the study highlights some advantages of dry-cured ham from local pig breeds and shows how trimming affects product's characteristics.

1. Introduction

Dry-cured ham is one of the most appreciated traditional meat products, highly valued by European consumers (Flores, 1997; Font-i-Furnols & Guerrero, 2014). However, its characteristic quality properties are mainly related to two main factors, the raw material quality and the processing methods (Čandek-Potokar & Škrlep, 2011; Toldrá & Flores, 1998). Similarly, production rules for different traditional dry-cured hams vary based on requirements for the origin and properties of raw hams, trimming and shaping, and processing conditions. The rules of processing into various traditional products foresee the use of specific pig genotypes and processing methods to obtain hams with the desired quality traits. Traditional dry-cured hams from the Mediterranean region, which are geographically protected, include the Slovenian dry-cured ham "*Kraški pršut*" and "*Istrski pršut*" (later is jointly protected by Croatia and Slovenia). Both are protected according to EU legislation (Commission Implementing Regulation (EU), 2012; Commission Implementing Regulation (EU), 2015). In both types, dry salting, no smoking and no additives are prescribed, but the rules regarding the raw material and ham trimming are different. In the case of "*Kraški pršut*", the origin of hams is not prescribed and the skin (and subcutaneous fat) is typically retained. On the other hand for "*Istrski pršut*" the origin and pig weight are prescribed and the skin above the knee joint with some subcutaneous fat is partially removed at trimming (Božac et al., 2011). Currently, for both products ("*Kraški pršut*" and "*Istrski pršut*") hams of modern breeds and hybrids are used. However, as products from local breeds are becoming increasingly popular with consumers, there is a growing interest in developing the products using raw hams from local pig breeds. The *"Krškopolje pig"* (KKP) breed, the Slovenian local breed, as well as other local pig breeds, are valued for higher fat content, in

* Corresponding author at: Agricultural Institute of Slovenia, Hacquetova ulica 17, 1000 Ljubljana, Slovenia.
E-mail address: meta.candek-potokar@kis.si (M. Čandek-Potokar).

https://doi.org/10.1016/j.meatsci.2025.109762
Received 26 November 2024; Received in revised form 10 January 2025; Accepted 27 January 2025
Available online 28 January 2025

Table 1
Raw ham properties, processing ham weight loss and salt intake.

Trait	K-CON	K-KKP	I-KKP	[1]K-KKP-K-CON	[1]K-KKP-I-KKP
SM muscle pHu	5.61 ± 0.04	5.56 ± 0.02	5.60 ± 0.03	−0.05	−0.04
Fat thickness, mm	28.6 ± 1.2	41.2 ± 3.3	27.5 ± 4.5	12.6**	13.7*
Trimmed ham weight, kg	15.9 ± 0.3	15.9 ± 0.5	14.0 ± 0.5	0.0	1.9*
Salting loss, %	3.1 ± 0.1	1.6 ± 0.1	1.6 ± 0.1	−1.5***	0.0
Processing loss, %	36.7 ± 0.6	29.6 ± 0.5	34.2 ± 0.5	−7.1***	−4.6***
Salt intake[2], kg	0.67 ± 0.02	0.64 ± 0.03	0.70 ± 0.02	−0.03	−0.06

SM = *semimembranosus muscle*; SM pHu = ultimate pH of SM; K-CON = "*Kraški pršut*" from conventional pig hybrid; K-KKP = "*Kraški pršut*" from local pig breed; I-KKP = "*Istrski pršut*" from local pig breed.

[1] Significance of differences (*t*-test) NS > 0.05; * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$. All values are reported as the mean ± standard error (SE). $N = 8$ per treatment group.

[2] Salt intake relative to the ham (4.2 %, 4.0 % and 5.0 % for K-CON, K-KKP, I-KKP, respectively).

particular higher intramuscular fat (IMF), distinctive fatty acid profiles and meat quality (Čandek-Potokar, & Nieto, R. (Eds.)., 2019), which are the characteristics that contribute to the desirable sensory quality of dry-cured hams (Toldrá & Flores, 1998). However, the studies published so far on "*Kraški pršut*" or "*Istrski pršut*" are rare and were only made with raw hams harvested from modern, conventional breeds and crossbreeds. In addition, the *"Krškopolje pig"* has not yet been studied with respect to its aptitude for processing and quality of dry-cured hams.

The aim of this study was therefore twofold: firstly, to compare the quality of dry-cured ham produced from the local and conventional pig breed (i.e. comparison of the fatty *"Krškopolje pig"* with the conventional hybrid pigs of heavy weight), and secondly, to evaluate which of the two trimming methods would be more suitable for the hams of *"Krškopolje pig"*.

2. Material and methods

2.1. Ham processing

For this study, raw hams of similar weight (15.9 kg; Table 1) were harvested from local breed *"Krškopolje pig"* (8 pigs, 16 hams) and from crossbred pigs of the Landrace × Large White (8 pigs, 8 hams). The Krškopolje pig hams were sourced from a pool of 26 hams (13 pigs), from 4 unrelated Krškopolje boars. For the conventional hybrid group, the hams were selected from a pool of over 100 carcasses. This pool of hams was sufficiently large to allow careful selection, so that one ham was taken per carcass and sire while also controlling for ham weight. All the hams were processed to dry-cured ham in the same batch in cooperation with a local meat processor. In the case of local breed, the right hams were trimmed and shaped according to the rules of "*Kraški pršut*" (group K-KKP, $n = 8$) while left hams were trimmed and shaped according to rules of "*Istrski pršut*" (group I-KKP, n = 8). The difference in the trimming method (Fig. 1) is that in K-KKP the skin and subcutaneous fat are kept, whereas in I-KKP the skin is removed resulting in a lower yield of shaping and trimming and lower weight of the trimmed ham (detailed description is given in Supplementary Table S1). The hams from conventional crossbred pigs were also shaped and trimmed according to PGI "*Kraški pršut*" method (group K-CON, $n = 8$). Before

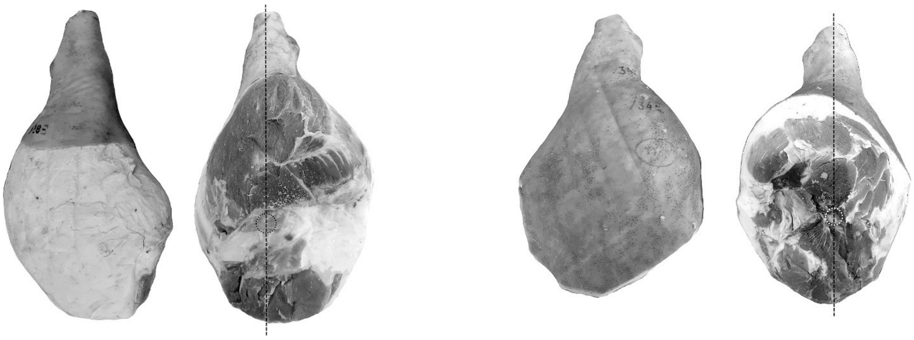


Fig. 1. Presentation of the trimming in "Istrski" (left) and "Kraški" pršut (right). The medial axis of the ham, including the location of the *ossis caput femoris*, is indicated by the dotted circle/line.

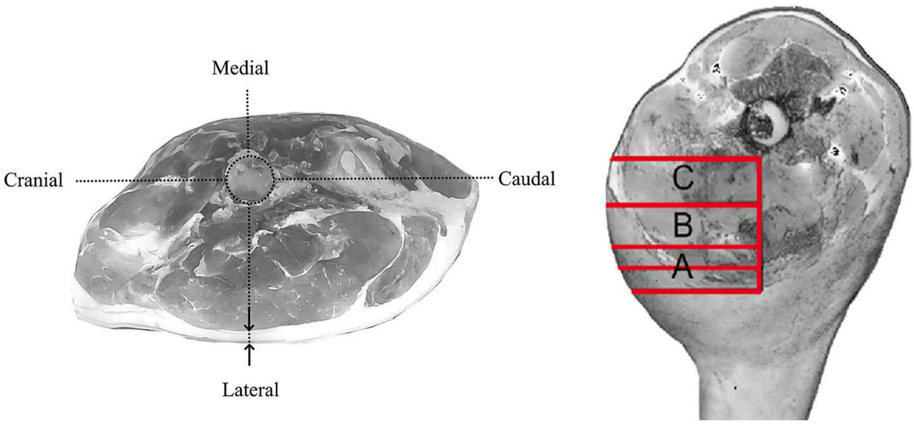


Fig. 2. Location on the green ham for fat thickness measurement (left) and sampling sites on dry-cured ham for instrumental (A), sensory (B), and physico-chemical (C) analyses (right). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

salting, the hams were weighed, the thickness of subcutaneous fat measured (location is depicted in Fig. 2) and the pH value in the SM muscle measured using an MP120 pH meter (Mettler-Toledo GmbH, Schwarzenbach, Switzerland), which was previously calibrated at pH 4.0 and 7.0. The instrument is equipped with automatic temperature compensation, which adjusts readings to maintain accuracy across a range of temperatures. The processing of the ham consisted of salting, resting, drying and ripening phases, in total the processing duration was approximately two years. Only salt was used for curing, no other additives were added. The salting phase lasted 14 days at 2–4 °C. On average, 0.6 kg of salt per ham was used in the initial salting and 0.4 kg in the second salting. The salt was applied in excess, and the salt uptake was estimated based on weight difference (Table 1). After salting the hams were washed and left to rest at 4–6 °C and 70–85 % relative humidity (RH) for 112 days. After the resting period, the hams were stored at 14–20 °C, 60–80 % RH for drying and ripening for 495 days. The total processing lasted 621 days. At the end of each processing stage, the hams were weighed individually to monitor processing losses. After processing, the hams were deboned and samples (consisting of *semimembranosus* (SM), *semitendinosus* (ST) and *biceps femoris* (BF) muscles covered by subcutaneous fat) were taken from the middle part of the ham as previously described (Škrlep et al., 2012). For the subsequent analyses, the sample was divided into three portions (Fig. 2) for the physico-chemical analysis (colour, chemical composition, volatile compounds, a 3 cm thick piece), instrumental texture (a 3 cm thick piece) and sensory analysis (a 5 cm thick piece).

2.2. Physico-chemical traits of dry-cured ham muscles

2.2.1. Colour measurements

Colour assessment was conducted in triplicate on the freshly cut surface of the muscles (immediately after exposing the muscle surface to the air) and the subcutaneous fat layer. A hand-held Minolta Chroma Meter CR-300 (Minolta Co. Ltd., Osaka, Japan) with the standard illuminant D65, standard observer of 2° and an 8 mm measuring area was used to assess colour traits (CIE L*, a*, b*). In addition, the values for chroma (C*) and hue angle (h°) were determined as the square root of (a*2 + b*2) and tan−1(b*/a*), respectively and the total colour difference between K-KKP vs K-CON and K-KKP vs I-KKP was calculated as $\Delta E^*ab = \left[(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2\right]^{1/2}$

2.2.2. Chemical analyses

The SM and BF muscle samples were cleaned of superficial fat and ground in liquid nitrogen using a laboratory mill (Grindomix GM200, Retsch GmbH and Co., Haan, Germany). Water, IMF and protein content were determined with near-infrared spectroscopy (NIR Systems 6500 Monochromator, Foss NIR System, Silver Spring, MD, USA) using the internal calibrations developed in our laboratory (see Supplementary Table S2 for calibration parameters). Total nitrogen content was obtained according to the Kjeldahl method (ISO 5983-2, 2005) using 1 g minced sample, cooper catalyst and sulfuric acid. The non-protein nitrogen (NPN) was determined according to Škrlep et al. (2012). Briefly, 2.5 g minced of sample was homogenized in 25 ml deionized water and centrifuged, then 10 ml of 20 % trichloreacetic acid was added and the mix was stirred well and left to stabilize for 60 min at room temperature. Thereafter it was centrifuged at 3000 rounds/min during 10 min at room temperature. After centrifugation, the supernatant was filtered, and 15 ml of filtrate were used for determination of NPN content using the Kjeldahl method (ISO 5983-2, 2005). Proteolysis index (PI) was calculated as the ratio of non-protein nitrogen to total nitrogen expressed as %. Salt (as chloride) content was determined according to the ISO 1841-1 (Volhard titration) and results are reported as % NaCl. The water activity (a_w) was determined using the Aqua LAB 4TE apparatus (Decagon Devices Inc., Pullman, WA, USA). Degree of lipid oxidation was assessed as thiobarbituric acid reactive substances (TBARS) as described in Marušić Radovčić et al. (2021). The results were expressed as mg malonaldehyde (MDA) / kg sample.

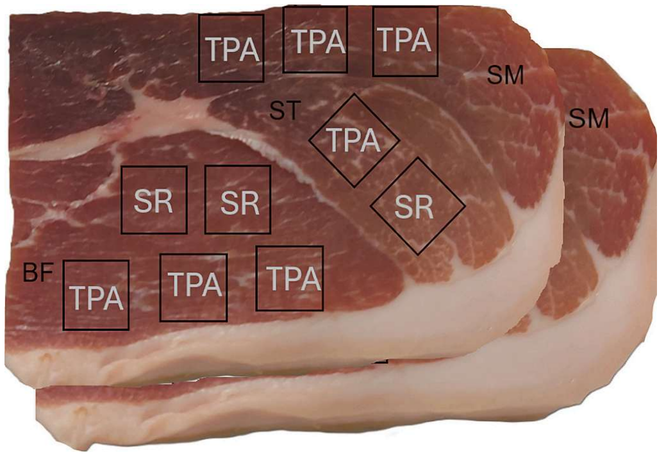


Fig. 3. A cross-section of dry-cured ham sample with designated muscles (BF-*m.biceps femoris*, SM-*m.semimembranosus*, ST-*m.semitendinosus*) and locations of instrumental texture measurements on parallelepiped subsamples (20 mm × 20 mm × 15 mm). Two 1.5 cm thick slices were used for TPA (texture profile analysis) and SR (stress-relaxation) test.

2.2.3. Texture profile analysis

Instrumental texture analysis was conducted on the SM, BF, and ST muscles as described in our previous publications (Pugliese et al., 2015; Škrlep et al., 2012). Briefly, two 1.5 cm thick slices (Fig. 2) of sample were cut, muscles trimmed of fat and cut into parallelepiped subsamples (20 mm × 20 mm × 15 mm), resulting in 10 cubes of BF, 6 cubes of SM and 4 cubes of ST. Three cubes of SM, BF and one for ST were used for Texture Profile Analysis (TPA) and two cubes of BF, one for ST were used for Stress Relaxation (SR) tests (Fig. 3). The tests were performed with a texture analyser (Ametek Lloyd Instruments, Ltd., Bognor Regis, UK) equipped with a 50 kg load cell and a 50 mm diameter compression plate. For the SR test, the samples were compressed perpendicularly to the fibre-bundle direction to 25 % of their initial height at a crosshead speed of 1 mm/s. For the TPA test, the samples underwent two compressions to 50 % of their original height at a crosshead speed of 1 mm/s. The following parameters were then calculated: hardness (N), cohesiveness, gumminess (N), springiness (mm), chewiness (N), and adhesiveness (N*mm).

2.3. Sensory analysis

The sensory analysis was conducted by an accredited laboratory with a panel of 8 authorized assessors previously trained in accordance with standard ISO 11132 (2012). Each sample was tasted in two rounds. The samples of the three groups were distributed evenly across sessions. The following sensory attributes were assessed on a dry-cured ham slice including 1 cm subcutaneous adipose tissue: odour of fresh meat, spicy, herbal, colour intensity of muscle and fat, surface moisture, colour homogeneity, visual quantity of IMF (marbling), saltiness, sweetness, sourness, bitterness, hardness, solubility and pastiness (Supplementary Table S3). Each attribute was evaluated on a 10 cm non-structured linear scale with increasing intensity of perception (0 = complete absent, 10 = maximum perception).

In addition, a hedonic sensory test was conducted with 102 consumers (42 males and 53 females, average age of 47 years). Consumers were asked to taste the products and i) rate their liking on a 5-point Likert scale (from "strongly dislike" to "strongly like and a neutral option "neither like nor dislike"), and ii) select all the attributes they found applicable to the sample using the so-called "Check-All-That-Apply" (CATA) method (Ares & Varela, 2014). In CATA analysis, participants are asked to select attributes from a provided list that they perceived while tasting the product. These attributes can include sensory, hedonic, and emotional responses (Ares & Varela, 2014). The attributes used in the CATA (hard, soft, soluble, crumbly, dry, raw, mature, salty, non-salty, sweet, fatty, lean, juicy, aromatic, tasty, unpleasant taste) were tested and selected together with the personnel from the consortium of dry-cured ham. Informed consent was obtained from all the participants prior to their involvement in the sensory testing.

2.4. Volatile compounds analysis

The volatile organic compounds (VOCs) were analysed by gas chromatography with mass spectrometry (GC–MS) according to Marušić et al. (2011) separately for BF and SM, as follows: a solid phase micro-extraction (SPME) and the identification and quantification of compounds was performed on GC/MS. For sample preparation, 5 g of minced BF or SM muscle was mixed with 25 ml of distilled water saturated with NaCl. A 10 ml portion was transferred to 20 ml vials, to which 100 μL of 4-methyl-2-pentanol (1.2 mg/kg) (internal standard) was added together with a magnetic stirrer, and then sealed with a PTFE septum. An SPME fibre coated with 2 cm of 50/30 μm DVB/Carboxen/PDMS (Supelco, Bellefonte, PA, USA) previously heated at 240 °C for 5 min was placed over the sample mixture. Extraction of volatile compounds in the 20-ml vials was conducted at 40 °C for 180 min with constant stirring. Following extraction, the SPME fibre was transferred to the injection port of the 6890 N gas chromatograph coupled to a 5975i mass selective detector (Agilent Technologies, Santa Clara, CA, USA). Helium was used as the carrier gas with a constant flow rate of 1 ml/min. The separation of volatile compounds utilized a ZB-5MS capillary column (30 m × 0.25 mm, film thickness 0.25 μm (Phenomenex, USA). Injection was performed in splitless mode, with an injector temperature of 230 °C and desorption time of 5 min. The chromatographic conditions were as follows: The initial temperature was set at 40 °C for 10 min, followed by an increase to 200 °C at a rate of 5 °C /min, then to 250 °C at a rate of 20 °C/min. The final temperature was maintained for 5 min, and the transfer line temperature was held at 280 °C. Mass spectra were recorded at 70 eV with a scanning rate of 1 scan/s across the m/z range of 50–450. Retention indices (RI) of the detected compounds were calculated using an in-house mixture of C8-C20 n-alkanes under the same chromatographic conditions. Identification of the compounds was performed using the NIST 2005 version 2.0 spectral library (NIST, Gaithersburg, MD, USA), and comparisons were made with literature values and in-house library based on retention indices.

2.5. Statistical analysis

Descriptive statistics (mean ± standard error) were calculated and independent samples *t*-test performed to evaluate significance of differences between treatment groups i) K-KKP vs. K-CON hams (effect of breed) and ii) K-KKP vs. I-KKP hams (effect of trimming method or dry-cured ham type). Fischer's Exact test was used to compare the results of CATA. Principal component analysis (PCA) was conducted to compare the volatile profiles of dry-cured hams relative to breed or trimming method; for PCA we used FactoMineR (Husson et al., 2023) and factoextra package (Kassambara & Mundt, 2023) of R statistical software version 4.3.2 (R Core Team, 2023). A PCA biplot based on VOCs (with loading values >0.5) was used to illustrate the separation between K-KKP vs. K-CON (based on 119 VOCs) and K-KKP vs. I-KKP (based on 135 VOCs) dry-cured hams. Descriptive statistics, *t*-tests and Fischer's Exact test were performed using statistical package SPPS version 28.0.0 (IBM Corp, 2021) and the level of significance was considered at *P*-value<0.05.

Table 2
Colour measurements of dry-cured ham.

Trait	K-CON	K-KKP	I-KKP	[1]K-KKP-K-CON	[1]K-KKP-I-KKP
SM					
CIE *L**	34.4 ± 0.8	34.0 ± 0.7	32.9 ± 0.7	−0.4	1.1
CIE *a**	13.1 ± 0.2	16.1 ± 0.6	14.4 ± 0.4	3.0 ***	1.7 *
CIE *b**	10.2 ± 0.3	9.2 ± 0.3	9.8 ± 0.5	−1.0 *	−0.6
c*	16.6 ± 0.3	18.6 ± 0.6	17.4 ± 0.5	2.0 **	1.2
H°	37.9 ± 0.9	29.9 ± 1.4	34.3 ± 1.1	−8.0 ***	−4.4 *
ST					
CIE *L**	40.2 ± 0.8	41.3 ± 0.9	39.5 ± 0.9	1.1	1.8
CIE *a**	12.6 ± 0.4	16.3 ± 0.7	15.7 ± 0.7	3.7 ***	0.6
CIE *b**	10.5 ± 0.6	9.9 ± 0.5	11.0 ± 0.2	−0.6	−1.1 *
c*	16.4 ± 0.5	19.1 ± 0.5	19.2 ± 0.5	2.7 **	−0.1
H°	39.7 ± 1.8	31.5 ± 2.1	35.3 ± 1.6	−8.2 *	−3.8
BF					
CIE *L**	38.4 ± 0.3	38.3 ± 0.4	36.0 ± 1.0	−0.1	2.3
CIE *a**	16.9 ± 0.4	19.2 ± 0.7	17.8 ± 0.7	2.3 **	1.4
CIE *b**	7.6 ± 0.2	7.1 ± 0.2	8.3 ± 0.3	−0.5	−1.2 **
c*	18.5 ± 0.3	20.5 ± 0.6	19.7 ± 0.7	2.0 **	0.8
H°	24.2 ± 1.0	20.5 ± 1.0	25.2 ± 1.3	−3.7 *	−4.7 **
FAT					
FAT *L**	76.2 ± 0.3	76.8 ± 0.5	72.5 ± 0.6	0.6	4.3 ***
FAT *a**	2.9 ± 0.2	1.9 ± 0.4	3.2 ± 0.5	−1.0 *	−1.3 *
FAT *b**	7.0 ± 0.3	6.6 ± 0.2	9.0 ± 0.5	−0.4	−2.4 ***
c*	7.5 ± 0.3	6.9 ± 0.2	9.7 ± 0.4	−0.6	−2.8 ***
H°	67.4 ± 1.8	74.2 ± 2.6	70.1 ± 3.5	6.8 *	4.1

SM = *semimembranosus muscle*; ST = *semitendinosus muscle*; BF = *biceps femoris muscle*. *L** = lightness; *a** = redness; *b** = yellowness; c* = chroma/saturation; H° = hue; K-CON = "*Kraški pršut*" from conventional pig hybrid; K-KKP = "*Kraški pršut*" from local pig breed; I-KKP = "*Istrski pršut*" from local pig breed.

[1] Significance of differences (t-test) NS > 0.05; * P < 0.05; ** P < 0.01; *** P < 0.001. All values are reported as the mean ± standard error (SE). N = 8 per treatment group.

3. Results

3.1. Raw ham properties and ham processing losses

The characteristics of raw hams were measured in order to monitor the differences in raw material i.e. the aptitude for processing since they are important for the process of dehydration, salt intake and consequently biochemical changes (Čandek-Potokar & Škrlep, 2011). Considering the breed effect (K-KKP vs. K-CON), raw hams entering the processing were equal in terms of weight while they were different in terms of fat thickness. Hams from local breed had thicker subcutaneous fat cover (Table 1). On the other hand, trimming and shaping of raw hams of local breed (left and right ham of the same animal) resulted in differences of weight and fat thickness. No differences in pH value of SM muscle were noted between treatment groups.

During processing weight of hams were monitored to assess the processing yields (presented as % weight loss) and salt intake (Table 1). Both breed and trimming method significantly affected the yields, while estimated salt intake was not statistically significant. Lower processing losses i.e. higher yields (salting, resting and ripening) were observed for hams of local breed (K-KKP) than hams of conventional modern cross-breed (K-CON). K-KKP hams exhibited lower weight losses (higher yields) than I-KKP hams which are more open after trimming and shaping. Salt intake, on the other hand was not significantly affected by either breed or trimming.

3.2. Physico-chemical traits of dry-cured ham muscles

3.2.1. Colour measurements

With regard to breed effect, the instrumental colour values of all three examined muscles (Table 2) showed higher a* and c* values in K-KKP than in K-CON hams denoting a redder and more saturated colour of hams from local breed. On the other hand, a higher b* value was noted

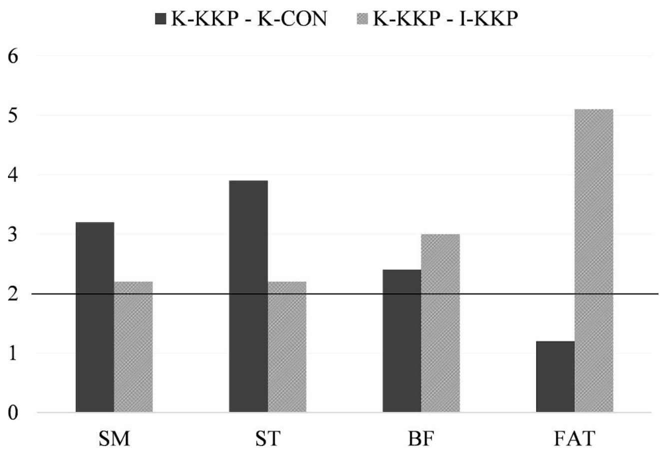


Fig. 4. Colour differences (E*ab) of muscles and fat between treatment groups (K-CON = "Kraški pršut" from conventional pig hybrid; K-KKP = "Kraški pršut" from local pig breed; I-KKP = "Istrski pršut" from local pig breed).

Table 3
Chemical properties of dry-cured hams.

Trait	K-CON	K-KKP	I-KKP	[1]K-KKP- K-CON	[1]K-KKP- I-KKP
SM					
Water, g/kg	434.5 ± 3.7	470.4 ± 6.7	435.9 ± 8.5	35.9 ***	34.5 **
IMF, g/kg	45.6 ± 2.0	48.2 ± 2.1	52.5 ± 2.7	2.6	−4.3
Proteins, g/kg	446.9 ± 2.9	409.9 ± 6.1	428.3 ± 7.5	−37.0 ***	−18.4
PI, %	18.1 ± 0.3	20.4 ± 1.2	18.2 ± 0.5	2.3	2.2
Salt, %	5.5 ± 0.1	5.7 ± 0.3	7.6 ± 0.2	0.2	−1.9 ***
Salt in dry matter (%)	9.8 ± 0.2	10.8 ± 0.5	13.5 ± 0.2	1.0	−2.7 ***
a_W	0.859 ± 0.005	0.875 ± 0.005	0.824 ± 0.012	0.016 *	0.051 **
TBARS, μg MDA/kg	0.58 ± 0.02	0.64 ± 0.03	0.74 ± 0.03	0.06	−0.11 *
BF					
Water, g/kg	546.8 ± 5.1	574.6 ± 5.0	521.2 ± 8.5	27.7 **	53.4 ***
IMF, g/kg	36.5 ± 1.6	38.5 ± 2.6	43.0 ± 3.0	2.0	−4.5
Proteins, g/kg	312.3 ± 2.4	290.7 ± 2.4	322.9 ± 5.6	−21.6 ***	−32.2 ***
PI, %	28.6 ± 0.5	27.0 ± 1.4	25.3 ± 0.9	−1.5	1.8
Salt, %	6.2 ± 0.2	6.4 ± 0.2	8.4 ± 0.2	0.2	−2.0 ***
Salt in dry matter (%)	13.7 ± 0.5	15.0 ± 0.6	17.6 ± 0.2	1.3	−2.7 ***
a_W	0.870 ± 0.004	0.884 ± 0.006	0.838 ± 0.009	0.014	0.046 ***
TBARS, μg MDA/kg	0.57 ± 0.02	0.45 ± 0.03	0.74 ± 0.02	−0.11*	−0.29***

SM = *semimembranosus muscle;* BF = *biceps femoris muscle*; IMF = intramuscular fat; PI = index of proteolysis; a_W = water activity; TBARS = thiobarbituric acid reactive substances; MDA = malondialdehyde.
K-CON = "*Kraški pršut*" from conventional pig hybrid; K-KKP = "*Kraški pršut*" from local pig breed; I-KKP = "*Istrski pršut*" from local pig breed.
[1] Significance of differences (*t*-test) NS > 0.05; * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$. All values are reported as the mean ± standard error (SE). N = 8 per treatment group.

for superficial SM muscle in dry-cured hams of K-CON than K-KKP denoting a more yellowish colour of modern crossbreed. Subcutaneous fat of K-KKP had higher a* and H° parameters, denoting a redder fat colour taint in hams from local breed. With regard to trimming method effect, differences noted for b* and H° parameters in muscle SM, b* in ST, and b* and H° parameters in BF indicate a less yellowish colour of K-KKP than I-KKP dry-hams which had more open structure. In addition, a significant effect on colour parameters of fat (except for H) denotes also a whiter, and less yellowish fat colour in K-KKP. To assess the impact of breed and trimming on the colour of dry-cured ham, the L*, a*, and b* parameters (Table 2) were used to calculate the total colour difference (E*ab) (Fig. 4). Overall, both breed and trimming methods had a significant impact on the colour of dry-cured ham, resulting in important degree of differences, as indicated by E*ab values greater than 2.0 (Francis & Clydesdale, 1975; Fig. 4). The degree of colour difference in the lean part was greater between breeds than between product types, while the degree of colour difference in the fat was greater between product types (trimming effect), with breed-related differences falling below the visible difference threshold.

Table 4
Instrumental texture profile of dry-cured hams.

Trait	K-CON	K-KKP	I-KKP	[1]K-KKP- K-CON	[1]K-KKP- I-KKP
SM					
Hardness, N	272.9 ± 8.5	165.3 ± 20.7	264.4 ± 22.5	−107.6***	−99.1**
Cohesiveness	0.506 ± 0.017	0.589 ± 0.027	0.509 ± 0.014	0.083 *	0.080*
Gumminess, N	137.6 ± 5.4	94.1 ± 9.3	132.9 ± 10.2	−43.5***	−38.8*
Springiness, mm	5.3 ± 0.2	5.3 ± 0.2	5.1 ± 0.2	0.0	0.2
Chewiness, N	728.0 ± 37.3	499.4 ± 46.2	689.2 ± 68.1	−228.6**	−189.8*
Adhesiveness, N*mm	−0.09 ± 0.03	−0.53 ± 0.13	−0.37 ± 0.15	−0.44**	−0.16
ST					
Hardness, N	79.3 ± 5.0	51.3 ± 3.1	96.7 ± 6.8	−28.0***	−45.4***
Cohesiveness	0.636 ± 0.022	0.471 ± 0.021	0.531 ± 0.022	−0.165***	−0.060
Gumminess, N	50.8 ± 4.4	24.4 ± 2.3	51.7 ± 4.5	−26.4***	−27.3***
Springiness, mm	5.3 ± 0.1	4.3 ± 0.2	5.0 ± 0.2	−1.0***	−0.7*
Chewiness, N	274.1 ± 27.6	107.7 ± 13.6	261.8 ± 30.5	−166.4***	−154.1***
Adhesiveness, N*mm	−1.74 ± 0.13	−1.53 ± 0.24	−0.97 ± 0.30	0.21	−0.56
Y90	0.609 ± 0.005	0.633 ± 0.011	0.586 ± 0.006	0.024	0.047**
BF					
Hardness, N	95.3 ± 6.0	72.9 ± 9.0	108.2 ± 4.7	−22.4	−35.3**
Cohesiveness	0.806 ± 0.026	0.719 ± 0.019	0.726 ± 0.030	−0.087*	−0.007
Gumminess, N	76.1 ± 5.6	53.0 ± 7.3	78.4 ± 5.5	−23.1*	−25.4*
Springiness, mm	5.3 ± 0.2	5.0 ± 0.2	5.4 ± 0.2	−0.3	−0.4
Chewiness, N	402.3 ± 33.2	264.6 ± 40.3	425.3 ± 43.9	−137.7*	−160.7*
Adhesiveness, N*mm	−1.07 ± 0.12	−1.65 ± 0.13	−0.56 ± 0.14	−0.58**	−1.09***
Y90	0.618 ± 0.008	0.645 ± 0.006	0.586 ± 0.007	0.027*	0.059***

SM = *semimembranosus muscle;* ST = *semitendinosus muscle*; BF = *biceps femoris muscle;* Y90 = stress relaxation test. K-CON = "*Kraški pršut*" from conventional pig hybrid; K-KKP = "*Kraški pršut*" from local pig breed; I-KKP = "*Istrski pršut*" from local pig breed.
[1] Significance of differences (t-test) NS > 0.05; * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$. All values are reported as the mean ± standard error (SE). N = 8 per treatment group.

3.2.2. Chemical analyses

Chemical properties of the dry-cured ham (Table 3) were also influenced by breed and trimming mode. Considering the effect of breed,

Table 5
Sensory analysis of dry-cured ham.

Whole ham slice	K-CON	K-KKP	I-KKP	[1]K-KKP- K-CON	[1]K-KKP-I-KKP
Expert panel (1–10)					
Fresh meat odour	3.6 ± 0.2	4.2 ± 0.3	3.5 ± 0.2	0.6	0.7
Spicy	1.5 ± 0.3	2.6 ± 0.7	1.7 ± 0.3	1.1	0.9
Herbal	2.4 ± 0.4	3.1 ± 0.3	1.6 ± 0.3	0.7	1.5**
Colour intensity of muscle	5.0 ± 0.1	6.0 ± 0.2	5.9 ± 0.1	1.0***	0.1
Colour intensity of ham fat	6.1 ± 0.3	5.7 ± 0.5	6.3 ± 0.1	−0.4	−0.6
Colour homogeneity	4.1 ± 0.2	4.4 ± 0.4	4.1 ± 0.4	0.3	0.3
Marbling	4.5 ± 0.2	6.0 ± 0.3	4.4 ± 0.3	1.5***	1.6***
Surface moisture	3.3 ± 0.2	4.3 ± 0.2	3.7 ± 0.2	1.0***	0.6 *
Saltiness	4.5 ± 0.1	3.8 ± 0.4	4.6 ± 0.3	−0.7	−0.8
Sweetness	1.7 ± 0.2	2.9 ± 0.2	2.0 ± 0.2	1.2***	0.9 *
Sourness	1.5 ± 0.2	1.4 ± 0.2	2.4 ± 0.5	−0.1	−1.0
Bitterness	2.1 ± 0.3	2.3 ± 0.3	3.1 ± 0.2	0.2	−0.8 *
Hardness	5.2 ± 0.2	3.6 ± 0.4	4.6 ± 0.2	−1.6**	−1.0 *
Solubility	4.7 ± 0.3	5.5 ± 0.5	4.6 ± 0.3	0.8	0.9
Pastiness	2.4 ± 0.3	3.3 ± 0.2	2.4 ± 0.2	0.9*	0.9 **
Consumer test (1–5)					
Overall liking	4.2 ± 0.1	4.4 ± 0.2	4.1 ± 0.1	0.2	0.3

K-CON = "*Kraški pršut*" from conventional pig hybrid; K-KKP = "*Kraški pršut*" from local pig breed; I-KKP = "*Istrski pršut*" from local pig breed. Overall liking = Five-point Likert scale (1 "strongly dislike", 2 "dislike", 3 "neither like nor dislike", 4 "like" to 5 "strongly like").

[1] Significance of differences (t-test) NS > 0.05; * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$. All values are reported as the mean ± standard error (SE). N = 8 per treatment group.

in BF and SM muscles, K-KKP exhibited higher water and protein content and higher water activity than K-CON hams, in line with their higher processing yield. No significant effect could be noted on salt content and proteolysis index. As for the trimming effect, higher water content and water activity found in K-KKP than I-KKP (SM and BF) are in line with higher yields of processing. Contrary to breed effect, trimming mode exerted an effect on salt, resulting in a lower salt content in K-KKP than I-KKP either expressed as salt % in sample or in dry matter. However, in spite of that, no differences were noted for proteolysis index due to trimming mode. Oxidation status assessed as TBARS, showed a lower oxidation in K-KKP than K-CON hams, but only in BF. The effect of trimming was more important and showed lesser degree of oxidation in BF and SM of K-KKP than I-KKP hams.

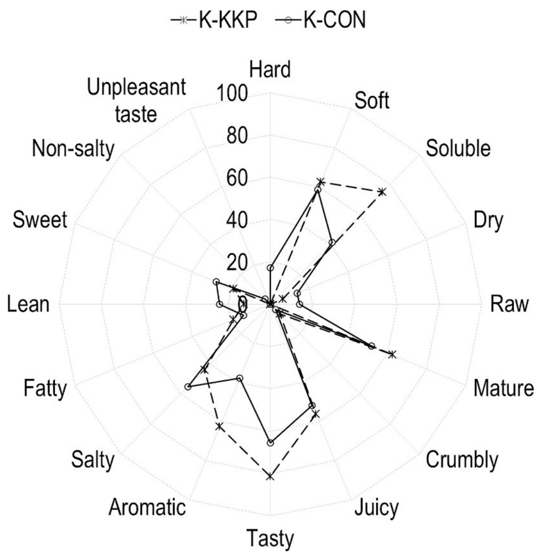
3.2.3. Texture profile analysis

The results of the TPA and SR tests for dry-cured ham muscles indicate that both breed and trimming method had a significant effect on most of the texture measurements (Table 4). With regard to breed effect, dry-cured hams of K-KKP had less hard (SM, BF, ST), less cohesive (ST, BF), less gummy (SM, BF, ST), less chewy (SM, BF, ST) texture, but were at the same time more adhesive (SM, BF) than K-CON. Stress relaxation coefficient was higher (BF, ST) in K-KKP dry-cured hams. Overall texture measurements indicate significantly softer and more plastic texture of dry-cured hams of local breed compared to conventional crossbreed.

When comparing hams of local breed submitted to different trimming methods, K-KKP group exhibited lower hardness (of SM, BF, ST), gumminess (of SM, BF, ST), and chewiness (of SM, BF, ST), along with higher adhesiveness of BF muscle. Stress relaxation coefficient was also higher (for BF, ST) in K-KKP than I-KKP dry-cured hams. These results indicate a softer and more plastic texture of K-KKP than I-KKP dry-cured hams which have more open structure.

3.3. Sensory analysis

Sensory profile of dry-cured hams was affected to a lesser degree by breed than by trimming mode (Table 5). With regard to visual appearance, dry-cured hams of local breed (K-KKP) received higher scores for colour intensity, marbling and surface moisture. When tasted, they were found sweeter but less hard and pastier. As for the differences related to trimming, the appearance and odour of K-KKP hams were scored higher for marbling, surface moisture, and herbal odour, while when tasted, they were found sweeter and less bitter. With regard to texture, K-KKP



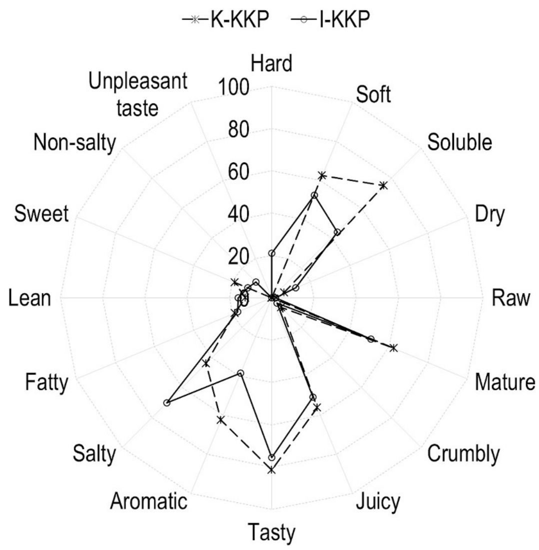


Fig. 5. CATA (Check-all-that-apply) analysis for comparisons K-KKP vs. K-CON and K-KKP vs. I-KKP.
K-CON = "Kraški pršut" from conventional pig hybrid; K-KKP = "Kraški pršut" from local pig breed; I-KKP = "Istrski pršut" from local pig breed.

Table 6
Relative abundance of main groups of VOCs[1] according to treatment.

Volatile compounds	K-CON	K-KKP	I-KKP	[2]K-KKP-K-CON	[2]K-KKP-I-KKP
SM					
Aldehydes	48.54 ± 0.75	53.15 ± 0.81	47.06 ± 1.32	4.61 ***	6.09 **
Alcohols	24.05 ± 0.99	21.44 ± 0.64	20.27 ± 1.00	−2.61 *	1.17
Acids	4.80 ± 0.32	6.59 ± 0.29	5.69 ± 0.25	1.79 ***	0.9 *
Ketones	7.21 ± 0.23	8.27 ± 0.24	9.36 ± 0.21	1.06 **	−1.09 **
Esters	8.60 ± 0.26	3.66 ± 0.12	8.45 ± 0.79	−4.94 ***	−4.79 ***
Aliphatic hydrocarbons	2.93 ± 0.12	3.10 ± 0.12	1.88 ± 0.29	0.17	1.22 **
Aromatic hydrocarbons	0.53 ± 0.05	0.52 ± 0.06	1.50 ± 0.08	−0.01	−0.98 ***
Furans	2.48 ± 0.12	2.31 ± 0.14	4.94 ± 0.34	−0.17	−2.63 ***
Terpenes	0.87 ± 0.06	0.97 ± 0.10	0.83 ± 0.06	0.10	0.14
BF					
Aldehydes	52.14 ± 0.60	54.94 ± 0.61	50.12 ± 0.86	2.8 **	4.82 ***
Alcohols	20.27 ± 0.30	19.50 ± 0.63	17.41 ± 0.51	−0.77	2.09 *
Acids	5.01 ± 0.23	7.73 ± 0.33	9.54 ± 0.52	2.72 ***	−1.81 *
Ketones	7.90 ± 0.24	6.89 ± 0.21	8.68 ± 0.46	−1.01 **	−1.79 **
Esters	4.59 ± 0.14	3.69 ± 0.18	5.20 ± 0.21	−0.9 ***	−1.51 ***
Aliphatic hydrocarbons	6.78 ± 0.32	4.17 ± 0.15	1.68 ± 0.08	−2.61 ***	2.49 ***
Aromatic hydrocarbons	1.03 ± 0.04	0.92 ± 0.06	1.64 ± 0.04	−0.11	−0.72 ***
Furans	1.64 ± 0.09	1.45 ± 0.08	4.88 ± 0.24	−0.19	−3.43 ***
Terpenes	0.64 ± 0.05	0.71 ± 0.05	0.84 ± 0.06	0.07	−0.13

VOCs = the volatile organic compounds; SM = *semimembranosus muscle*; BF = *biceps femoris* muscle.
K-CON = "*Kraški pršut*" from conventional pig hybrid; K-KKP = "*Kraški pršut*" from local pig breed; I-KKP = "*Istrski pršut*" from local pig breed.
[1] for the individual compounds, see the supplementary Table S4 and S5.
[2] Significance of differences (t-test) NS > 0.05; * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$. All values are reported as the mean ± standard error (SE). N = 8 per treatment group.

hams were found less hard, and pastier than I-KKP. Consumer tasting with CATA did not show major differences (Fisher's Exact test $P > 0.05$), between K-KKP and K-CON dry-cured hams. However, based on numeric difference consumers found K-KKP dry-cured hams more frequently as soluble, mature, tasty, aromatic while K-CON more often as hard, salty, lean, sweet, raw and dry (Fig. 5). If comparing K-KKP and I-KKP, "soluble" was the only attribute significantly more frequent in K-KKP. However, based on numeric difference consumers found K-KKP dry-cured hams more frequently as soft, soluble, mature, aromatic, while I-KKP more often as hard and salty (Fig. 5). The overall liking score given by consumers was in average the highest for K-KKP (Table 5), however differences in average score were not significant, a tendency was noted for difference in liking of K-KKP and I-KKP.

3.4. Volatile compounds analysis

In total 176 VOCs (87 in SM and 89 in BF) were identified in dry-cured hams grouped into nine chemical groups: aldehydes, alcohols, acids, ketones, esters, aliphatic hydrocarbons, aromatic hydrocarbons, furans, and terpenes (Table 6, Supplementary Tables S4 and S5). The aldehydes were quantitatively the most important group of VOCs, with 49.6 % and 52.4 % of the relative abundance in SM and BF, respectively. Alcohols were the second must abundant group with 21.9 % and 19.1 % in SM and BF respectively. The relative abundance of other chemical groups was below 10 %. Breed and trimming method both had a strong influence on the volatile profile of the dry-cured ham and many individual VOCs were significantly affected by breed (49 VOCs in SM, 37 VOCs in BF,) or trimming method (41 VOCs in SM, 65 VOCs in BF). Additional PCA analysis showed a clear differentiation of dry-cured hams between K-KKP and K-CON (breed effect) or K-KKP and I-KKP (effect of trimming way) based on the difference in volatile profile (Figs. 6 and 7). The combination of numerous VOCs with similar importance/contribution signifies that aroma profile of dry-cured ham is very complex.

Regarding the effect of the breed, K-KKP hams showed a higher relative abundance of aldehydes, acids and ketones and lower amounts of alcohols and esters in the SM muscle than K-CON hams. In the BF muscle, the K-KKP hams also had a higher abundance of aldehydes and acids and lower amounts of ketones, esters and aliphatic hydrocarbons than the K-CON hams. The PCA shows that even with the same processing conditions, breed differences (K-KKP vs. K-CON) led to different volatile profiles, with numerous VOCs contributing to a similar extent to the differentiation of dry cured ham. A clear differentiation was achieved based on VOCs (loading values <0.5) (Fig. 6).

When comparing the effect of trimming method applied to the same raw material i.e. hams of local KKP breed, higher levels of aldehydes and acids and lower levels of ketones and esters were found in the SM muscle of K-KKP ham than in the SM of I-KKP ham. In the BF muscle, the K-KKP hams had higher levels of aldehydes, alcohols and aliphatic hydrocarbons and lower levels of acids, ketones, esters, aromatic hydrocarbons and furans than I-KKP. The PCA shows a very distinct volatile profile of K-KKP and I-KKP i.e. the same raw material submitted to different trimming method. A clear differentiation was achieved based on VOCs (loading values <0.5) (Fig. 7).

4. Discussion

The properties of raw hams entering the dry curing process, such as intramuscular fat (IMF) content and salt intake, directly influence dehydration dynamics (Čandek-Potokar & Škrlep, 2011) and the final product's quality (Petrova et al., 2015). Research has shown that raw hams from local pig breeds, which have not undergone genetic improvement, differ significantly from those of conventional modern genotypes, particularly in fat tissue content and composition (Poklukar et al., 2020). This distinction was confirmed in our study, where the raw hams of conventional crosses had thinner subcutaneous fat. We used the left and right hams from the same carcass to test the effect of trimming. And, due to the different shaping and trimming, the weight and fat thickness of the raw hams entering the process were different. Fat serves as a barrier to salt diffusion and water evaporation and leaner hams experience more intense dehydration than fatter ones (Čandek-Potokar & Škrlep, 2011). Our results confirmed that hams from local breeds with thicker subcutaneous fat experienced lower overall processing losses. Given the greater fat thickness in hams from local pig breeds and the strong correlation between various fat depots (Wood et al., 2008), it is consistent that hams of local breed had lower salt intake than hams of leaner hybrid pigs, primarily due to the IMF acting as a barrier. During processing, complex biochemical changes occur which determine the final product quality (Čandek-Potokar & Škrlep, 2012). The colour of dry-cured ham is one of the attributes important for consumers and correlated with chemical traits (Pérez-Alvarez et al., 1999). With regard to breed effect, the observed colour differences corroborate with the conclusion of Lebret et al. (2015) that local breeds have redder meat than conventional modern breeds. The effect of the trimming method on the colour of muscle and fat, on the other hand, could be related to greater exposure of tissues that are susceptible to oxidation (Faustman et al., 2010) in line also with higher TBARS in I-KKP. Seasoning losses

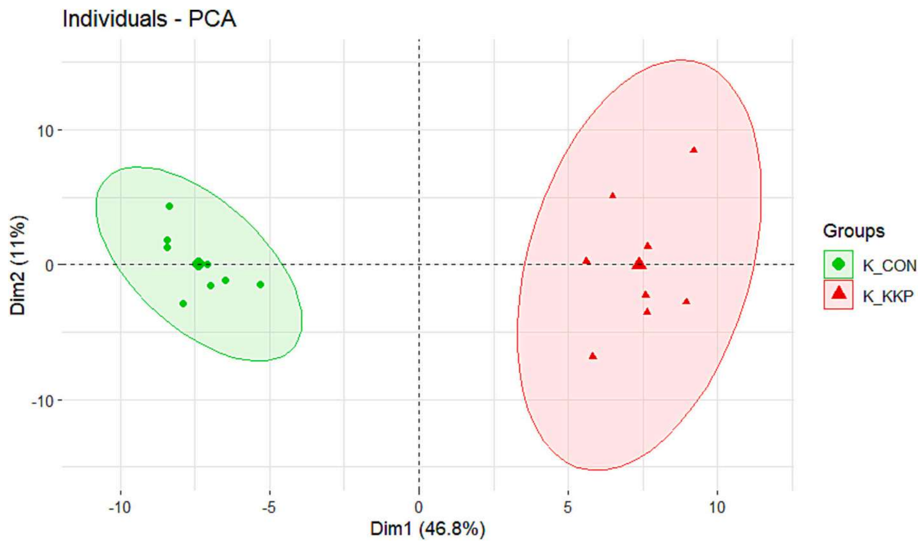


Fig. 6. PCA plot based on volatile organic compounds (loading values>0.5) illustrating the separation of K-KKP and K-CON dry-cured hams. K-CON = "Kraški pršut" from conventional pig hybrid; K-KKP = "Kraški pršut" from local pig breed.

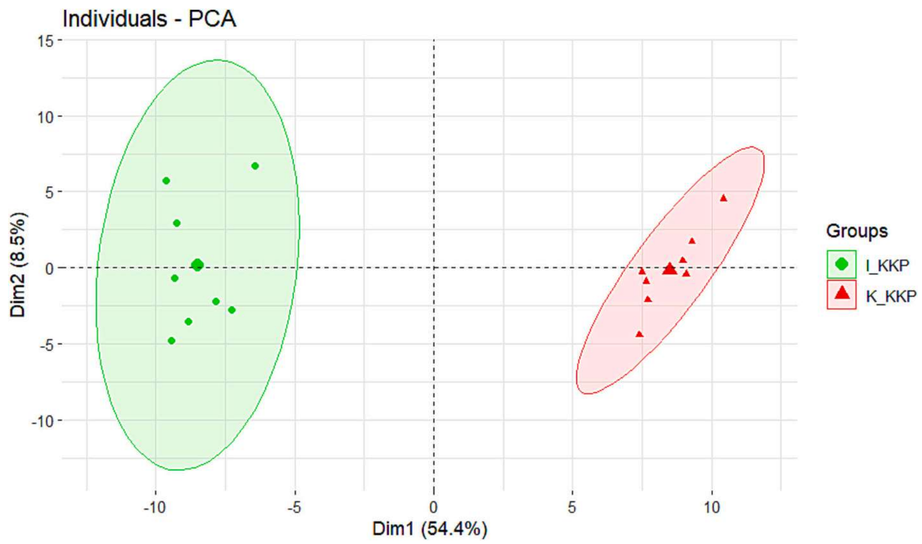


Fig. 7. PCA plot based on volatile organic compounds (loading values>0.5) illustrating the separation of K-KKP and I-KKP dry-cured hams. K-KKP = "Kraški pršut" from local pig breed; I-KKP = "Istrski pršut" from local pig breed.

affect water and salt content, which in turn impacts the texture of the final product (Ruiz-Ramírez et al., 2005). In our study, we observed that water content and a_W values for the treatment groups were consistent with the results of processing losses. Despite similar salt intake in hams of both genotypes and trimming methods, a higher salt content was determined in dry-cured hams trimmed and shaped according to I-KKP. This is attributable to the concentration phenomenon and is consistent with the negative correlation between moisture and salt content (Čandek-Potokar et al., 2002). The proteolysis index, which can be considered as an indicator of texture development (Ruiz-Ramírez et al., 2006) and has been related to salt level (Parolari et al., 1994), was unexpectedly not significantly affected by breed or trimming. Namely, the results of instrumental measurements of texture profile and sensory evaluation of hardness, solubility and pastiness demonstrate differences in dry-cured ham texture that can be related to breed or trimming method. The softer and more plastic texture observed in dry-cured hams from local breed (K-KKP hams) is consistent with many studies (Monin et al., 1997; Ruiz-Ramírez et al., 2005; Serra et al., 2005; Virgili et al., 1995) that show a close relationship between moisture content and texture profile (generally, drier the muscle, the higher its hardness). The results obtained for the instrumentally assessed texture were also confirmed in sensory testing in which K-KKP hams were softer, more soluble and pastier than K-CON (breed effect) or I-KKP (effect of trimming method). Sensory traits play a vital role in determining the overall acceptability of dry-cured ham. Hams from the local breed typically had a sweeter and slightly less salty taste compared to those from the conventional breed, likely due to a higher fat content, which serves as a precursor for aromatic compounds (Toldrá & Flores, 1998). However, when hams from the local breed underwent different (Istrski) trimming, higher number of sensory attributes were affected such as lower herbal scent, lower sweetness and higher bitterness and saltiness ($P < 0.10$). Saltiness is a well-recognized sensory attribute commonly perceived to have an inverse relationship with sweetness (Guàrdia et al., 2010; Petričević et al., 2018; Schivazappa & Virgili, 2020). With regard to bitterness the association with saltiness is less clear. A soft, defective texture as a result of low salt may contribute to the bitter taste of dry-cured ham (Zhou et al., 2019; Zhou et al., 2021). In general, bitterness and saltiness are the dominant taste qualities associated with mineral salts. These tastes involve similar receptors, which may explain the unclear effects on perception, potentially influenced by the concentration of the salts (Sood et al., 2024). Consumer testing provided K-KKP hams with the highest overall liking score and described the product as more soluble, juicy, aromatic, sweeter and less salty than K-CON or I-KKP. Dry-cured ham aroma is primarily due to the presence of volatile organic compounds (VOCs), which are largely produced through lipolysis and proteolysis (Toldrá, 1998). In this study, aldehydes were identified as the most abundant group of VOCs, a finding consistent with the extended aging period (2 years), as aging significantly contributes to aldehyde formation (Moretti et al., 2004). PCA (Figs. 6 and 7) revealed distinct differences in aroma profiles based on breed or trimming method, with the later having a more pronounced effect. This is evidenced by the greater number of VOCs with significantly different relative abundances due to trimming than breed. Regarding the breed effect, hams from the local KKP breed exhibited higher levels of aldehydes, ketones, and acids, suggesting a more intense, complex, and rich aroma. Previous research has shown that VOCs in hams vary among pig breeds due to differences in raw material properties, particularly fat content and its degree of oxidation (Wei et al., 2023),. Sensory analysis indicated a sweeter taste in K-KKP hams. The favourable characteristics of K-KKP hams align with findings from other studies on local breeds, such as the Iberian pig (García et al., 1991) and the Chinese autochthonous black Dahe pig (Wei et al., 2023) and highlight the value of local pig breeds in producing high-quality dry-cured ham. The trimming effect revealed that K-KKP hams had higher aldehyde levels but lower ketone and ester abundances compared to I-KKP hams, potentially contributing to a more complex, fresh, green, and fruity aroma in K-KKP than I-KKP hams. Consistent with the small differences noted in expert sensory analysis, the consumer hedonic test revealed only slight variations between the products, with a modest preference for K-KKP dry-cured hams.

5. Conclusion

To identify the optimal processing method for hams from the local breed, our study compared local and conventional breeds using two different trimming methods. Hams from the local breed, which are characterized by thicker fat and higher fat content, exhibited lower processing losses and produced dry-cured hams with higher moisture content, a softer texture, and a sweeter taste compared to those from the conventional breed. In contrast, hams from the local breed, that were more extensively trimmed (according to "*Istrski pršut*") before processing experienced higher processing losses, resulting in lower moisture content, higher salt levels, and a firmer texture. These hams also had a less sweet, saltier, and more bitter taste, with increased oxidation indicators such as TBARS and hexanal. Each type of ham exhibited a distinct volatile profile, enabling a clear differentiation. Although the focus of this study was solely on trimming and not other processing aspects, it is worth noting that the salting applied resulted in relatively salty product, and future studies should address also salting aspect of product optimisation.

Informed consent

Informed consent was obtained from each consumer for the sensory test of dry-cured hams. Likewise, informed consent was obtained from all participants in the sensory analysis panel.

CRediT authorship contribution statement

Bojana Savić: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation. **Martin Škrlep:** Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Formal analysis. **Nives Marušić Radovčić:** Writing – review & editing, Methodology, Investigation, Formal analysis. **Sandra Petričević:** Writing – review & editing, Methodology, Investigation. **Marjeta Čandek-Potokar:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization.

Declaration of competing interest

Authors declare no conflict of interests.

Acknowledgments

This study has received funding from Slovenian Research and Innovation Agency (grants P4-0133, L7-4568) and Ministry of Agriculture, Forestry and Food (L7-4568).

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.meatsci.2025.109762.

Data availability

The data have not been deposited in a repository but can be made available upon reasonable request.

References

Ares, G., & Varela, P. (2014). Comparison of novel methodologies for sensory characterization. In *Novel Techniques in Sensory Characterization and Consumer Profiling* (pp. 365–389). https://doi.org/10.1201/b16853-15

Božac, R., Kos, I., Janječić, Z., Kuzmanović, Ž., Konjačić, M., & Nežak, J. (2011). Effect of different crossbreeds on chemical and sensory profiling of Istrian dry-cured ham. *Acta Alimentaria, 40*(3), 315–326. https://doi.org/10.1556/aalim.2010.0008

Čandek-Potokar, M., Monin, G., & Zlender, B. (2002). Pork quality, processing, and sensory characteristics of dry-cured hams as influenced by Duroc crossing and sex. *Journal of Animal Science, 80*(4), 988–996. https://doi.org/10.2527/2002.804988x

Čandek-Potokar, M., & Nieto, R. (Eds.).. (2019). *European Local Pig Breeds—Diversity and Performance. A Study of Project TREASURE. 2019* pp. 1–303). London, UK: Intech Open. https://doi.org/10.5772/intechopen.83749

Čandek-Potokar, M., & Škrlep, M. (2011). Dry ham ("Kraški pršut") processing losses as affected by raw material properties and manufacturing practice. *Journal of Food Processing and Preservation, 35*(1), 96–111. https://doi.org/10.1111/j.1745-4549.2009.00462.x

Čandek-Potokar, M., & Škrlep, M. (2012). Factors in pig production that impact the quality of dry-cured ham: A review. *Animal, 6*(2), 327–338. https://doi.org/10.1017/S1751731111001625

Commission Implementing Regulation (EU). (2012). No 506/2012 of 14 June 2012 entering a name in the register of protected designations of origin and protected geographical indications (Kraški pršut (PGI)). *Official Journal of the European Union, L, 154*, 20–21.

Commission Implementing Regulation (EU). (2015). 2015/1840 of 7 October 2015 entering a name in the register of protected designations of origin and protected geographical indications (Istarski pršut/Istrski pršut (PDO)). *Official Journal of the European Union L, 267*(1), 1–2.

Faustman, C., Sun, Q., Mancini, R., & Suman, S. P. (2010). Myoglobin and lipid oxidation interactions: Mechanistic bases and control. *Meat Science, 86*(1), 86–94. https://doi.org/10.1016/j.meatsci.2010.04.025

Flores, J. (1997). Mediterranean vs northern European meat products. Processing technologies and main differences. *Food Chemistry, 59*(4), 505–510. https://doi.org/10.1016/S0308-8146(97)00011-3

Font-i-Furnols, M., & Guerrero, L. (2014). Consumer preference, behavior and perception about meat and meat products: An overview. *Meat Science, 98*(3), 361–371. https://doi.org/10.1016/j.meatsci.2014.06.025

Francis, F. J., & Clydesdale, F. M. (1975). *Food Colorimetry: Theory and Applications* (pp. 26–45). Westport, CT, USA: AVI Publishing Company Inc.

García, C., Berdagué, J. J., Antequera, T., López-Bote, C., Córdoba, J. J., & Ventanas, J. (1991). Volatile components of dry cured Iberian ham. *Food Chemistry, 41*(1), 23–32. https://doi.org/10.1016/0308-8146(91)90128-B

Guàrdia, M. D., Aguiar, A. P., Claret, A., Arnau, J., & Guerrero, L. (2010). Sensory characterization of dry-cured ham using free-choice profiling. *Food Quality and Preference, 21*(1), 148–155.

Husson, F., Josse, J., Le, S., & Mazet, J. (2023). *FactoMineR: Multivariate Exploratory Data Analysis and Data Mining With R. R Package Version 2* (p. 8). Retrieved from https://cran.r-project.org/package=FactoMineR Accessed May 22, 2024.

IBM Corp. (2021). *IBM SPSS statistics for Windows (Version 28.0.0) [Computer software]*.

ISO 5983-2. (2005). *Animal Feeding Stuffs - Determination of Nitrogen Content and Calculation of Crude Protein Content*.

ISO 11132. (2012). *Sensory Analysis-Methodology-Guidelines for Monitoring the Performance of a Quantitative Sensory Panel*. Genève, Switzerland: International Organization for Standardization.

Kassambara, A., & Mundt, F. (2023). Factoextra: Extract and Visualize the Results of Multivariate Data Analyses. R Package Version 1.0.7. Retrieved from https://cran.r-project.org/package=factoextra.

Lebret, B., Ecolan, P., Bonhomme, N., Méteau, K., & Prunier, A. (2015). Influence of production system in local and conventional pig breeds on stress indicators at slaughter, muscle and meat traits and pork eating quality. *Animal, 9*(8), 1404–1413. https://doi.org/10.1017/S1751731115000609

Marušić, N., Petrović, M., Vidaček, S., Petrak, T., & Medić, H. (2011). Characterization of traditional Istrian dry-cured ham by means of physical and chemical analyses and volatile compounds. *Meat Science, 88*(4), 786–790. https://doi.org/10.1016/j.meatsci.2011.02.033

Marušić Radovčić, N., Poljanec, I., Petričević, S., Mora, L., & Medić, H. (2021). Influence of muscle type on physicochemical parameters, lipolysis, proteolysis, and volatile compounds throughout the processing of smoked dry-cured ham. *Foods, 10*(6), 1228. https://doi.org/10.3390/foods10061228

Monin, G., Marinova, P., Talmant, A., Martin, J. F., Cornet, M., Lanore, D., & Grasso, F. (1997). Chemical and structural changes in dry-cured hams (Bayonne hams) during processing and effects of the dehairing technique. *Meat Science, 47*(1–2), 29–47. https://doi.org/10.1016/j.meatsci.2003.08.006

Moretti, V. M., Madonia, G., Diaferia, C., Mentasti, T., Paleari, M. A., Panseri, S., … Gandini, G. (2004). Chemical and microbiological parameters and sensory attributes of a typical Sicilian salami ripened in different conditions. *Meat Science, 66*(4), 845–854. https://doi.org/10.1016/j.meatsci.2003.08.006

Parolari, G., Virgili, R., & Schivazappa, C. (1994). Relationship between cathepsin B activity and compositional parameters in dry-cured hams of normal and defective texture. *Meat Science, 38*(1), 117–122. https://doi.org/10.1016/0309-1740(94)90100-7

Pérez-Alvarez, J. A., Sayas-Barberá, M. E., Fernández-López, J., Gago-Gago, M. A., Pagán-Moreno, M. J., & Aranda-Catalá, V. (1999). Chemical and color characteristics of Spanish dry-cured ham at the end of the aging process. *Journal of Muscle Foods, 10*(2), 195–201. https://doi.org/10.1111/j.1745-4573.1999.tb00395.x

Petričević, S., Radovčić, N. M., Lukić, K., Listeš, E., & Medić, H. (2018). Differentiation of dry-cured hams from different processing methods by means of volatile compounds, physico-chemical and sensory analysis. *Meat Science, 137*, 217–227. https://doi.org/10.1016/j.meatsci.2017.12.001

Petrova, I., Aasen, I. M., Rustad, T., & Eikevik, T. M. (2015). Manufacture of dry-cured ham: A review. Part 1. Biochemical changes during the technological process. *European Food Research and Technology, 241*, 587–599. https://doi.org/10.1007/s00217-015-2490-2

Poklukar, K., Čandek-Potokar, M., Batorek Lukač, N., Tomažin, U., & Škrlep, M. (2020). Lipid deposition and metabolism in local and modern pig breeds: A review. *Animals, 10*(3), 424. https://doi.org/10.3390/ani10030424

Pugliese, C., Sirtori, F., Škrlep, M., Piasentier, E., Calamai, L., Franci, O., & Čandek-Potokar, M. (2015). The effect of ripening time on the chemical, textural, volatile and sensorial traits of biceps femoris and semimembranosus muscles of the Slovenian dry-cured ham Kraški pršut. *Meat Science, 100*, 58–68. https://doi.org/10.1016/j.meatsci.2014.09.012

R Core Team. (2023). *R: A language and Environment for Statistical Computing. Version 4.3.2*. Vienna, Austria: R Foundation for Statistical Computing. Retrieved from https://www.R-project.org/ Accessed May 22, 2024.

Ruiz-Ramírez, J., Arnau, J., Serra, X., & Gou, P. (2005). Relationship between water content, NaCl content, pH and texture parameters in dry-cured muscles. *Meat Science, 70*(4), 579–587. https://doi.org/10.1016/j.meatsci.2005.02.007

Ruiz-Ramírez, J., Serra, X., Gou, P., & Arnau, J. (2006). Efecto del índice de proteolisis sobre la textura del jamón crudo curado. *Archivos Latinoamericanos de Producción Animal, 14*(2), 62–64.

Schivazappa, C., & Virgili, R. (2020). Impact of salt levels on the sensory profile and consumer acceptance of Italian dry-cured ham. *Journal of the Science of Food and Agriculture, 100*(8), 3370–3377. https://doi.org/10.1002/jsfa.10370

Serra, X., Ruiz-Ramírez, J., Arnau, J., & Gou, P. (2005). Texture parameters of dry-cured ham m. biceps femoris samples dried at different levels as a function of water activity and water content. *Meat Science, 69*(2), 249–254. https://doi.org/10.1016/j.meatsci.2004.07.004

Škrlep, M., Čandek-Potokar, M., Žlender, B., Robert, N., Santé-Lhoutellier, V., & Gou, P. (2012). PRKAG3 and CAST genetic polymorphisms and quality traits of dry-cured hams—III. Associations in Slovenian dry-cured ham Kraški pršut and their dependence on processing. *Meat Science, 92*(4), 360–365. https://doi.org/10.1016/j.meatsci.2012.06.021

Sood, S., Methven, L., & Cheng, Q. (2024). Role of taste receptors in salty taste perception of minerals and amino acids and developments in salt reduction strategies: A review. *Critical Reviews in Food Science and Nutrition, 1-15*. https://doi.org/10.1080/10408398.2024.2365962

Toldra, F. (1998). Proteolysis and lipolysis in flavour development of dry-cured meat products. *Meat Science, 49*, S101–S110. https://doi.org/10.1016/S0309-1740(98)90041-9

Toldrá, F., & Flores, M. (1998). The role of muscle proteases and lipases in flavor development during the processing of dry-cured ham. *Critical Reviews in Food Science, 38*(4), 331–352. https://doi.org/10.1080/10408699891274237

Virgili, R., Parolari, G., Schivazappa, C., Bordini, C. S., & Borri, M. (1995). Sensory and texture quality of dry-cured ham as affected by endogenous cathepsin B activity and muscle composition. *Journal of Food Science, 60*(6), 1183–1186. https://doi.org/10.1111/j.1365-2621.1995.tb04551.x

Wei, G., Li, X., Wang, D., Huang, W., Shi, Y., & Huang, A. (2023). Insights into free fatty acid profiles and oxidation on the development of characteristic volatile compounds in dry-cured ham from Dahe black and hybrid pigs. *LWT, 184*, Article 115063. https://doi.org/10.1016/j.lwt.2023.115063

Wood, J. D., Enser, M., Fisher, A. V., Nute, G. R., Sheard, P. R., Richardson, R. I., … Whittington, F. M. (2008). Fat deposition, fatty acid composition and meat quality: A review. *Meat Science, 78*(4), 343–358. https://doi.org/10.1016/j.meatsci.2007.07.019

Zhou, C., Wang, C., Tang, C., Dai, C., Bai, Y., Yu, X., Li, C., Xu, X., Zhou, G., & Cao, J. (2019). Label-free proteomics reveals the mechanism of bitterness and adhesiveness in Jinhua ham. *Food Chemistry, 297*, Article 125012. https://doi.org/10.1016/j.foodchem.2019.125012

Zhou, C. Y., Pan, D. D., Cao, J. X., & Zhou, G. H. (2021). A comprehensive review on molecular mechanism of defective dry-cured ham with excessive pastiness, adhesiveness, and bitterness by proteomics insights. *Comprehensive Reviews in Food Science and Food Safety, 20*(4), 3838–3857. https://doi.org/10.1111/1541-4337.12779