



# Hardness of dry-cured ham as a factor of consumer choice and its relationship to sensory acceptability

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## ABSTRACT

This study investigated consumer attitudes towards Slovenian dry-cured ham, Kraški pršut with protected geographical indication (PGI), having different levels of hardness (soft, semi-hard and hard). A total of 626 participants took part in a two-step evaluation: a choice simulation of dry-cured ham pieces followed by a sensory evaluation using the check-all-that-apply (CATA) method on sliced samples and overall liking assessment. Instrumental measurements of texture profile confirmed the tactile-based classification of dry-cured hams (performed by the processor) into soft, semi-hard, and hard categories. Consumer choices of dry-cured ham pieces were relatively evenly distributed (32%, 29%, 38% for soft, semi-hard, and hard categories, respectively), but with a statistically significant preference for harder hams. Visual appearance was more often a reason for choice than tactile sensation (44% and 23%, respectively). Although choice simulation indicated some preference for hard hams, tasting of dry cured hams revealed that soft hams were more frequently perceived as 'juicy' and less frequently as 'very salty', albeit less frequently noted as 'mature'. These findings highlight the importance of both visual and tasting attributes in determining consumer preference for dry-cured ham.

## 1. Introduction

Texture is a critical quality attribute of dry-cured ham for consumer acceptability (Morales *et al.*, 2013). When buying dry-cured ham sold in pieces, consumers rely on its visual appearance and the tactile sensation of hardness. The hardness of dry-cured ham is influenced by the processing method, associated processing losses, and its final water content. Research indicates a negative non-linear relationship between water content and ham hardness. This relationship is further affected by factors such as pH, salt content, and the extent of proteolysis (Petrova *et al.*, 2015). A soft and pasty texture of dry-cured hams has been

associated with negative consumer attitudes (Morales *et al.* 2013; Virgili *et al.*, 1995). To quantify mechanical texture properties, objective measurement methods, such as texture profile analysis (TPA) and stress relaxation (SR), are commonly used (Fulladosa *et al.*, 2021). However, these instrumental techniques cannot fully capture consumers' subjective perception of the texture of dry-cured ham. Therefore, sensory evaluation by consumers is essential for understanding their texture preferences, allowing the meat industry to tailor product characteristics and thereby enhance consumer satisfaction and market competitiveness. A positive consumer attitude towards a product means a greater preference for it (Guerrero *et al.*, 1998).

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Although numerous studies have explored consumer preferences for dry-cured hams, limited information is available for Kraški pršut (EC, 2012). The Slovenian processing industry seeks a deeper understanding of the relationship between visually based consumer choices and the sensory appreciation of the product. This study was, therefore, designed to investigate this relationship.

## 2. Materials and methods

The study was conducted with visitors during the main Slovenian agricultural fair. Participants ( $n = 626$ ) were adults ( $>18$  years old) and provided informed consent prior to the test. The material for this study was prepared by the biggest producer of Kraški pršut. Dry-cured hams ( $n=59$ ) of similar maturation length were classified into hardness categories (soft, semi-hard, hard) based on tactile assessment of the exposed surface. Nine hams (three from each hardness category) were sliced to prepare 153 packages for sensory testing, while 50 ham quarters were prepared for the choice test. Care was taken that the samples (slices and pieces/quarters) included the key muscles: *semimembranosus* (SM), *biceps femoris* (BF), and *semitendinosus* (ST). Consumers were invited to select a preferred piece/quarter of dry-cured ham (as presented on the market) from randomly presented triplets (soft, semi-hard, hard). After making their choice, they were asked to articulate the reasons behind their selection. Their explanations were then categorized as relating either to visual appearance or to texture/tactile sensation. Afterwards they were offered nine slices (three from each ham group) for tasting and asked to evaluate the samples by checking the descriptors, i.e., using the check-all-that-apply method (CATA) to mark those descriptors they perceived during tasting and to provide an overall liking score (on a 1-5 Likert scale; see below).

### 2.1 Texture analysis of dry-cured ham muscles

Fifty-nine samples of dry-cured hams were used for instrumental texture analysis of SM, BF, and ST muscles of dry-cured ham according to Škrlep et al. (2012). The tests were conducted with a TPA analyzer (Ametek Lloyd Instruments, Ltd., Bognor Regis, UK) using a 50 kg load cell and a 50 mm diameter compression plate. For the SR test, samples were compressed to 25% of their initial height at 1 mm/s. For the TPA test, samples underwent

two compressions to 50% at 1 mm/s. The following parameters were calculated: hardness, cohesiveness, gumminess, springiness, chewiness, adhesiveness and stress relaxation test ( $Y_{90}$ ).

### 2.2. Consumer testing

#### 2.2.1. Consumer choice of dry-cured ham based on visual and tactile appraisal

An initial choice test was conducted in which consumers were asked to select their preferred piece from random triplets of dry-cured ham samples that had been previously categorized into soft, semi-hard, and hard textures (this information was kept from consumers). The first question was: “Which piece of dry-cured ham would you choose?”. An optional follow-up question was: “Why did you choose this particular piece?”.

#### 2.2.2. CATA analysis and overall liking score

The tasting was conducted as a blind test, during which participants were asked to select all sensory impressions they perceived from the provided CATA descriptors. The provided CATA descriptors were: very soft, soluble, very dry, raw, mature, tough, juicy, tasty, off flavour, aromatic, very fatty, sweet, very salty, other (with an option to specify), which were pre-selected in collaboration with the experts from the dry-cured ham industry. At the end of tasting, consumers rated their overall satisfaction using a 5-point scale, defined as 1 = I do not like it at all and have never bought this product; 2 = I do not like it and probably will not buy this product; 3 = I am not sure (neutral opinion); 4 = I like it and will buy it; 5 = I really like it and will definitely buy it.

### 2.3. Statistical analysis

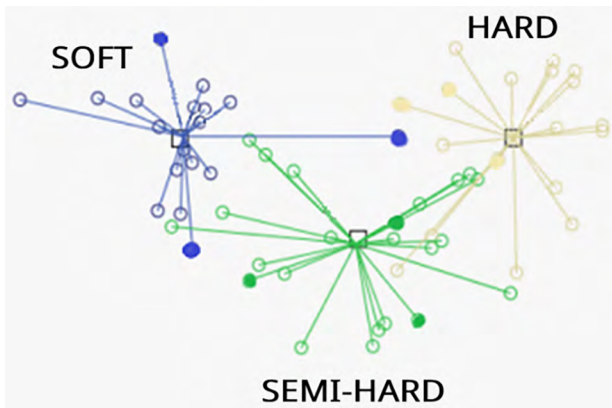
Statistical analysis was conducted using SPSS 23.0. To verify if hardness groups could be separated based on texture traits a canonical discriminant analysis was performed. Fisher's exact test was used to analyze CATA responses.

## 3. Results and discussion

### 3.1. Canonical discriminant analysis

Discriminant analysis revealed a clear separation of ham hardness groups based on instrumental texture measurements (Figure 1), confirming the accuracy of

the producer's tactile classification. Texture characterization showed that soft hams were less hard, gummy, and chewy, but more adhesive than hard hams, with semi-hard hams displaying intermediate properties (data not shown). Compared with hard hams, soft hams also contained higher moisture levels, greater water activity ( $a_w$ ), and a greater PI, along with lower salt content (data not shown), consistent with findings reported in the literature (Pérez-Alvarez *et al.*, 1999; Ruiz-Ramírez *et al.*, 2006; Ruiz-Ramírez *et al.*, 2005; Serra *et al.*, 2005).



**Figure 1.** Canonical discriminant analysis based on texture traits of SM, BF, ST

### 3.2. Consumer testing of dry-cured ham

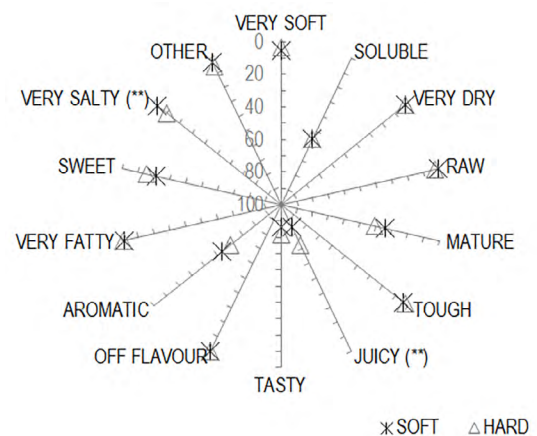
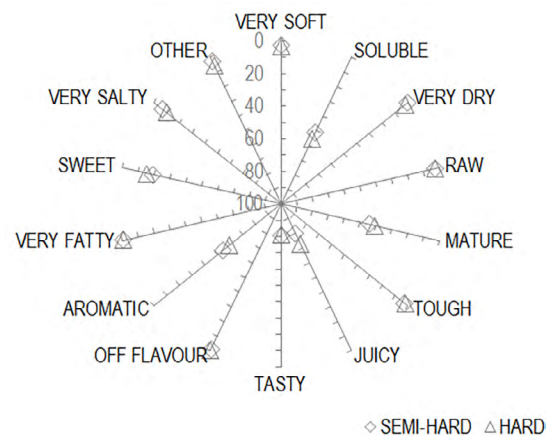
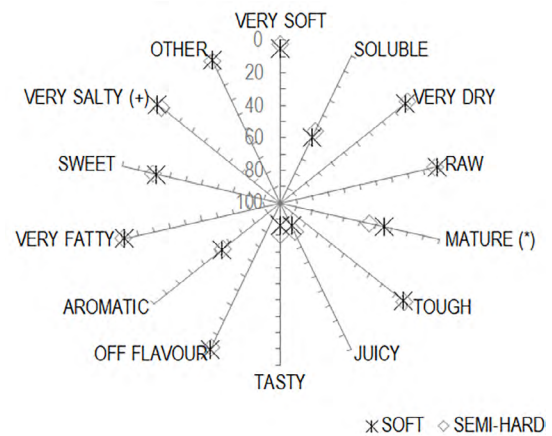
#### 3.2.1. Choice simulation

Consumers selected dry-cured ham pieces from the different hardness categories in similar proportions with a slight preference for the hard ones (32%, 29%, and 38% for soft, semi-hard, and hard, respectively). Although the processor anticipated a clear preference for hard pieces, the difference was moderate. When justifying their choice, consumers more often attributed their selections to visual attributes (e.g. nice color, too fatty, meat to fat ratio) than to tactile sensations (data not shown). This can be attributed to the fact that appearance, especially colour and visual fat, is the most influential intrinsic attribute in shaping consumers' expectations (Font-i-Furnols & Guerrero, 2014). Furthermore, no differences in hardness group choice were found between genders or age groups.

#### 3.2.1. Consumer preferences towards dry-cured ham

Despite important differences in the texture of dry-cured hams between the hardness groups, only small differences in consumer sensory perceptions

were found (Figure 2). Namely, semi-hard hams were more frequently checked as 'mature' than soft hams, and soft hams were more frequently checked as 'juicy' and less frequently as 'very salty'. The perception of semi-hard hams as more mature than soft hams suggests that consumers associate maturity with hardness. This trend was also reflected in comparisons between soft and hard hams, although the difference was not statistically significant. No sensory differences (based on CATA) were detected between semi-hard and hard hams.



**Figure 2.** Results of CATA analysis with pair-wise comparisons of hardness groups

The higher frequency of perception of soft hams, compared with the other ham categories, as 'juicy' and less frequently as 'very salty' aligns with observed physicochemical traits (data not shown) and is supported by the existing literature. Studies have demonstrated that hams with higher moisture content and lower salt levels are perceived as juicier and less salty (Savić et al., 2024; Schivazappa & Virgili, 2020). The overall liking scores, which were high and statistically not different across all hardness categories (soft: 4.47, semi-hard: 4.42, hard: 4.53), indicate general consumer satisfaction with products regardless of hardness group and explain the small differences observed in the CATA responses. Once more, the result did not align with the processor's expectation that consumers would favour

harder hams; in fact, there was a slight preference for softer hams, reflected in more frequent selection of 'juicy' and less frequent selection of 'salty' as sensory descriptors.

#### 4. Conclusion

Discriminant analysis based on instrumental texture measurements validated the processor's classification of hams into three hardness categories. In the consumer choice simulation, selection relied more on visual than tactile perception. Although hard hams were slightly preferred in the choice step, soft hams were more frequently characterized as juicy and less frequently as salty.

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