Evaluation of dry-cured ham pastiness through rheological measurements of aqueous extracts obtained *in vitro* mimicking the mastication process.

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Abstract. - Pastiness is a dry-cured ham defect that can be determined by sensory and chemical analysis. Since pastiness produces an increase of saliva viscosity, rheology might be useful to instrumentally evaluate this defect. The aim of this study was to evaluate the rheological behaviour of water extracts obtained *in vitro* mimicking the mastication of dry-cured ham samples with different pastiness intensities. Commercial samples from different groups (non-pastiness (NPG), medium pastiness (MPG) and high pastiness (HPG) groups) were sensorially and rheologically analysed. Effect of temperatures and HPP treatments at 7 ºC, 20 ºC and 35ºC were also evaluated. Results showed that apparent viscosity of the water extracts increased with the increase of pastiness and decreased with temperature. Significant differences ($p<0.05$) were observed between NPG/MPG and HPG samples and between 25 ºC and 37 ºC in HPG. After HPP, sensory pastiness disappeared in samples from MPG at any temperature and decreased from 6.8 to 0.2 in samples from HPG only when HPP35 was used. Although the increase on viscosity of oral fluid is related to the sensory pastiness, other factors seem to be involved in the mechanism of pastiness perception. Despite this, HPG samples can be distinguished from MPG and NPG samples.

Key words – Defective textures, pastiness, viscosity, rheology, instrumental measurements.

Highlights

– Dry-cured ham (DCH) pastiness defect is measurable by sensory and chemical analysis

– Viscosity of oral fluids generated during mastication of DCH is related to pastiness

– Water extracts viscosity using a rheometer increases with pastiness.

– It is possible to develop an instrumental method to measure pastiness perception

1. Introduction

Development of texture and flavour characteristics of dry-cured ham is due to the lipolysis and proteolysis processes occurring during ripening (Toldrá, 1998). However, an excessive proteolytic activity may produce damages in the structure leading to negative flavour characteristics and defective textures such as pastiness (Arnau, Guerrero & Sárraga, 1998; Toldrá, 2006). Pastiness is a mouth sensation described as the feeling, like a flour-water paste, during the mastication process (Guerrero, Gou & Arnau, 1999) being well-differentiated from softness that is described as a palatable texture in the mouth (Resano *et al.*, 2010).

Pastiness is a defect that has a considerable incidence in dry-cured ham production, *Biceps femoris* being the muscle more prone to developing this defect. Tapiador & García-Garrido (2003) found an incidence of 12% in industrial dry-cured ham production whereas Arnau (2013) in another study found an incidence of 24% in hams with a pH in the *Semimembranosus* muscle at 24 h *post mortem* (pH_{SM24h}) < 5.6 and 10% in hams with a pH_{sM24h} > 5.6. To reduce the incidence of this problem, the use of non-destructive determination of salt and fat contents using devices implemented on the production line in the industry to readjust salting process (De Prados *et al.*, 2015; Fulladosa, De Prados,

et al., 2015; Fulladosa, Muñoz, *et al.*, 2015; García-García *et al.*, 2019) as well as the optimization of drying processes (Coll-Brasas *et al.*, 2021) could be useful. Corrective actions of this defect have also been described using mild thermal treatments applied with power ultrasound (Contreras, Benedito, Bon & Garcia-Perez, 2018; Contreras, Benedito, Quiles, Lorenzo, Fulladosa & Garcia-Perez, 2020). The use of High Pressure Processing (HPP) treatments (Coll-Brasas *et al.*, 2019; Fulladosa, Serra, Gou & Arnau, 2009) have also been reported to be effective to this end. HPP, commonly used in industry to eliminate pathogenic microorganisms and extend the product shelf-life (Aymerich, Picouet & Monfort, 2008; Rendueles *et al.*, 2011), can also affect the texture of the product, producing a decrease of pastiness intensity and an increase of hardness and stringiness (Fulladosa *et al.*, 2009; Lorido, Estévez, Ventanas & Ventanas, 2015). Moreover, these changes were found to be different depending on the HPP temperatures used and the initial texture characteristics of the samples (Coll-Brasas *et al.*, 2019). In this study, HPP processing at different temperatures was used to produce different changes of pastiness intensity and to compare if these changes were differently perceived when using sensory and rheological analysis.

Defective textures in dry-cured ham can be quantified with instrumental texture tests (Morales, Guerrero, Serra & Gou, 2007) but pastiness has only been measured by sensory analysis. In some studies, pastiness has been related to the proteolysis index (PI), showing this index as a good estimate of this defect (Careri *et al.*, 1993; García-Garrido, Quiles-Zafra, Tapiador & Luque de Castro, 1999; Morales *et al.*, 2008; Ruiz-Ramírez, Arnau, Serra & Gou, 2006). However, the cost and the time required for both sensory and chemical analysis show the need for finding simpler and faster techniques for routine analysis.

Sensory viscosity of saliva whilst masticating is highly correlated to pastiness defect (Coll-Brasas *et al.*, 2019). Rheological measurements of the oral dry-cured ham fluid or water whilst masticating, that can be obtained *in vitro* mimicking the mastication, might be useful to instrumentally evaluate pastiness perception. Viscosity analysis of the water extracts using a rheometer might allow for a faster, repeatable and cheaper measurement of pastiness intensity. Chen & Stokes (2012) described rheology studies as effective for overall sensory characterization since rheology dominates texture sensation at the early stage of chewing. Besides, rheology has been previously used to evaluate the mouthfeel of different components in wine (Laguna, Sarkar, *et al.*, 2017) and also to compare the relationship between rheological properties of commercial full fat and fat-free/low fat versions of liquid and soft solid colloidal systems (milk, yoghurt, soft cream cheese) with their sensory properties (Laguna, Farrell, *et al.*, 2017). However, quantifying the sensory mouthfeel feelings with an instrumental technique is not easy (Laguna, Sarkar, *et al.*, 2017) and the effect of different experimental conditions needs to be evaluated.

The aim of this study was to evaluate if the rheological measurement of viscosity is related with pastiness perception. To do so, first, the rheological behaviour of the water extracts obtained *in vitro* mimicking the mastication of dry-cured ham samples with different pastiness intensities were studied at different temperatures (25 and 37 ºC) to define the best temperature of analysis. Afterwards, changes in sensory pastiness and in flow behaviour were evaluated in water extracts coming from samples with modified texture after being submitted to HPP at different temperatures (7 ºC (HPP7), 20 ºC (HPP20) and 35 ºC (HPP35)). Finally, characterization of commercial dry-cured ham samples was also performed in terms of sensory pastiness and viscosity of the water extracts using the developed method.

2. Material and methods

2.1 Samples

Twenty whole dry-cured hams from lean crosses of Large White and Landrace breeds and salted according to the traditional system of Serrano ham, were obtained at the end of process from a commercial producer. The sensory pastiness intensity of *Biceps femoris* (BF) muscle was determined by using some slices obtained from each ham and the sensory analyses were performed as described in section 2.4. Among them, three hams were selected with a sensory pastiness qualification of 0, 2.0 and 6.8, in a scale from 0 (absence of pastiness) to 10 (maximum intensity). These samples were considered to correspond to the non-pastiness group (NPG, that considers hams with pastiness intensity <0.5), medium pastiness group (MPG, that considers hams with pastiness intensity between 0.5 and 2.0) and high pastiness group (HPG, that considers hams with pastiness intensity >2.0) respectively as previously defined in Coll-Brasas *et al.*, (2019). Hams with a sensory pastiness of 2.0 were classified as MPG because in the market the maximum pastiness intensity values are about 6 or 7 not 10.

For each selected ham, BF muscle was completely sliced in 1.5 mm-thick slices. A total of 25 samples of BF muscle (approximately a total of 15 g per sample) were obtained for each ham, vacuum packaged and stored at 4 ºC ± 2 ºC to be used in further rheological evaluations in the different experiments. Samples for sensory analysis after application of different HPP were also prepared.

Besides, 50 sliced commercial packages of dry-cured ham containing *Biceps femoris* muscle were selected from the market. All packages contained lean type dry-cured ham from different brands including different elaboration procedures. From each commercial package, at least 2 samples of BF muscle (approximately a total of 15 g per sample) were obtained to be used in further rheological experiments. From each package, 5 samples for the sensory evaluation were also obtained.

2.2 Obtaining water extracts and rheological measurements.

Water extracts, which represent saliva in the bolus during the mastication process, were obtained *in vitro* using a new procedure that simulates the mastication process. In short, the sample (15 g of BF muscle) was cut into small pieces (0.5 cm x 0.5 cm approximately) and 15 ml of distilled water/liquid was added. Then, samples were sheared using a homogenizer Ultra-Turrax T18 basic (IKA Werke GmbH & Co. KG, Staufen, Germany) at low revolutions moving vertically through the ham container 20 times and then adding 10 ml extra of distilled water. After that, the preparation was again sheared in the container 5 times more and the mixture was smashed 25 times using a spatula. Subsequently, the preparation was introduced in a Falcon tube of 50 ml and then centrifuged at 4000 rpm during 3 minutes at a maximum temperature of 15 ºC using a centrifuge (Eppendorf 5810 R and a rotor Eppendorf A-4-62; Eppendorf AG, Hamburg, Germany). The obtained supernatant (water extract) was immediately analysed using a rheometer.

Rheological properties of the water extracts were measured in a RheoStress controlled stress rheometer monitored by Rheowin Pro Software v. 3.1 (Haake, Karslruhe, Germany) with a parallel-plates sensor system (60 mm) with a gap between plates of 0.5 mm. Between 2.5 and 3 ml of water extract was placed with a spoon in the pre-heated plate at a defined constant temperature. The temperature was controlled by using a Phoenix P1 Circulator device (Thermo Haake, Karslruhe, Germany); to avoid evaporation, a temperature cover was used.

Flow curves were obtained from stepped shear stress ramp (steady state approximation: 20 s per point). Ranges of shear stresses, in logarithmic distribution, were used to obtain shear rates between 0.05 and 100 s^{-1}. Data from the flow curves were fitted to the Ostwald

de Waele fit ($\sigma = K\dot{\gamma}^n$), where *k* (Pa·s) is the consistency index and *n* is the flow index. For each water extract, two measurements at least were performed.

2.3 Experimental protocols

2.3.1 Effect of temperature on rheological behaviour of water extracts

The effect of different temperatures (25 ºC and 37 ºC) on flow index (*n*), consistency index (*k*) and viscosities at 1, 10 and 100 s^{-1} were evaluated in water extracts from NPG, MPG and HPG. The temperature of 25 ºC was selected because it represents the room conditions in which rheological analysis could be performed whereas 37 ºC was chosen to be the temperature of the oral cavity. Five extractions from each ham and temperature of analysis were taken. Each extraction was measured in duplicate.

2.3.2 Effect of HPP at different temperatures on rheological and sensory properties of BF muscle of dry-cured ham

The effect of HPP at different temperatures was studied on sensory properties of the dry-cured ham samples with different pastiness intensities and on rheological properties of their water extracts. To do so, samples were submitted to 600 MPa during 6 min in NC Hyperbaric WAVE 6000/120 equipment (NC Hyperbaric, Burgos, Spain) using an initial temperature of 7 ºC (HPP7) (n = 9), 20 ºC (HPP20) (n = 9) and 35 ºC (HPP35) (n = 9). Before application of HPP, samples were kept to the assigned temperature until getting a homogeneous temperature in the entire sample. For each temperature, 6 samples were used for rheological measurements (2 HPG, 2 MPG and 2 NPG). Changes in the rheological behaviour of their water extracts after HPP were analysed using the rheometer at 37 ºC in duplicate. Five samples prepared for sensory analysis and submitted to the mentioned HPP temperature conditions (5 HPG, 5 MPG and 5 NPG) were also analysed.

2.3.3 Characterization of commercial dry-cured ham samples

Sensory pastiness intensity of BF of fifty commercial dry-cured ham samples were analysed by 5-member expert panellist. Viscosity of their water extracts was evaluated in duplicate using a rheometer at 37 ºC. Characterization analysis of the marketed dry-cured ham and the relationship between sensorial and rheological measurements were evaluated.

2.4 Sensory analysis

The evaluation of the pastiness intensity of BF muscle in all the samples was performed using an unstructured scoring scale from 0 (absence of pastiness) to 10 (maximum intensity) by five-member expert panellists. To ensure the quality of their evaluations, all the selected panellists had at least 15 years of experience on sensory evaluations of dry-cured ham samples. Panellists were selected and trained according to ASTM (1981), ISO 8586-1 (1993) and ISO 8586-2 (1994). They were routinely trained every three months. Additionally, 2 specific training sessions for pastiness attribute were also performed before each session of sensory analysis. The average score of the 5 experts for each sample was used for the statistical analysis. Samples were coded with three random numbers and presented to the panellists balancing the first-order and the carry-over effects as much as possible according to (Macfie, Bratchell, Greenhoff & Vallis, 1989). Between all the samples, water was used to rinse the mouth.

For the selection of the three whole hams, a total of 4 sessions were performed with 5 samples per session. In the case of commercial samples, a total of 10 sessions were carried out in which 5 samples per session were randomly selected and evaluated.

All the samples were assigned to the NPG, MPG or HPG as previously defined in Coll-Brasas *et al.*, (2019). In short, NPG included hams with sensory pastiness lower than 0.5, MPG included hams with a sensory pastiness from 0.5 to 2.0 and HPG included hams with a sensory pastiness higher than 2.0.

2.5 Statistical analysis

A two-way ANOVA was used to evaluate the effect of the temperature (25 and 37 ºC) on the instrumental viscosity (at 1, 10 and 100 s^{-1}) of samples from different pastiness intensity groups (NPG, MPG and HPG). Similarly, the effect of the HPP treatment at different temperatures (HPP7, HPP20 and HPP35) was also performed on sensory pastiness and instrumental viscosity at 10 s^{-1} on samples with different pastiness intensity (NPG, MPG and HPG). Also, a t-test was performed to evaluate whether viscosity at 10 s^{-1} was significantly different or not from different sensory pastiness groups (NPG, MPG and HPG). Differences between mean values were tested by means of the Tukey test ($p \leq 0.05$). All the analyses were performed using the XLSTAT v2020.1.1 (2020) (Addinsoft, Paris, France).

3. Results and discussion

3.1 Rheological characterization of water extracts of dry-cured ham samples from different pastiness intensity groups

The flow curve parameters of the water extracts from samples assigned to different pastiness intensity groups are presented in Table 1. Parameters showed a shear-thinning behaviour with flow index (*n*) values ranging from 0.07 to 0.36 and a consistency index (*k*) ranging from 0.03 to 0.66 indicating a pseudoplastic behaviour. The *k* and *n* values showed different behaviour for the different pastiness intensity groups and temperatures of analysis. The samples with high pastiness intensity showed higher consistency index and lower flow indexes being farther to the Newtonian behaviour (i.e. $n = 1$). Flow curves of the water extracts were adjusted to the Ostwald de Waele fit showing r ranges from 0.9407 – 0.9991 and 0.9174 – 0.9987 on samples with non-pastiness at 25 and 37 ºC, respectively; from 0.8799 – 0.9993 and 0.8359 – 0.9980 on samples from MPG at 25 and

37 ºC, respectively; and from 0.9405 – 0.9876 and 0.9812 – 0.9974 on samples from HPG at 25 and 37 ºC, respectively.

Viscosity of samples with different pastiness intensities when analysed at different temperatures were significantly different (Table 2). An increase of viscosity of the water extracts at 1, 10 and 100 s^{-1} with the increase of the pastiness intensity group was observed ($p \leq 0.05$). However, significant differences were found between the HPG and NPG/MPG (Table 2). These results are in agreement with Coll-Brasas *et al.*, (2019), who found a correlation between the perception of pastiness intensity and the perception of saliva viscosity reported by the expert panellists during mastication (i.e., what water extracts represented) ($r = 0.894$). A high proteolysis in dry-cured ham muscles leads to the generation of smaller fractions of proteins that affects the texture of the sample (Toldrá & Flores, 1998). López-Pedrouso *et al.*, (2018) found that protein fragments increased in samples with a higher proteolysis index, most of the fragments being the result of the hydrolysis of the myosin heavy chain and α-actin myofibrillar proteins. We can hypothesize that during the mastication of HPG dry-cured ham samples, a higher number of protein fragments will be solubilized in water than in NPG and MPG samples, increasing the viscosity of saliva during mastication and also of the water extracts obtained when mimicking this process.

Viscosity values at 1, 10 and 100 s^{-1} decreased with the temperature of the analysis, but significant differences were only found for HPG ($p \leq 0.05$). Viscosity values were higher at low temperatures (25 ºC), because an increase in temperature causes higher kinetic energy in molecules and consequently a fall in viscosity, as described by the Arrhenius equation.

For further experiments, the measurement of viscosity at a shear rate of 10 s^{-1} was chosen because similar viscosity variations were observed at all the studied shear rates but 10 s^{-1}

is the closest to the chewing speed (Sharma, Kristo, Corredig & Duizer, 2017). Similarly, although both temperatures provided good discrimination of viscosity between pastiness intensity groups, 37 ºC was chosen because it is the temperature of the oral cavity.

3.2 Effect of HPP treatment on sensory pastiness and water extract viscosity of dry-cured ham samples with different pastiness intensity

The effect of HPP treatment at 600 MPa on both sensory pastiness and water extract viscosity at 10 s^{-1} for dry-cured ham samples with different pastiness intensity is shown in Tables 3 and 4. The HPP produced a significant effect on sensory pastiness ($p \leq 0.05$), which was different depending on the HPP temperature used and on the initial pastiness intensity of the sample (Table 4). Pastiness intensity disappeared in samples from MPG ($p \leq 0.05$) after HPP at any of the temperatures. In contrast, when the pastiness intensity was high (HPG), only the HPP treatment at 35 ºC produced a significant reduction of pastiness. These results are in agreement with that previously reported by Coll-Brasas *et al.*, (2019) who found that HPP treatments produced changes in texture to a different extent depending on the processing temperature and the initial textural characteristics of the samples. Texture modifications due to HPP can be attributed to the aggregation of myosin molecules, which denature and form disulphide bonds at pressures higher than 400 MPa (Angsupanich, Edde & Ledward, 1999; Orlien, 2017; Yamamoto, Yoshida, Morita & Yasui, 1994), which produces changes in ultrastructure increasing hardness and decreasing pastiness (Garcia-Gil *et al.*, 2014; Picouet *et al.*, 2012).

The decrease of pastiness in samples from HPG could only be achieved when a temperature of 35 ºC was used. This fact could be explained because of the more intensive effect of pressure when it is applied together with temperature (Cheftel & Culioli, 1997). It is important to mention that it was estimated that HPP35 samples achieved temperatures above 53 ºC during the HPP treatment, because of the adiabatic increase of temperature

during pressurization (US Food & Drug Administration, 2014) that depends on the pressure applied but also on the initial temperature and the product composition (Patazca, Koutchma & Balasubramaniam, 2007; Picouet *et al.*, 2016). We can hypothesize that when the structure is damaged and partially denatured, high temperatures are needed to produce changes and to create new rearrangements. In contrast, when the proteins are not so deeply affected by proteolysis and still have the native structure (NPG/MPG), the effect of the HPP treatment is more important. Contreras, Benedito, Quiles, Lorenzo, Fulladosa, Gou, *et al.*, (2020) attributed the textural changes produced by mild thermal treatments using power ultrasounds to the shrinkage of the myofibrils that increased the hardness and improved the texture.

For the reasons mentioned above, rheological behaviour of water extracts from the same dry-cured ham samples after application of HPP showed lower *k* values (less consistent) and had a more Newtonian behaviour (higher *n* values) (Table 3). After the shrinkage of myofibrils, the release of protein fractions is lower, leading to less consistent water extracts (Tornberg, 2005).

Viscosity of the water extracts at 10 s^{-1} decreased for all the pastiness intensity groups after HPP (Table 4). A significant decrease of instrumental viscosity in NPG samples was found after HPP at any temperature ($p \leq 0.05$) although no decrease of pastiness in sensory analysis (no initial defect was present) was observed. In contrast, although a significant decrease of viscosity in HPG samples was also found after HPP at any temperature ($p \leq 0.05$), sensory changes were only perceived after HPP at 35 ºC. It seems that some protein fractions that affect sensory pastiness (during human mastication) are not being detected by instrumental viscosity measurements (in water extracts). Other changes induced by HPP on the ham (such as an increase of hardness) could be also responsible for the lower viscosity values of the extract of these HPP treated hams.

Further studies are needed to elucidate the impact of these fractions and other textural attributes of the samples on sensory and rheological properties of pasty hams.

3.3 Pastiness of commercial dry-cured hams and viscosity of their water extracts

The relative frequency of commercial samples from different pastiness intensity groups is shown in Figure 1 (n = 50). Most of the commercial samples had a pastiness intensity lower than 0.5 (44%) whereas 38% and 18% of the samples had a medium and a high pastiness intensity, respectively. It must be noted that pastiness intensities higher than 6 were not found in the market but pastiness intensity higher than 2.0 were already considered defective by the consumers.

The viscosity of the commercial samples from the three pastiness intensity groups is shown in Table 5. According to results found in section 3.1, results obtained from the commercial samples showed significant differences of viscosity between HPG and MPG/NPG ($p<0.05$). No significant differences were found between NPG and MPG. Therefore, although using samples from different sources and processed differently, viscosity measurements using the rheometer allows us to distinguish commercial samples with high pastiness intensity from the medium and the non-pastiness ones. However, as expected, samples with medium or non-pastiness intensity cannot be distinguished. A clear relationship between sensory pastiness and viscosity could not be stablished. However, a routine analytical test able to discriminate the most defective samples from low defective ones might still be of interest for the dry-cured ham industry. More experimental work is needed to find a relationship between sensorial and rheological analysis.

4. Conclusions

In the present study, for the first time, an *in-vitro* approach for measuring changes in oral fluid viscosity has been proposed as a way to instrumentally evaluate pastiness defect in dry-cured ham. Rheological properties of water extracts obtained *in vitro* mimicking the mastication of ham has been characterized showing that the apparent viscosity values at 10 s^{-1} are related to the sensory pastiness intensity. HPP treatment was shown to decrease both pastiness and viscosity values but the different effect observed may indicate that other factors are implied. Further studies are needed to clarify the relationship between protein fractions produced in proteolysis, sensory pastiness and rheological parameters. These results show that it is possible to develop a fast, low-cost routine method to instrumentally measure pastiness perception in dry-cured ham. Although only samples with high pastiness intensity can be distinguished from those with low defective intensity, discrimination of the most defective samples is still of interest for the dry-cured ham industry.

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TABLES

Table 1. Flow curve parameters (consistency index (*k*; (Pa·s)^n) and flow index (*n*)) of water extracts from dry-cured ham samples with different pastiness intensity.

Temperature	Pastiness intensity groups	n	*k* Mean ± Standard deviation	*n* Mean ± Standard deviation
25 ºC	Non-Pastiness group (NPG)	5	0.06±0.02	0.36±0.18
	Medium Pastiness group (MPG)	5	0.07±0.03	0.20±0.25
	High Pastiness group (HPG)	5	0.66±0.21	0.07±0.04
37 ºC	Non-Pastiness group (NPG)	5	0.05±0.02	0.35±0.17
	Medium Pastiness group (MPG)	5	0.03±0.01	0.33±0.18
	High Pastiness group (HPG)	5	0.38±0.13	0.15±0.09

n: represent the number of water extracts. Each water extract was analysed in duplicate.

Table 2. Viscosity (η) of water extracts from dry-cured ham samples with different pastiness intensity.

Temperature	Pastiness intensity groups	n	η_1 Pa·s Mean ± Standard deviation	η_{10} Pa·s Mean ± Standard deviation	η_{100} Pa·s Mean ± Standard deviation
25 ºC	Non-Pastiness (NPG)	5	0.054^{c} ±0.015	0.015^{c} ±0.003	0.006^{c} ±0.001
	Medium Pastiness (MPG)	5	0.067^{c} ±0.030	0.012^{c} ±0.005	0.006^{c} ±0.002
	High Pastiness (HPG)	5	0.590^{a} ±0.184	0.094^{a} ±0.025	0.023^{a} ±0.005
37 ºC	Non-Pastiness (NPG)	5	0.045^{c} ±0.017	0.010^{c} ±0.002	0.005^{c} ±0.001
	Medium-Pastiness (MPG)	5	0.029^{c} ±0.015	0.007^{c} ±0.004	0.004^{c} ±0.004
	High-Pastiness (HPG)	5	0.347^{b} ±0.117	0.062^{b} ±0.017	0.016^{b} ±0.003

^{abc}Different letters within columns indicate significant differences ($p \leq 0.05$).

n: represent the number of water extracts. Each water extract was analysed in duplicate.

Table 3. Flow curve parameters (consistency index (*k*; (Pa·s)^n) and flow index (*n*)) of water extracts analysed at 37 ºC at a shear rate of 10 s^{-1} from dry-cured ham samples with different pastiness intensity submitted to different HPP treatments.

		Non-Pastiness Group		**Medium Pastiness Group**		**High Pastiness Group**	
HPP Treatment	**n**	***k*** **Mean ± Standard deviation**	***n*** **Mean ± Standard deviation**	***k*** **Mean ± Standard deviation**	***n*** **Mean ± Standard deviation**	***k*** **Mean ± Standard deviation**	***n*** **Mean ± Standard deviation**
Control	15	0.049±0.018	0.347±0.171	0.034±0.009	0.329±0.176	0.383±0.134	0.154±0.092
HPP7	6	0.013±0.005	0.549±0.180	0.016±0.008	0.561±0.199	0.018±0.003	0.633±0.033
HPP20	6	0.018±0.009	0.325±0.120	0.012±0.004	0.698±0.121	0.018±0.003	0.572±0.060
HPP35	6	0.018±0.009	0.438±0.229	0.009±0.005	0.544±0.135	0.027±0.004	0.464±0.071

Control: samples not submitted to High Hydrostatic Pressure); HPP7: samples submitted to High Hydrostatic Pressure at 7 ºC; HPP20: samples submitted to High Hydrostatic Pressure at 20 ºC; HPP35: samples submitted to High Hydrostatic Pressure at 35 ºC.
n: represent the number of water extracts. Each water extract was analysed in duplicate.

Table 4. Effect of HPP at different temperatures on sensory pastiness and viscosity (η) of water extracts analysed at 37 ºC at a shear rate of 10 s^{-1} from dry-cured ham samples with different pastiness intensity measured at 37 ºC.

		Non-Pastiness Group		Medium Pastiness Group		High Pastiness Group	
HPP Treatment	**n**	**Sensory pastiness Mean ± Standard deviation**	**η (10 s^{-1}) Mean ± Standard deviation**	**Sensory pastiness Mean ± Standard deviation**	**η (10 s^{-1}) Mean ± Standard deviation**	**Sensory pastiness Mean ± Standard deviation**	**η (10 s^{-1}) Mean ± Standard deviation**
Control	15	0.0	0.010^{a} ±0.002	2.0 ± 0.3^{a}	0.007^{a} ±0.004	6.8^{a} ±0.8	0.062^{a} ±0.017
HPP7	6	0.0	0.004^{b} ±0.003	0.0^{b}	0.004^{ab} ±0.001	6.2^{a} ±1.4	0.007^{b} ±0.001
HPP20	6	0.0	0.004^{b} ±0.002	0.0^{b}	0.003^{b} ±0.001	5.8^{a} ±1.5	0.006^{b} ±0.001
HPP35	6	0.0	0.005^{b} ±0.001	0.0^{b}	0.005^{ab} ±0.002	0.2^{b} ±0.3	0.007^{b} ±0.002

^{ab}Different letters indicate significant differences ($p \leq 0.05$) within columns. Control: samples not submitted to High Hydrostatic Pressure); HPP7: samples submitted to High Hydrostatic Pressure at 7 ºC; HPP20: samples submitted to High Hydrostatic Pressure at 20 ºC; HPP35: samples submitted to High Hydrostatic Pressure at 35 ºC.

n: represent the number of samples sensory evaluated by the 5-member expert panellists.

Table 5. Sensory pastiness and water extract viscosity at 10 s^{-1} and analysed at 37 ºC of commercial samples (n = 50) from the different pastiness intensity groups.

Pastiness intensity groups	n	Sensory pastiness Mean ± Standard deviation	η_{10} Mean ± Standard deviation	Minimum η_{10}	Maximum η_{10}
Non-Pastiness group (NPG) (≤ 0.5)	24	0.1^{c} ±0.2	0.014^{b} ± 0.015	0.004	0.075
Medium Pastiness group (MPG) (0.5 – 2.0)	15	1.2^{b} ±0.4	0.016^{b} ± 0.013	0.004	0.052
High Pastiness group (HPG) (≥ 2.0)	11	3.6^{a} ±1.4	0.111^{a} ± 0.177	0.010	0.477

[ab]Within columns, different letters indicate significant differences ($p \leq 0.05$).
n: represent the number of samples sensory evaluated by the 5-member expert panellist. From each of them, 2 water extracts were obtained and analysed in duplicate.

FIGURES

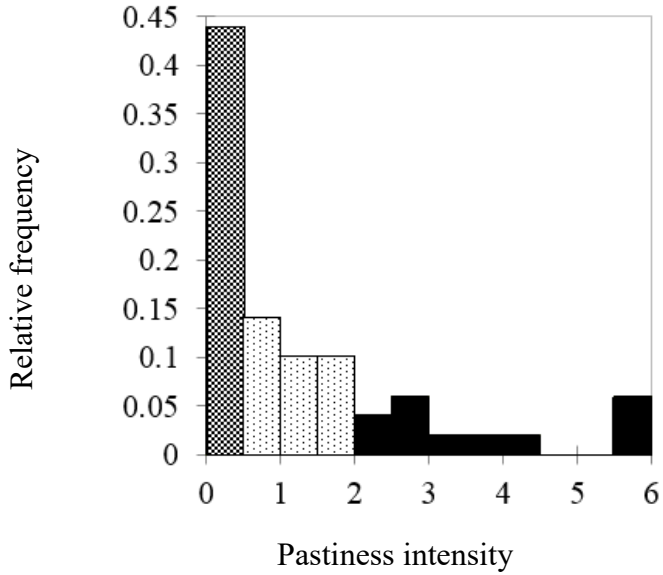

Figure 1. Distribution of commercial sliced dry-cured ham packages according to sensory pastiness intensity. Non-pastiness group, Medium pastiness group, High pastiness group.