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ORIGINAL PAPER

Effect of rosemary addition on the sensorial and physicochemical qualities of dry-cured ham slices. Measurement of camphor transfer

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Abstract
This study determined the effect of three concentrations (R1: high, R2: medium and R3: low) of rosemary added to dry-cured ham slices vacuum packaged. pH and the colour parameters were evaluated at 0, 7, 14, 28 and 60 days of storage; visual appearance, odour, flavour and camphor content were assessed at days 7, 14, 28 and 60. The rosemary concentration changed the colour parameters, significantly altering the visual appearance ($p < 0.001$ at 7 and 14 days; $p < 0.5$ at day 28), but did not affect the pH, neither odour nor flavour. Nevertheless, significant differences were found with the time on R1 and R2 in odour ($p < 0.01$ and $p < 0.001$, respectively) and in flavour ($p < 0.001$). Camphor content was similar in all samples but changed over the time in R1 ($p < 0.001$) and R2 ($p < 0.01$). In conclusion, despite the differences observed, it is evident that the addition of this spice was to the liking of the panellists, in any of the concentrations used.

Keywords Rosemary · Sliced ham · Quality · Aromatic transfer · Vacuum packaging

Introduction

Dry-cured ham is one of the most valued meat products by Mediterranean consumers [1]. It is of a tremendous economic relevance [2] occupying a large part of the Spanish business activity [3] with a production of 307,000 tonnes in 2021 [4]. This meat product is processed under traditional practices [5] which the origin is due to the application of a salting and curing process that arose from the need to keep the meat edible for as long as possible [6]. This product is commercialised in different ways such as whole or boneless but, nowadays, it is usual to commercialise dry-cured ham in ready-to-eat packaging [7] with slices of ham. In Spain, there are professional "ham cutters" who slice dry-cured ham, since sensory parameters are mainly influenced by the kind of cut [8]. The type of packaging also affects the quality of the final product, influencing colour [9], odour [10], flavour [11] and texture [12]. Packaging also offers possibilities to create new products adding spices and aromatic herbs [8], which have been used as sensory properties' enhancer and for food preservation [13].

Dry-cured ham is traditionally seasoned with salt and other additives such as preservatives and antioxidants [14] in accordance with Regulation (EC) No 1129/2011 of the European Parliament and of The Council of 11 November 2011 to establish a list of food additives in the Union. Nevertheless, due to the critical view of meat products developed by consumers [15], the demand for new healthier meat products has increased [16, 17]. It could be reducing, substituting ingredients or incorporating new healthy ones such as spices. One of these healthy ingredients that could be added to create new meat products is rosemary (*Rosmarinus officinalis* L.), which is native to Mediterranean region [18].

Some studies confirm that rosemary has antimicrobial properties [19], anti-breast–colorectal–prostate cancer [20–22], antioxidant properties [23] and even it is known as a memory herb [24]. This spice is composed of hydroxybenzoic acid, hydroxycinnamic acid, triterpenic acid, flavonoids,

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and phenolic diterpenes [25] with camphor being one the most important volatile compounds [26]. Camphor, which has a characteristic camphoraceous odour and is used commercially as a moth repellent [27], is credited with specific bioactive effects such as anesthetic effect [28], pesticidal and insecticidal properties [29], antimicrobial activity [30] or mild ex*p*ectorant activity [31]. In addition, it has a precursor borneol, another aromatic compound of rosemary, which is transformed into camphor and may cause the camphor content of rosemary to increase over time [32, 33].

At present, rosemary, which use dates back to the ancient Greece [34], is widely used to the main food dishes on account of its aromatic odour. Rosemary has been used to season other meat products such as salami [35], lamb burgers [36] or dairy products such as cheese [37]. However, it is the first study that determines the effect of rosemary addition in dry-cured ham.

The main purpose of this study is to satisfy part of the consumers demand for new quality meat products, with the addition of low concentrations of rosemary on sliced dry-cured ham in vacuum packaging and checking that the product is to the taste of the consumers. Thus, the sensorial acceptance and physicochemical quality were studied. Furthermore, the transfer of aromatic compounds from rosemary to the sliced ham was evaluated by analysing the camphor content using headspace-stir bar sorptive extraction–gas chromatography/mass spectrometry (HS-SBSE–GC–MS).

Materials and methods

Experimental design

Slices of dry-cured ham were obtained from female Duroc pigs, belonging to the official label "Jamón Serrano TSG", slaughtered with 120 kg of live weight approximately. Animals were raised under intensive conditions and were slaughtered in accordance with the Regulation (EC) No 1099/2009 of 24 September 2009 on the protection of animals at the time of slaughter. Ten dry-cured hams (8 ± 1 kg and pH > 5.6), manufactured by the provider of Benibaldo, S.A.U. (Albacete, Spain), were sliced (0.9 ± 0.1 mm thickness) by a professional ham cutter and the slices, obtained from "maza" area, were deposited in trays (Model 16,409, 26 cm, Manchaplas, S.L., Albacete, Spain) until reaching a weight of 100 g. Then ground rosemary (Sucesores de Muñoz y Pujante, S.L., Cabezo de Torres, Murcia, Spain, with moisture < 15%, essence > 0.5%, total ashes < 12% and insoluble ashes < 3 5%) was added to the trays with a stainless-steel dredger (Model KCFINE, Kitchen Craft, 7.3 × 7.3x9.1, 140 g, Amazon, Spain), in a room at a temperature between 12 ℃ and 15 ℃. All trays were preserved under vacuum conditions with a vacuum machine (Model JB-350/M, José Bernad, S.L.) and vacuum bags (Model 90 M, 350 × 300 mm^2, Gutplask, S.L., Getafe, Madrid, Spain) with an efficiency of 11.4 m^2/kg, tensile strength at break 21–43 MPa, a slow resistance to penetration > 1 N, elongation at break 400–600%, initial sealing temperature > 0.1 ℃, oxygen permeability rate < 70 cm^3/m^2/24 h, water vapour permeability 120–190 g/m^2/24 h, dynamic friction coefficient < 0.50 and surface tension ≥ 38 dyn/cm. After packaging, samples were kept in the dark at 2 ℃ until the analysis. To carry out the objectives of this study, four groups of samples (sachets of ham slices of 100 g each) were prepared: three groups of trays were spiced with different amounts (R1, high: 0.200% w/w; R2, medium: 0.150% w/w and R3, low: 0.100% w/w). A non-spiced control group was prepared.

A total of 192 trays were prepared, of which 20 were used to analyse physicochemical parameters, 160 to determine sensory quality, and 12 to assess the transfer of aromatic compounds from rosemary to sliced ham.

The added rosemary concentrations were established based on the results obtained in a preliminary sensory analysis by 30 members of the university community using a triangle test. Each panellist got three samples for testing the differences among two control samples and another spiced with the lowest concentration of rosemary chosen (0.100% w/w) based on visual appearance. The results were analysed according to [38] who indicated the minimum number of correct answers for a perceptible difference. In this experiment, 24 of 30 panellists answered correctly so, according to the previous author, the perceptible difference was 0.1%. Thus, this concentration was considered the lowest added to dry-cured ham slices.

Analysis of samples

Physicochemical quality (pH and colour parameters)

Physicochemical parameters were assessed in all groups of samples at 0, 7, 14, 28 and 60 days of storage.

pH was measured using a Crison GLP 22 pH-metre (pH & Ion-metre-Crison Instruments, S.A., Barcelona, Spain) connected to a penetration electrode. In each sachet, five measurements were determined directly in slices randomly selected which involved the penetration electrode. The penetration electrode of the pH metre was nailed into the previously rolled slices.

Lightness (L*), redness (a*) and yellowness (b*) were determined using a CR 400 chroma metre (Minolta, Osaka, Japan) equipped with a light source D65 and 10° standard observer angle. Equipment was previously calibrated using a standard white tile. Five readings were registered on the surface of each slice and each value was the mean of three determinations. In addition, the hue angle ($h^* = \tan^{-1} [b^*/a^*]°$) and chroma ($C^* = [a^2 + b^2]^{1/2}$) were calculated [39].

Sensorial quality

A hedonic test was performed at 7, 14, 28 and 60 days of storage to determine the visual appearance, odour and flavour attributes of the three groups of spiced dry-cured ham (R1, R2 and R3). The sensorial analyses were carried out at mid-morning in the test room of the university for 45 min approximately. Before the tasting, the samples were kept at environmental temperature for half an hour.

Thirty panellists, belonging to the university community, participated in this study (the same ones who took part in the triangular test described above; habitual consumers of dry-cured ham; between 20 and 70 years old; 48% women). The participants, all non-trained consumers, received instructions for about 15 min, at the beginning of each session, on how to perform the test.

In each session, three spiced slices, one from each group of samples (R1, R2 and R3), were presented in plastic plates, codified with a number of three-digit code. Mineral water and toasted bread were provided to each panellist for oral cleaning between samples. For each attribute (visual appearance, odour and flavour), panellist evaluated the samples using the next hedonic scale: 1 = "Do not like it", 2 = "Slightly dislike it", 3 = "Neither like it nor dislike", 4 = "Like it" and 5 = "I like it very much".

Analysis of camphor in dry-cured ham

One of the major aromatic compounds of rosemary is camphor [26]. Thus, to study the transfer of the aromatic compounds from rosemary to dry-cured ham, this compound was used as a marker of the transfer that was analysed by HS-SBSE–GC–MS. The chromatographic method is based on that proposed by [8] for saffron. To validate the method, 200 mg of seasoned dry-cured ham from each group was used (each tray was divided into four equal parts and 50 mg were taken from each part) for 7, 14, 28 and 60 days of storage. These 200 mg were introduced into a 10 mL vial. Then the insert and the Twister stir bar [polydimethylsiloxane-coated stir bar, of 0.5 mm film thickness × 20 mm length; Twister, Gerstel GmbH (Mülheim an der Ruhr, Germany)] were placed into the vial. The vials were sealed with an aluminum crimp cap and were introduced in a 30◦C stove for 40 min. These 200 mg were analysed in triplicate to detect and quantify camphor, using 36 total vials.

The volatile compounds were desorbed from Twister using an automated thermal desorption unit (TDU, Gerstel) mounted on an Agilent 7890A gas chromatography system coupled to a quadrupole Agilent 5975C electron ionisation mass spectrometric detector (Agilent Technologies, Palo Alto, CA, USA) equipped with a fused silica capillary column (BP21 stationary phase; 30 m length, 0.22 mm internal diameter and 0.25 µm film thickness; SGE, Ringwood, Australia). The carrier gas was helium with a constant column pressure of 20.75 psi.

The selectivity was evaluated by comparing the chromatograms obtained for each 36 vials analysed, using the majority ion (93) of camphor. The precision of the method exhibited RSD values lower than 2.6%, which showed good selectivity [40]. Regression equation was determined ($y = 10^7x$) and the correlation coefficient obtained was 0.999, indicating good linearity. The method also showed a good sensitivity, the limit of detection was 0.95 µg camphor/100 g dry-cured ham and limit of quantification was 2.89 µg camphor/100 g dry-cured ham.

Mass spectrometry data acquisition was performed in the positive scan mode; Nevertheless, to prevent matrix interferences, the mass spectrometry quantification was performed in the SIM mode using the major ion of camphor.

Statistical analysis

The statistical package SPSS 24.0 version (SPSS Inc., Chicago, IL, USA) was used to analyse the effect of the concentration of ground rosemary added to the slices of dry-cured ham on the physicochemical (pH and colour) and sensorial (visual appearance, odour and flavour) quality and the camphor transfer. First, a Shapiro–Wilk test was determined for checking the normality and a Levene's test of homogeneity of variance. Afterwards, a one-way analysis of variance (ANOVA) was carried out. A Tukey's test at a significance level of $p = 0.05$ was determined to check the differences between pairs of groups. In addition, in each group of samples, an ANOVA test was carried out to test the storage time effect. Pearson correlation coefficients between all parameters measured were estimated. A stepwise discriminant function analysis was carried out to select a linear combination of the independent variables that best allowed differentiating among the spiced groups.

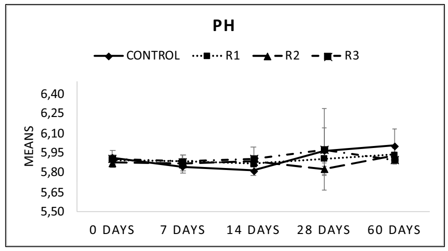
Results

Physicochemical quality (pH and colour parameters)

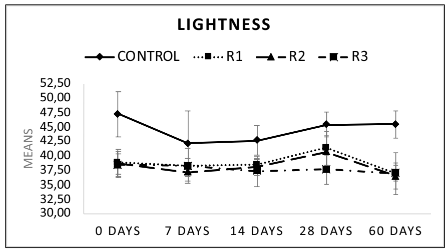
pH and colour parameters' (L*, a*, b*, C* and h*) values in each group of samples of ham slices [control, R1 (0.200% w/w), R2 (0.150% w/w) and R3 (0.100% w/w)] and changes during the storage period are shown in Fig. 1.

No statistical differences were observed among groups at any time in pH. Control group showed a significant increase

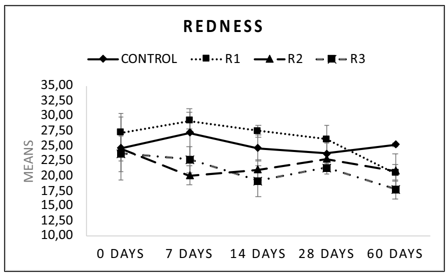
Fig. 1 pH, lightness (L*), redness (a*), yellowness (b*), chroma (C*) and hue (H*) values on sachets of slices of ham spiced with rosemary during storage time. Control: slices of ham without rosemary; R1: 0.200% w/w; R2: 0.150% w/w; R3: 0.100% w/w. NS: no significance. *, ** and *** indicate significance levels at 0.05, 0.01 and 0.001, respectively. **a**–**c** Different letters in the same type of sample indicate significant differences ($p < 0.05$) due to the effect of storage period in the same type of slices. x–z, Different letters at the same time of storage, indicate significant differences ($p < 0.05$) due to the concentration of rosemary



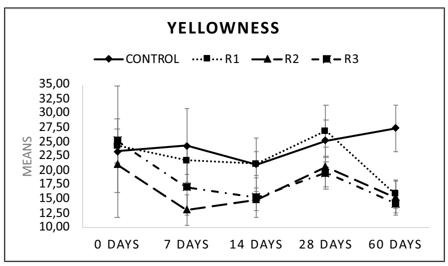
pH					
STORAGE PERIOD (DAYS)	CONCENTRATION				ANOVA
	CONTROL (n=5)	R1 (n=5)	R2 (n=5)	R3 (n=5)	
0	ab				NS
7	ab				NS
14	ab				NS
28	ab				NS
60	b				NS
Effect of storage	*	NS	NS	NS	



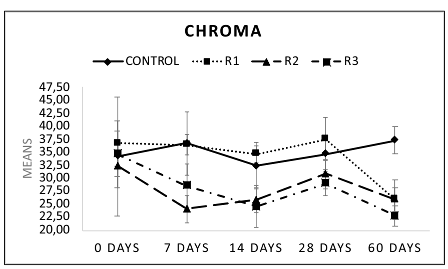
LIGHTNESS					
STORAGE PERIOD (DAYS)	CONCENTRATION				ANOVA
	CONTROL (n=5)	R1 (n=5)	R2 (n=5)	R3 (n=5)	
0	y	x,ab	x,ab	x	***
7		ab	ab		NS
14	y	x,ab	x,ab	x	**
28	y	xy,b	x,b	x	**
60	y	x,a	x,a	x	***
Effect of storage	NS	*	*	NS	



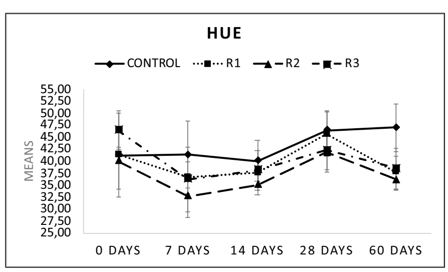
REDNESS					
STORAGE PERIOD (DAYS)	CONCENTRATION				ANOVA
	CONTROL (n=5)	R1 (n=5)	R2 (n=5)	R3 (n=5)	
0		b	b	c	NS
7	yz	z,b	x,a	xy,bc	***
14	y	y,b	x,a	x,ab	***
28	xy	y,b	x,a	x,ab	**
60	y	x,a	x,a	x,a	***
Effect of storage	NS	***	***	***	



YELLOWNESS					
STORAGE PERIOD (DAYS)	CONCENTRATION				ANOVA
	CONTROL (n=5)	R1 (n=5)	R2 (n=5)	R3 (n=5)	
0		ab	ab		NS
7	y	y,bc	x,a	xy	**
14	yz	z,abc	x,ab	xy	**
28	xy	y,c	xy,b	y	*
60	y	x,a	x,ab	xy	***
Effect of storage	NS	***	*	NS	



CHROMA					
STORAGE PERIOD (DAYS)	CONCENTRATION				ANOVA
	CONTROL (n=5)	R1 (n=5)	R2 (n=5)	R3 (n=5)	
0		b	c	b	NS
7	y	y,b	x,a	x,ab	***
14	y	y,b	x,ab	x,ab	***
28	xy	y,b	x,bc	x,ab	**
60	y	x,a	x,ab	x,a	***
Effect of storage	NS	***	***	**	



HUE					
STORAGE PERIOD (DAYS)	CONCENTRATION				ANOVA
	CONTROL (n=5)	R1 (n=5)	R2 (n=5)	R3 (n=5)	
0	y	xy,a	xy,a	y,a	*
7		a	a	ab	NS
14		a	ab	ab	NS
28		b	b	b	NS
60	y	x,a	x,ab	x,ab	**
Effect of storage	NS	***	**	*	

($p < 0.05$) in this parameter from 14 days, reaching values of 6.0, while in spiced samples, a great stability was observed with storage time with values ≈ 5.9.

L* values of spiced samples (R1, R2 and R3) were similar at all times analysed and were higher in the non-spiced samples ($p < 0.001$ at 0 and 60 days; $p < 0.01$ at 14 and 28 days).

The rosemary concentration factor caused significant differences in a* ($p < 0.001$ at 7, 14 and 60 days and $p < 0.01$ at 28 days), b* ($p < 0.01$ at 7 and 14 days, $p < 0.05$ at 28 days and $p < 0.001$ at 60 days), C* ($p < 0.001$ at day 7, 14 and 60 and $p < 0.01$ at day 28) and h* ($p < 0.05$ at day 0 and $p < 0.01$ at day 60).

Regarding the effect of storage time, there was a high stability in lightness, redness, yellowness, chroma and hue in control samples. However, these chromatic coordinates varied in the spiced groups, with different levels of significance depending on the concentration of rosemary added and an evident decrease in the values, especially in the spiced samples with a greater quantity of rosemary (R1). At the end of the experiment, the following order was observed for all colour parameters analysed: control > R1 ≈ R2 ≈ R3.

Sensorial quality

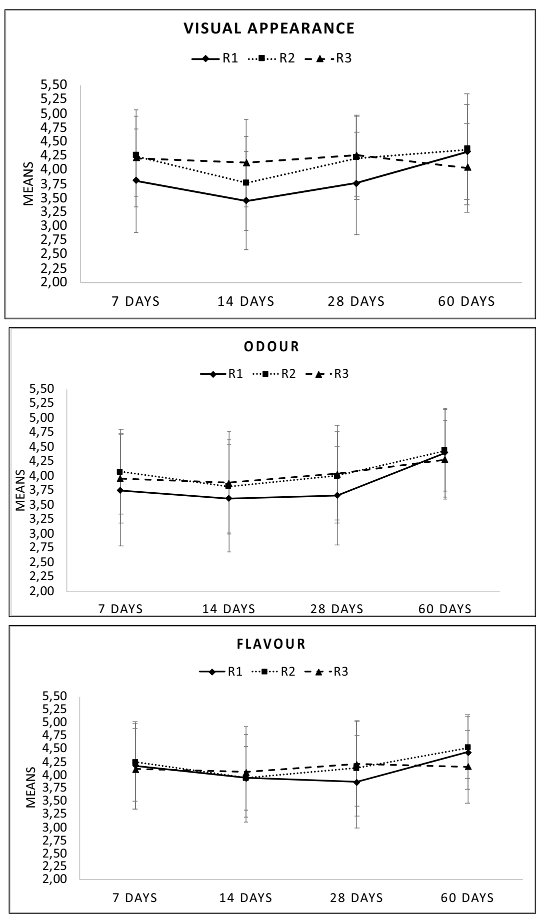
The score given by the panellists with respect to the visual appearance, odour and flavour of seasoned ham slices during the storage period is shown in Fig. 2. Since the purpose was to discover the ideal concentration of rosemary, the sensory tests were carried out by comparing the spiced ham slices. The gender of the panellists did not affect the results. Values were close to 4 (like it) in all time analysed.

The concentration of rosemary added caused significant differences in visual appearance ($p < 0.01$ at 7 and 14 days; and $p < 0.05$ at 28 days) which values followed next trend: R3 = R2 > R1; but differences between groups disappeared at the end of the study. Curiously, the concentration of rosemary did not affect the odour or flavour.

The scores given by the panellists in R1 and R2 samples remained stable until 28 days and then a significant increase was observed (in R1, $p < 0.01$ for visual appearance and odour and $p < 0.05$ for flavour; in R2, $p < 0.05$ for all sensorial parameters). However, a great stability was observed in the sensorial parameters in samples seasoned with the lowest concentration of rosemary (R3), without changes during the study.

Transfer of aromatic compounds from rosemary

Table 1 shows camphor content and its trend throughout the storage time period in spiced samples. No statistical differences were found among groups. R1 and R2 showed a similar trend ($p < 0.05$ in R1 and $p < 0.01$ in R2), with a significant increase at 28 days after adding rosemary and then



VISUAL APPEARANCE				
STORAGE PERIOD (DAYS)	CONCENTRATION			ANOVA
	R1 (n=30)	R2 (n=30)	R3 (n=30)	
7	x,ab	y,ab	y	**
14	x,a	xy,a	y	**
28	x,a	y,ab	y	*
60	b	b		NS
Effect of storage	**	*	NS	

ODOUR				
STORAGE PERIOD (DAYS)	CONCENTRATION			ANOVA
	R1 (n=30)	R2 (n=30)	R3 (n=30)	
7	a	ab		NS
14	a	a		NS
28	a	ab		NS
60	b	b		NS
Effect of storage	**	*	NS	

FLAVOUR				
STORAGE PERIOD (DAYS)	CONCENTRATION			ANOVA
	R1 (n=30)	R2 (n=30)	R3 (n=30)	
7	ab	ab		NS
14	ab	a		NS
28	a	a		NS
60	b	b		NS
Effect of storage	*	*	NS	

Fig.2 Sensory characteristics (visual appearance, odour and flavour) of sachets of slices of ham. Effect of the different added concentration of rosemary. R1: 0.200% w/w; R2: 0.150% w/w; R3: 0.100% w/w. NS: no significance. *, ** and ***, indicate significance levels at 0.05, 0.01 and 0.001, respectively. x, y, values in the same row with different superscript are significantly different due to the group. **a**, **b**, Values in the same column with different superscript are significantly different due to the different storage period (0, 7, 14, 28 and 60 days)

a decrease, reaching similar values to those shown at the beginning of the experiment. A great stability was observed in the spiced samples with the lowest concentration of rosemary (R3).

Table 2 represents the correlation between camphor content with the rest of parameters analysed. There were significant correlations ($p < 0.05$) with odour ($r = 0.61$) and with pH ($r = -0.59$) for R1 and R2, respectively.

A stepwise discriminant function analysis was carried out to select a linear combination of the independent parameters (physicochemical, sensorial characteristics and camphor content) that best allowed differentiating among groups, at 7, 14, 28 and 60 days. The parameters that truly marked the difference among groups are presented in Table 3. According to our study, it was found that the variables that discriminated the different groups varied over time. Camphor

Table 1 Determination of camphor (µg / 100 g ham ± s.d.) in sachets of sliced dry-cured ham during the storage period

Parameter	Storage period (days)	Concentration			ANOVA
		R1 ($n = 3$)	R2 ($n = 3$)	R3 ($n = 3$)	
Camphor	7	17.73 ± 1.67^{ab}	19.39 ± 2.58^{ab}	17.67 ± 2.37	NS
	14	10.99 ± 5.63^{a}	12.95 ± 3.89^{a}	22.28 ± 6.49	NS
	28	24.07 ± 4.01^{b}	29.37 ± 7.61^{b}	21.27 ± 4.51	NS
	60	16.96 ± 2.06^{ab}	14.27 ± 2.41^{a}	21.33 ± 15.47	NS
Effect of storage period		*	**	NS	

* and ** indicate significance levels at 0.05 and 0.01, respectively

^{a,b}values in the same column with different superscript are significantly different for the different storage period (7, 14, 28 and 60 days)

R1 0.200% w/w, *R2* 0.150% w/w, *R3* 0.100% w/w rosemary, *NS* no significance, *s. d.* standard deviation

Table 2 Correlation coefficients between camphor content with sensory and physicochemical parameters

Group	Visual Appearance	Flavour	Odour	pH	L*	a*	b*	C*	h*
R1	0.42	0.32	0.61*	– 0.97	0,25	– 0.15	0.19	0.05	0.34
R2	0.30	0.40	0.36	– 0.59*	0.48	0.37	0.56	0.51	0.57
R3	0.50	– 0.18	0.45	0.08	– 0.57	– 0.31	– 0.20	– 0.30	– 0.09

R1: 0.200% w/w, *R2* 0.150% w/w, *R3* 0.100% w/w

*indicates correlation significant at the 0.05 level

Table 3 Canonical discriminant functions: standardised canonical discriminant function coefficients at 7, 14, 28 and 60 days of storage

Storage period (days)	Function 1			Function 2		
	Variance (%)	Parameter	Standardised coefficient	Variance (%)	Parameter	Standardised coefficient
7	93.00	Odour	– 3.42	7.00	Camphor	– 2.46
		Flavour	3.17		pH	2.37
		Camphor	2.84		L*	1.63
14	100	pH	5.04			
		Odour	3.45			
		Flavour	2.69			
28	93.30	pH	3.26	6.70	Odour	1.05
		Flavour	2.67		L*	0.96
		Odour	– 1.82		Visual Appearance	– 0.57
60	86.10	Flavour	3.81	13.90	a*	1.62
		pH	1.90		Flavour	– 1.46
		Visual appearance	– 1.89		Odour	1.39

content discriminated at 7 days and pH, odour and flavour discriminated in all storage period.

Discussion

Physicochemical quality

pH

The slightly increase in the pH values of control group during the storage period is in agreement with the findings of [41] in stored sliced dry-cured ham for 63 days. It is also in accordance with [42] in dry-cured beef. In contrast, [43] on the effect of storage under vacuum conditions for 8 months on dry-cured ham quality, reported a decrease in pH during storage time.

As no previous studies have investigated the use of rosemary for seasoning dry-cured ham, its addition in cured ham could only be compared with the study of [14], who noticed a decrease in pH with time during the same storage period in sliced ham seasoned with saffron. Authors, such as [44], used rosemary in dry ewe sausages and pointed out a significant increase of pH during drying process. Our values of pH were unaffected by the different concentrations of rosemary both between groups and with storage time. Other authors also showed the stability of this parameter with the addition of rosemary powder in salchichón [45].

The initial pH of raw pork leg contributes to the final texture of dry-cured ham [46]. However, when the curing process is complete, the pH is essential to prevent the growth of pathogenic microorganisms [47]. Cured ham is a ready-to-eat meat product [48] that is not subjected to high temperatures that inhibit the growth of these pathogens [49]. For this reason, it is necessary a pH < 6.0 [50] and combined with other factors such as low water activity and keeping sliced ham at refrigeration temperatures [51]. For this reason and based on the pH results obtained in our study, we could conclude that the addition of rosemary to cured ham slices could prevent the growth of pathogens. This is in agreement with [52] who investigated the sensitivity of *Listeria monocytogenes* to rosemary in ready-to-eat pork liver sausages.

Colour parameters

Colour plays a strong role in the daily life of humans [53] which is one of the most decisive attributes that can define consumer preferences [54] and willingness to purchase [55]. It can be judged by the eye [56] and is considered the major indicator of product quality [57] being part of the sensorial acceptance of dry-cured ham [58]. Nevertheless, colour is influenced by lots of factors such as breed, pH, temperature, packaging or lightning [59] and even the addition of spices [14], other ingredients and additives [60, 61].

In general, the addition of rosemary caused significant differences overall colour parameters. Changes in the L* value negatively affect consumers' purchase intention [62], as it is a parameter that reveals colour changes [63]. The stability of the L* coordinate in control group during storage coincides with [64], who studied sliced vacuum-packed dry-cured ham during 120 days and determined that L* remained constant throughout all storage period. Nevertheless, the addition of rosemary in our study caused significant differences in the groups seasoned with the highest concentrations (R1 and R2) of rosemary. This contrasts with the results caused by the addition of other spices like saffron, as shown by the results of [14].

According to [65], redness indicates colour stability and is important for cured ham colour fading measurements [66, 67]. The decrease in a* coordinate with time in seasoned groups could be attributed to the oxidation and changes of red pigments that provoke browning in dry-cured meat products [68]. However, in our study, this decrease could be related to the carotenoids and chlorophylls responsible for rosemary's colour strength [44, 69] that change over time. [70], who studied the effect of rosemary on the colour of dried sausages, showed that redness increased in sliced dry sausages kept in dark at refrigeration temperatures. Therefore, the raw material to which this spice is added could have a different effect on the evolution of a* during storage time.

According to [71], b* parameter express both the chromatic (a*) and the exudative (L*) aspects of meat colour. In our study, a* and b* parameters in seasoned groups varied significantly during storage time (except b* in R3). By contrast, [14] reported a great stability in a* and b* parameters in ham slices in vacuum packaging during storage time at 60 days. This demonstrates the different effect that the spice used can have on the colour of dry-cured ham.

Chroma (C*), considered the quantitative attribute of colourfulness [72] and hue (h*), considered the qualitative attribute of colour [73], are the main parameters to the objective determination of colour differences [74]. There are no previous studies that have analysed the effect of rosemary on the colour of sliced cured ham; therefore, our results provide the first data. In other products such as dry sheep sausage, [44] observed a significant decrease in C* but a stable h* in the study of the effect of rosemary.

Sensorial quality

Sensory properties of meat products have a considerable influence on the acceptance of these products by consumers, stablishing a subjective opinion of their quality [75]. Hedonic tests are considered one of the best methods for judging food quality as it is essential for the development of new products in food industry [76].

Many authors [77–79] have studied the sensory characteristics of ham. Other authors [80, 81] have studied the addition of spices effect in other cured meat products but, this study is the first to our knowledge to determine the sensory properties of rosemary-flavoured sliced ham. On the other hand, the trend towards the consumption of healthier meat products by consumers without artificial additives or colouring agents [82], favours the use of spices, since they can provide their characteristic odour and flavour [83] introducing new healthy meat products to the market.

Sensory attributes varied throughout storage period in R1 and R2 with higher scores at the end of the storage. However, all groups were to the taste of the panellists. Changes in visual appearance suggest that the decrease values of colour parameters (Fig. 1) lead to greater consumers' acceptability. It should be noted that the increase in odour and flavour values at 60 days in R1 and R2 could correspond to a better integration of the aromatic compounds with the cured ham.

The acceptance of seasoning by the panellists throughout the study has also been cited by [14] in which all groups of dry-cured ham seasoned with saffron were accepted at any time of storage. In contrast, other experiences indicating the acceptability of dry-cured ham during storage, obtained lower scores because of its brownish appearance and the increase of rancid odour and flavour in vacuum-packed slices [11, 84]. According to [85], it is indicative of lipid oxidation that provokes the decrease of food acceptability [86] (note that we did not do analyses of lipid oxidation). In our study, the acceptability of dry-cured ham during storage period could be due to the addition of rosemary, which could mask the colour of ham and the effect of lipid oxidation or reduce it by its antioxidant properties [87].

Transfer of aromatic compound from rosemary

Since rosemary aromatic compounds are not in dry-cured ham [88], to determine the transfer from rosemary to ham, the camphor content, one of the major aromatic compounds of rosemary, was calculated [87].

In R1 and R2, there was a decrease of camphor from 7 to 14 days. This decrease was detected by consumers, who gave lower scores at day 14 than at 7 days to seasoned dry-cured ham. At 28 days after adding rosemary, there was a significant increase in camphor content which was not detected by consumers. Finally, there was a rapid decrease of camphor at 60 days, similar values to those shown at the beginning of the experiment. This decrease, as opposed to our results from 7 to 14 days, significantly increased the punctuation to sliced dry-cured ham. A great stability was observed in R3.

The method validated used to determine the transfer of aromatic compounds only could analyse the camphor in the surface layer of the slice. Thus, it could explain higher camphor content at 7 days. At 14 days, camphor could be absorbed because fat is a lipophilic medium that absorbs apolar substances, such as aromatic compounds, reducing its content in the surface layer of the slices. The internal layers could become saturated at day 28 due to the rapid absorption from day 7 and the transformation of borneol to camphor [32, 33]. At 60 days, the recovering of the initial values could be due to all layers absorbed the aromatic compounds and the method only detected camphor content in the surface layer. It should be noted that panelists could have detected camphor content in all layers of the ham slice, awarding the highest scores. This evolution also occurs with other aromatic compounds such as safranal, as shown by the results of [14] whose precursor is picrocrocin.

Previous studies such as [89–91] have analysed the relationship between volatile compounds with sensory parameters of different types of ham. However, due to the novelty of this study, we have not found information on the relationship between camphor concentration and ham quality parameters. On the other hand, the main aromatic compound of rosemary (camphor) correlated positively and significantly with odour ($p < 0.05$; $r = 0.61$) in the group with the highest concentration of rosemary (R1). This contrasts with what was obtained in a previous study on ham [14], in which a similar result ($r = 0.65$) was observed among the main aromatic compound of saffron (safranal) with the same sensory parameter, but in the spiced samples with the lowest concentration of saffron. This demonstrates the different power that spices can have in food matrices.

Conclusion

The addition of rosemary caused a high stability on the pH; however, colour parameters changed during storage time with a decrease of the values (particularly in R1). All concentrations of rosemary added affected positively to sensory characteristics with values close to 4 (like it). Camphor varied throughout storage at medium and high concentration of rosemary. At the end of the experiment, the rosemary aromatic compounds were integrated with the ham.

Lastly, it could be interesting to study the effect of other spices on the quality of dry-cured ham and even other cured meat products to increase this range of products and thus, meet consumers demand for healthier meat products.

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data curation, E.M.G.-S., writing—original draft preparation, E.M.G.-S., H.V., and G.L.A.; writing—review and editing, E.M.G.-S., H.V., and G.L.A.; visualisation, E.M.G.-S., H.V., and G.L.A.; supervision, H.V. and G.L.A.; project administration, H.V. and G.L.A.; funding acquisition, G.L.A. All authors have read and agreed to the published version of the manuscript.

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Declarations

Conflict of interest The authors declare no conflict of interest.

Compliance with ethics requirements The study does not involve research on human participants and/or animals.

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