



RESEARCH ARTICLE

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Replacing soybean meal with Narbon vetch (*Vicia narbonensis* L.) in pig diets: composition of subcutaneous fat and fresh loin, and sensory attributes of dry-cured product

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Abstract

Aim of study: To evaluate the consequences for pork quality traits of replacing soybean meal with Narbon vetch in pig diets.

Area of study: Castilla-Leon, Spain.

Material and methods: 48 Duroc × Iberian barrows were fed diets with 0% (V0), 5% (V5), 10% (V10) and 20% (V20) inclusion of Narbon vetch. Pork quality traits investigated were 1) intramuscular fat, protein and moisture content of fresh loin, 2) fatty acid composition of subcutaneous fat, and 3) sensory attributes (Triangle test and a Simple Difference Test with a non-trained taste panel) of cured loin.

Main results: Inclusion of Narbon vetch in the diet showed no significant effect on intramuscular fat, protein and moisture in fresh loin samples. Stearic acid was higher in subcutaneous fat of V5 than in V0 and V10 ($p < 0.05$), and oleic acid was higher in V10 than in V0, V5 and V20 ($p < 0.05$); no other differences in fatty acid composition were observed. Taste panelists tended to be able to distinguish V10 from V0 cured loins ($p < 0.10$), and were able to distinguish V20 from V0 loins ($p < 0.05$), in particular due to a perceived difference in taste, texture and marbling. No differences in intensity of the texture, marbling, aroma and color of cured loins were found between V0 and V5.

Research highlights: Inclusion of Narbon vetch in pig diets did not significantly affect fresh loin composition or fatty acid composition of subcutaneous fat. Consumers perceived a difference in sensory characteristics of cured loin with replacement of soybean meal with Narbon Vetch, but they did not characterize this as more favorable.

Additional key words: sustainable pig production; local feed crops; meat quality; taste panel; soybean replacement; chemical composition; fatty acid composition; sensory attributes.

Abbreviations used: IMFat (intramuscular fat); IMM Moist (intramuscular moisture); IMProt (intramuscular protein); SFA (saturated fatty acids); UFA (unsaturated fatty acids)

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Introduction

Because of the unsustainability of reliance on imports of soybean meal in Europe, the European Union is calling for research focusing on alternative feed resources based on local agricultural production. "Localization" of feed production is generally considered more sustainable because it requires less energy for transport, and it improves local economic viability (Wägeli *et al.*, 2016). Narbon vetch (*Vicia narbonensis* L.) is well adapted to the Mediterranean climate (Nadal Moyano *et al.*, 2012). The crop is currently marginally produced in Spain, in particular in the autonomous community of Castilla y León, but neither the size of the land cultivated nor its production obtained is known with certainty (Gomez Izquierdo *et al.*, 2020a). This local legume is resistant to unfavorable climatic and soil conditions and to common pests, and has a positive nutritional profile (Gómez-Izquierdo *et al.*, 2018). Its production yield varies between 470 and 4000 kg/ha, and can reach a yield of over 5000 kg/ha on fertile soils, surpassing that of common legumes (Franco-Jubete & Ramos, 1996). With a protein content between 21 to 30%, a relatively high amount of sulfur-containing amino acids, and a low fat content, its nutritional composition is higher than that of several other legume species (Gomez Izquierdo *et al.*, 2020a). For example, Narbon vetch was reported to have a protein content of 25% compared with 18% in a black bean variety, 21% in a spring bean variety, 23% in a winter bean variety and 19% in bitter vetch (Gómez Izquierdo *et al.*, 2020b). Furthermore, Kökten *et al.* (2010) reported that the unsaturated fatty acid content of 80.1% was similar to five other *Vicia* species (between 77.6% and 83.1%), but with 29.9% it was richer in oleic acid whereas with 48.5% it was lower in polyunsaturated fatty acids than the other *Vicia* species (between 7.7% and 15.8%, and between 65.6% and 73.5%, respectively). However, in pig feeds, the presence of γ -glutamyl-S-ethenyl-cysteine (GEC) in Narbon vetch results in an unpleasant taste (Enneking & Maxted, 1995). Gomez Izquierdo *et al.* (2020b) described in pigs that, as a consequence, this resulted in a decreased daily feed intake and body weight gain for up to four weeks after introduction of Narbon vetch in the diet; however, since the reduction in body weight gain was proportional to that in feed intake, it resulted in a mostly nonsignificant reduction in feed efficiency. They concluded that economic implications of substituting commercial diets with Narbon vetch will depend on the extra total amount of feed that may be required and associated feed costs, and on the fixed cost of additional days on-farm that are required to reach a given slaughter weight.

Rauw *et al.* (2020) discussed that a potential reduction in profitability with inclusion of local feed ingredients in pig diets may be compensated when products can be sold

as differentiated products and by opening up innovative market opportunities. This is feasible when meat quality improves with inclusion of local feed ingredients (Lebret, 2008). Consequences of inclusion of Narbon vetch in pig diets for the composition of pork and meat quality traits have not been investigated so far.

The objective of this study was to investigate the consequences for pork quality traits of substituting different levels of soybean meal with Narbon vetch. We investigated three independent measures of pork quality in Duroc \times Iberian pigs: 1) intramuscular fat, protein, and moisture content of fresh loin; 2) fatty acid composition of subcutaneous fat, and 3) sensory attributes of cured loin.

Material and methods

Animals, management, and diet formulations

Forty-eight individually-marked Duroc \times Iberian barrows, originating from the company San Jamón, were used in this experiment; one pig died for unknown reasons and was removed from the experiment. A growth and feeding trial was conducted at the Porcine Testing Center of Castilla-Leon (ITACyL) in Hontalbilla, Segovia, between the 28th of December 2018 and the 25th of April 2019; the effect of inclusion of Narbon vetch on production traits has been described by Gomez Izquierdo *et al.* (2020b). The Spanish policy for the protection of animals used in research and other scientific purposes RD53/2013 (BOE, 2013) was followed in this experiment. The project was approved by the ITACyL Ethics Committee on Animal Experimentation, reference number 2018/37/CEEA.3.

For each of four dietary treatments, a total of 12 pigs were housed individually in one of 4 adjacent rooms (3 pigs per treatment per room). Between 0 to 53 days of the trial, a growth diet was fed; a fattening-finishing diet was fed between d 54 and 125 of the trial. Within each of the growing and fattening-finishing diets, four different compositions were formulated. In diets V0, V5, V10, and V20, soybean meal was substituted with 0%, 5%, 10%, and 20% of Narbon vetch (*Vicia narbonensis* L.), respectively. These feed formulations were kept both during the growing period and during the fattening-finishing period (Tables S1 and S2 [suppl]; Gomez Izquierdo *et al.*, 2020b). A random sample of all formulated feeds was analyzed by the Porcine Testing Center (CPP). Fatty acid composition of each of the diets is given in Table 1. During the entire experiment, water and feed were provided *ad libitum*. Body weight was measured approximately weekly during the 125d trial, and daily body weight gain, daily feed intake, and daily feed conversion efficiency were estimated for each of 16 periods; those results were described by Gomez Izquierdo *et al.* (2020b).

Table 1. Fatty acid composition^[1] of the diets in the growing phase and the fattening-finishing phase, including 0 (V0%), 5 (V5%), 10 (V10%), and 20% Narbon vetch (V20%).

Content (%)	Growing period			
	V0	V5	V10	V20
C12:0	0.03	0.18	0.15	0.19
C14:0	0.42	0.42	0.46	0.37
C16:0	16.75	15.93	15.91	15.72
C16:1	0.67	0.65	0.73	0.56
C17:0	0.12	0.11	0.12	0.11
C17:1	0.10	0.09	0.10	0.08
C18:0	4.54	4.19	4.52	3.75
C18:1	29.70	30.58	32.41	29.1
C18:2	43.04	43.46	41.39	45.4
C18:3	3.70	3.49	3.25	3.9
C20:0	0.28	0.31	0.30	0.30
C20:1	0.65	0.60	0.65	0.52
Content (%)	Fattening-finishing period			
	V0	V5	V10	V20
C12:0	0.11	0.11	0.22	0.06
C14:0	0.57	0.49	0.64	0.42
C16:0	17.65	16.81	17.57	15.97
C16:1	0.96	0.86	1.04	0.83
C17:0	0.13	0.13	0.14	0.12
C17:1	0.12	0.11	0.12	0.09
C18:0	5.13	4.64	5.49	4.26
C18:1	34.89	34.56	36.12	33.85
C18:2	37.41	39.25	35.65	41.28
C18:3	2.00	2.04	1.95	2.13
C20:0	0.29	0.31	0.31	0.34
C20:1	0.73	0.69	0.74	0.65

^[1] Fatty acid composition is expressed as a percentage of the fatty acids included in the study.

Intramuscular fat, protein and moisture in loin

On the 26th of April, 2019 (day 126 on trial), all animals were slaughtered at the commercial processing plant “El Navazo” in Fuentes de Bejar, Salamanca, Spain. Pigs were stunned, exsanguinated, scaled, and eviscerated according to standard commercial procedures. Entire loins (*Longissimus dorsi*) were removed from the vertebral column. Because meat characteristics may differ in different parts of the muscle (Norman *et al.*, 2004), in a sample with a thickness of approximately 2 to 3 cm, taken from the top part of the loin (closer to the head), intramuscular fat (IMFat), protein (IMProt) and moisture (IMMoist) were analyzed by near-infrared spectroscopy (NIRS) as described by Solís *et al.* (2001), with a relative expanded uncertainty of 3.7% for

moisture, 6.5% for protein and 11.6% for fat. Briefly, samples were minced in a meat mincer. Homogenized samples were inserted in circular quartz crystal capsules of 3.8 cm in diameter. The near-infrared spectrum was read with a spectrometer (Foss Iberia, FossNIRSystem 6500), between 400 and 2500 nm. The average of two readings was used for determination of IMFat, IMProt, and IMMoist with the program WINISI (ISI, 1998).

Out of the 47 pigs, 10 pigs per treatment were selected with a body weight closer to the average slaughter weight of 174 kg (\pm 9.78); of these animals, one loin was taken from the left side of the carcass. Loins were trimmed of external fat, and kept 24 h at a temperature of 3 °C. Loins were then rubbed with curing agents (18 g NaCl, 1.8 g NO₃, and 1.8 g NO₂ per kg loin) and kept for six days at a temperature of 4 °C and a humidity level of over 75%. After the salting process, loins were stuffed into artificial casings where they underwent the drying/ripening process for at least 69 days at a room temperature of 10 °C and a humidity level of over 75%. The drying process was carried out at ‘Cárnicas y Embutidos Tabanera’ in Bernardos, Segovia, Spain. Loins were then individually vacuum-packed, and stored in the dark at 3 °C until they were presented to the taste panel between two and four months later.

Subcutaneous fatty acid composition

For all animals, subcutaneous fat samples were taken 10 cm from the tail insertion area in the coxal region of the carcass. Analysis of subcutaneous fat samples is a common procedure in Iberian pig production (Pérez-Palacios *et al.*, 2008). Fatty acids analyses were carried out using gas chromatography (Agilent Technologies, 7890B GC System), as previously described by Delgado-Chavero *et al.* (2013), and following the rules established by the Spanish government (BOE, 2004). Fatty acids included the percentage lauric acid [C12:0], myristic acid [C14:0], palmitic acid [C16:0], palmitoleic acid [C16:1], margaric acid [C17:0], margaroleic acid [C17:1], stearic acid [C18:0], oleic acid [C18:1 n-9], linoleic acid [C18:2 n-6], α -linolenic acid [C18:3 n-3], arachidic acid [C20:0], and gadoleic acid [C20:1]. Percentage of saturated fatty acids (SFA) was calculated by adding C12:0, C14:0, C16:0, C17:0, C18:0, and C20:0; percentage of unsaturated fatty acids (UFA) was calculated by adding C16:1, C17:1, C18:1 n-9, C18:2 n-6, and C18:3 n-3. Fatty acid composition was expressed as a percentage of the fatty acids included in the study.

Sensory characteristics of loin

Cured loins were sliced with an industrial meat slicer in homogeneous slices of 1.2 mm thickness. In order to minimize variation due to sampling location,

5 cm of both extremes of the loin were discarded. Slices from all ten loins were mixed and kept at room temperature prior to testing. Untrained taste panel members were chosen among workers at ITACyL in the region of Castilla y León (10th of October 2019) and INIA in the region of Madrid (5th of December). The tests took place at these institutions. At each institution, 46 panelists were first tested with the Triangle test followed by a Simple Difference Test. Panelists at ITACyL were between 25 and 72 years old (47 ± 13); panelists at INIA were between 26 and 67 years old (45 ± 9). At ITACyL, participants consisted of 18 females and 23 males; 5 persons did not disclose their gender. At INIA, participants consisted of 30 females and 15 males; one person did not disclose his or her gender. All panelists were familiar with the cured loin product.

The tests took place in a room following the Spanish norm for the design of test rooms, UNE-EN ISO 8589:2010 (UNE-EN, 2010a), and in the presence of three researchers at each trial and session. A brief orientation session was given prior to the test to familiarize the panelists with the test procedures and product characteristics. In the Triangle test, as described by Meilgaard *et al.* (2016) and according to the Spanish norm UNE-EN ISO 4120:2008 (UNE-EN, 2008), panelists were individually presented with three samples of one slice of loin each, labelled A, B, and C. Panelists were instructed that two samples were identical and one was different. The objective of this test was to determine whether a sensory difference exists between loins from pigs fed with soybean meal ingredients *vs.* a Narbon vetch replacement. In the trial at ITACyL, the samples in the Triangle test consisted of loins from V0 *vs.* V10; at INIA, the samples in the Triangle test consisted of loins from V0 *vs.* V20. Plates were prepared in excess of expected number of participants; the odd slice of loin was allocated consecutively to label A, B, or C; plates were randomly presented to the participants. At ITACyL, for 21 out of 46 panelists, the odd slice was V0 while for 25 out of 46 panelists the odd slice was V10; at INIA, for 23 out of 46 panelists the odd slice was V0 while for the other 23 panelists the odd slice was V20. Participants were asked to explain why they felt the sample was different.

After the triangle test, the same panelists proceeded with a Simple Difference Test, as described by Meilgaard *et al.* (2016) and according to the Spanish norm UNE-ISO 8587:2010 (UNE-EN, 2010b), in which they were individually presented with two samples of one slice of loin each, labelled A and B. The objective of this test is to determine whether a sensory difference exists between loin from pigs fed with soybean meal ingredients *vs.* a Narbon vetch replacement. Both at ITACyL and at INIA, the samples consisted of one slice V0 and one slice V5 loin. This comparison was chosen because 5% of Narbon vetch inclusion in the diet resulted in the smallest reduction in

daily feed intake and body weight gain in pigs during the growing-finishing-fattening phase (Gómez Izquierdo, 2020b). Participants were asked which sample they preferred and if this was due to the perceived texture, taste, marbling, aroma and/or color. Participants were furthermore asked to rate the intensity of the texture, marbling, aroma and color on a scale from 1 (little) to 10 (much), and indicate whether they liked these traits more, less or similarly than their usual preference. Finally, participants were asked if they were willing to buy the product: yes, no, or 'depends on the price'.

Statistical analysis

The SAS program (SAS Institute, Cary, NC, USA) was used for the statistical analyses. Parameters IMFat, MProt, IMMoist and fatty acid composition in subcutaneous fat samples were analyzed with the following model (PROC GLM):

$$Y_{ij} = \mu + \text{Treatment}_i + e_{ij}, \quad (1)$$

where Y_{ij} = the parameter measured on animal j , and Treatment_i = effect of dietary treatment i (fixed effect; V0, V5, V10, V20); $e_{ij} \sim \text{NID}(0, \delta^2 e)$. The effect of room was removed from the model since it was not significant. Following Jørgensen & Pedersen (1998), because meat composition and fatty acid compositions are based on proportions, values were transformed, after dividing by 100, with the logit transformation for analysis ($g(x) = \ln(x/(1-x))$). Least squares means are presented of back-transformed values ($g^{-1}(y) = \exp(y) / (1+\exp(y))$). Since the standard errors are based on the logit transformed values and cannot be back-transformed, they are not presented. Partial Pearson correlation coefficients between the traits were estimated after adjusting for the effect of treatment.

Significance of the number of correct responses in the triangle test was tested within trial (conducted at ITACyL *vs.* INIA) following the table of minimum number of correct responses required for significance provided by Meilgaard *et al.* (2016). In the Attribute Difference Test, a linear effect of age on preference (V0 *vs.* V5) and degree of preference (more, less or similarly than their usual preference) was tested with the multinomial logit model (PROC CATMOD) including the effect of age. Non-linear effects of age (after grouping age in five categories: less than 30, 30 to 40, 40 to 50, 50 to 60, and 60 to 72 years of age), sex (male, female) and location (ITACyL, INIA) were tested independently with the frequency procedure (PROC FREQ); the non-parametric chi square test was used when the expected numbers were greater than 5, else, the Fisher's exact test was used. Following Norman (2010), ratings of the intensity of the texture, marbling, aroma and color (on a 10-point scale) of loin from V0 and V5 were analyzed with a parametric method.

The individual repeated measurements on samples from V0 and V5 were analyzed with the following model:

$$Y_{ij} = \mu + \text{Treatment}_i + e_{ij}, \quad (2)$$

where Y_{ij} = the parameter measured on animal j , Treatment_i = effect of treatment i (V0, V5); $e_{ij} \sim \text{NID}(0, \delta^2 e)$. ‘Treatment’ was identified as the repeated effect in the model for each panelist. The unstructured variance-covariance structure was used for repeated measures analysis; the model included the random effect of the individual. Data are presented as means \pm S.E.M. Results are determined statistically significant with associated p -levels of 0.05 or less.

Results

Different levels of inclusion of Narbon vetch in the diet showed no significant effect on IMFat, IMProt or IMMoist in loin samples (Fig. 1a), or fatty acid composition of C12:0, C14:0, C16:0, C16:1, C17:0, C18:2, C18:3, C20:0, C20:1, SFA, and UFA in subcutaneous fat samples (Fig. 1a,b) ($p > 0.05$). The only significant

effect was detected in C18:0, where levels were higher in V5 than in V0 and V10 ($p < 0.05$; Fig. 1a), and in C18:1, where levels were higher in V10 than in V0, V5 and V20 ($p < 0.05$; Fig. 1a). In addition, the proportion of UFA/SFA was 1.88 (± 0.03) in V0, 1.82 (± 0.03) in V5, 1.90 (± 0.03) in V10, and 1.83 (± 0.03) in V20; UFA/SFA was lower in V10 than in V0, V5, and V20 ($p < 0.05$).

In the Triangle Test, of 46 panelists, a total of 21 correct responses were registered at ITACyL and 22 correct responses at INIA. Following the table of minimum number of correct responses required for significance provided by Meilgaard *et al.* (2016), this indicates that panelists at ITACyL tended to distinguish between loins from V0 and V10 ($p < 0.10$), and panelists at INIA were able to distinguish between loins from V0 and V20 ($p < 0.05$). At ITACyL, 11 panelists identified correctly V10, and 10 panelists identified correctly V0 as the odd sample; at INIA, 9 panelists identified correctly V20, and 13 panelists identified correctly V0 as the odd sample. When only considering panelists that correctly identified the odd sample, both at ITACyL and INIA, panelists indicated that taste, and to a lesser extent texture, was the most

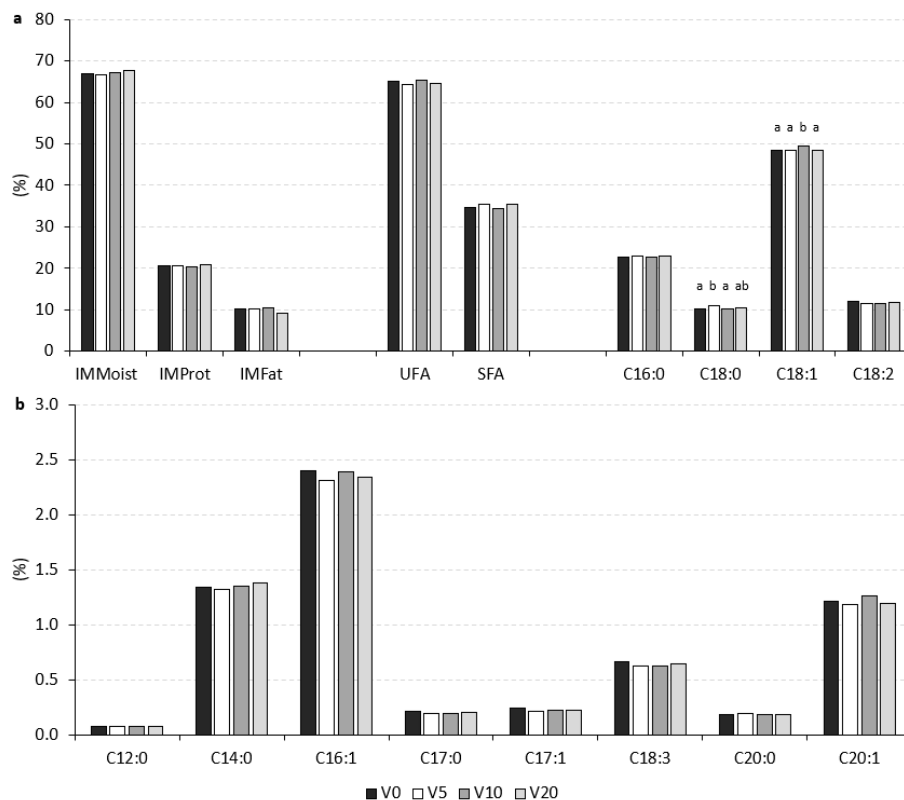


Figure 1. Least squares means of (a) intramuscular moisture (IMMoist), protein (IMProt), and fat (IMFat) content in loin samples, and percentage of unsaturated fatty acids (UFA), saturated fatty acids (SFA), palmitic acid [C16:0], stearic acid [C18:0], oleic acid [C18:1 n-9], linoleic acid [C18:2 n-6], and (b) lauric acid [C12:0], myristic acid [C14:0], palmitoleic acid [C16:1], margaric acid [C17:0], margaroleic acid [C17:1], α -linolenic acid [C18:3 n-3], arachidic acid [C20:0], and gadoleic acid [C20:1] of subcutaneous fat samples. Note the difference in scale between Fig. 1a and Fig. 1b. Fatty acid composition is expressed as a percentage of the fatty acids included in the study.

distinguishable feature; at ITACyL, panelists also distinguished both loin samples based on marbling; color and aroma were mentioned as a distinguishing feature in less than 10% of the cases (Fig. 2).

None of the effects of age (both linear and after grouping), sex and location were significant in the Attribute Difference Test ($p > 0.05$). Overall, 67% of panelists regarded the color of V5 loin samples to be better than usual, while 57% of panelists regarded the color of V0 loin samples to be better than usual ($p < 0.001$, Fig. 3); 91% of panelists regarded the texture of V5 loin samples to be better than usual, while 83% of panelists regarded the texture of V0 loin samples to be better than usual ($p < 0.001$, Fig. 3). Significantly more panelists indicated they regarded the aroma of the loin samples to be same or better than usual in V0 (58%) than in V5 (42%; $p < 0.05$, Fig. 3). When only panelists were considered that successfully passed the Triangle Test, the results were very similar (results not presented). Average ratings, on a 10-point scale, of the intensity of the texture, marbling, aroma and color did not significantly differ between loin from V0 and V5 (Fig. 4; $p > 0.05$); when only panelists were considered that successfully passed the Triangle Test, the results were very similar and non-significant ($p > 0.05$).

Overall, 53% of panelists preferred loin from V0 and 47% preferred loin from V5; 81% of panelists affirmed they would buy loin from V0 or depending on the price, while 83% of panelists affirmed they would buy loin from V5 or depending on the price. A slightly higher percentage of panelists that successfully passed the Triangle Test preferred loin from V0 (60%) over loin from V5 (40%); 93% of those panelists affirmed they would buy loin from V0 or depending on the price, while 78% of those panelists affirmed they would buy loin from V5 or depending on the price (Fig. 3). These results were not significant, indi-

cating that panelists had no preference for loin from V0 or V5 ($p > 0.05$).

Discussion

Because of a favorable nutritional composition, which is higher than that of several other legume species, the animal feed industry is interested in substituting soybean meal with locally produced Narbon vetch in Spain (AGROPAL, 2015, 2017; Gomez Izquierdo, 2020a). However, it is crucial that inclusion of Narbon vetch does not negatively affect meat quality and sensory attributes of pork (Grunert *et al.*, 2004). If meat quality and sensory attributes improve, this may facilitate product differentiation which may open up novel market opportunities. Meat quality and sensory attributes of fresh and cured pork are influenced by several parameters, including composition, color, water-holding capacity and texture (Ryu *et al.*, 2008). In addition, stress reactions of pigs at slaughter may diminish meat quality parameters (Terlouw, 2005). In the present study we analyzed three different pork quality characteristics: 1) intramuscular fat, protein, and moisture content of fresh loin; 2) fatty acid composition of subcutaneous fat, and 3) sensory attributes of cured loin.

Intramuscular fat, protein and moisture in fresh loin

High levels of intramuscular fat contribute to reduced moisture losses during meat processing since lean shows a higher diffusion rate for water than fat; therefore, IMFat determines the technological properties of the meat for dry-curing (Ventanas *et al.*, 2005). In addition, high IMFat is closely and positively related to flavor, juiciness, marbling, color, and tenderness of dry-cured loin (Warner, 2017; Nieto *et al.*, 2019). Ventanas *et al.* (2007b) showed that Spanish consumers preferred dry cured loins with higher IMFat content, which received better scores for preference and juiciness. Our results indicate that substituting different levels of soybean meal with Narbon vetch did not significantly affect intramuscular fat, protein, or moisture in fresh loin samples.

Subcutaneous fatty acid composition

Pigs deposit lipids that originate from dietary fatty acids and de novo synthesis of fatty acids (mostly short-chain fatty acids) (Kloareg *et al.*, 2007). Since the pig is a monogastric animal, its fatty acid composition is a reflection of the dietary fatty acids, therefore, nutrition is the main factor through which fatty acid composition in pigs

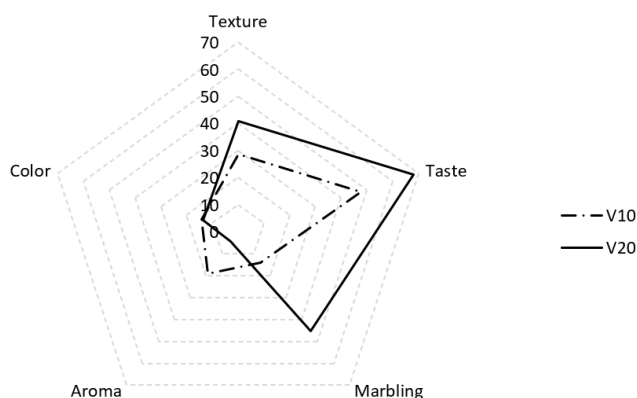


Figure 2. Percentage of panelists who indicated that texture, taste, marbling, aroma, and/or color was the distinguishing feature between loin samples from V10 vs. V0 (V10), and between loin samples from V20 vs. V0 (V20). Of 46 panelists in each group, 25 people (V10) and 24 people (V20) that were unable to correctly answer the Triangle Test were excluded.

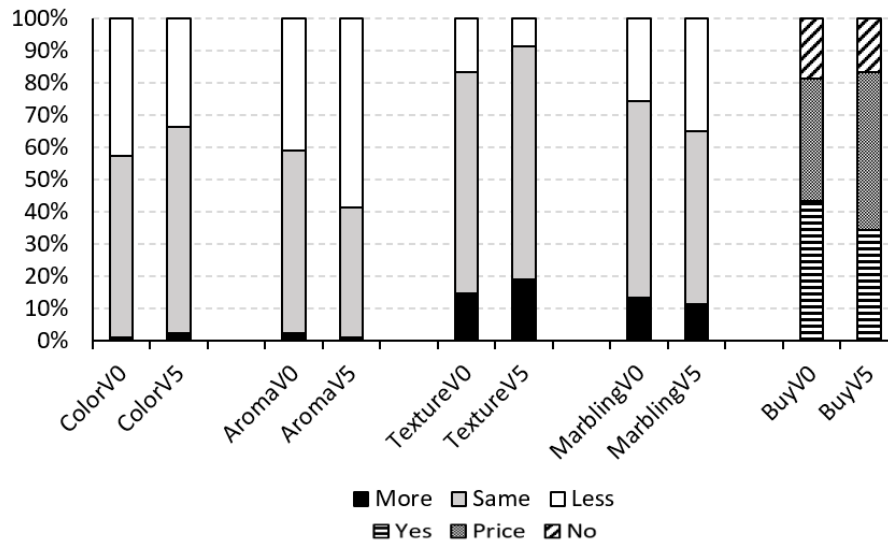


Figure 3. Hundred-percent stacked columns of the percentage of panelists that indicated they liked the color, aroma, texture, and/or marbling ‘more’, ‘the same’, or ‘less’ than usual in loin samples of V0 and V5, and hundred-percent stacked columns of the intention to buy loin from V0 or V5 (‘yes’, ‘depends on the price’, ‘no’).

may be altered (Raes *et al.*, 2004; Kloareg *et al.*, 2007). In the present study, fatty acid composition of the feed ingredients Narbon vetch *vs.* soybean meal were not individually analyzed. However, in the study of Lee *et al.* (2013), soybean meal was high in linoleic acid (C18:2; 55%), oleic acid (C18:1; 16%), palmitic acid (C16:0; 13%), and linolenic acid (C18:3; 10%), whereas Narbon vetch varieties were shown to have a linoleic acid content of 44-52%, an oleic acid content of 25-30%, a palmitic acid content of 8-15%, and a linolenic acid content of 3-5% (Lo Presti *et al.*, 2008; Kökten *et al.*, 2010; Renna *et al.*, 2014). Based on those estimates, it could be expected that the oleic acid content would increase when a larger proportion of soybean meal is substituted with Narbon vetch. However, in the present study, there was no indication of a linear effect of amount of Narbon vetch inclusion on fatty acid composition of the diets, likely because the

content of other feed ingredients (barley and wheat) also changed to some extent. Instead, the significantly higher content of oleic acid in subcutaneous fat of pigs fed diet V10 coincides with a higher overall oleic acid content in diet V10 in the fattening-finishing phase. In contrast, the stearic acid content was highest in the diets V0 and V10 but lowest in the associated subcutaneous fat samples. This could result from *de novo* synthesis of, for example, oleic acid from dietary stearic fatty acid (Kloareg *et al.*, 2005). Our results show that substituting different levels of soybean meal with Narbon vetch did not affect other fatty acid contents of subcutaneous fat.

Fatty acid metabolism and profile may differ between IMFat and subcutaneous fat, between IMFat of different muscles, and between samples taken at different positions (Raj *et al.*, 2010). Ros-Freixedes *et al.* (2014) observed that measurements of oleic acid, SFA, mono- and polyunsaturated fatty acids were positively phenotypically correlated between the same fatty acid measurement taken in subcutaneous fat, lumbar multifidus (LM) muscle, or gluteus medius (GM) muscle ($r = 0.34$ to 0.63). The benefit of sampling of subcutaneous fat is that it reduces depreciation cost of sampling from high value retail cuts (Ros-Freixedes *et al.*, 2014). Because fatty acid composition is a reflection of the dietary fatty acids, in Spain, fatty acid profile of subcutaneous fat sampled at the coxal region is used as a descriptor for Iberian ham authentication and fraud detection based on their feeding regime of acorns (Niñoles *et al.*, 2007; González-Domínguez *et al.*, 2020). Because of moderate to high heritability estimates, Gjerlaug-Enger *et al.* (2011) suggested that fatty acids in subcutaneous fat sampled at the coxal region could be used for genetic improvement of fatty acid composition

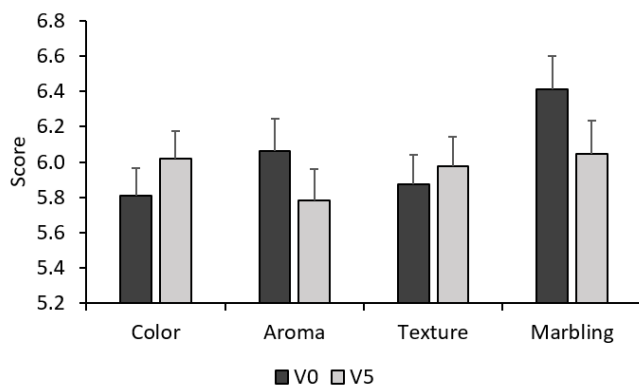


Figure 4. Average ratings, on a 10-point scale, of the intensity of the color, aroma, texture, and marbling between loin from V0 and V5.

towards favorable changes in eating quality, improved human nutrition, and technological quality of pork products. According to Ruiz *et al.* (1998), fatty acid profile in muscle reflects the feeding regime during the last phase of feeding, whereas the fatty acid profile in subcutaneous fat reflects longer term differences.

Various studies reported a positive effect of unsaturated fat content on juiciness and tenderness of fresh meat and meat products, whereas other studies found no effect (Ruiz-Carrascal *et al.*, 2000). Although little is known about the relationship between fatty acid composition and sensory attributes of dry-cured products, Ruiz-Carrascal *et al.* (2000) found that hardness, dryness and fibrousness of dry-cured ham was inversely related with the content of oleic and palmitoleic acids. High oleic fatty acid content of pig fat, resulting from an acorn diet rich in oleic acid, is partly responsible for the high-quality taste of dry-cured products from free-range Iberian pigs (Jurado *et al.*, 2008). Iberian pigs fed indoors are fed diets low, medium, or high in oleic acid content; the higher the oleic acid content, the higher the quality of dry-cured products but also the costlier (Carrapiso *et al.*, 2020). For example, Ventanas *et al.* (2007a) showed that feeding Iberian pigs indoors a diet with high-oleic sunflower oil partially imitates the composition and quality traits of hams from free-range pigs fed high-oleic acorns. Since the oleic acid content of Narbon vetch is approximately twice that of soybean meal (Kökten *et al.*, 2010; Lee *et al.*, 2013), more research is needed to investigate whether diets can be formulated with Narbon vetch that result in increased dietary oleic acid content for improved pork quality traits.

Sensory characteristics of loin

Although, in the present study, substitution of different levels of soybean meal with Narbon vetch showed little to no effect on the meat quality traits considered, taste panelists tended to be able to distinguish loins from V10 from those of V0, and were able to distinguish loins from V20 from those of V0, in particular due to a perceived difference in taste, texture and marbling, but not in color or aroma. This suggests variation in meat characteristics resulting from Narbon vetch inclusion that were not analyzed in this study. When asked to score the intensity of texture, marbling, aroma and color of loin from pigs fed 0% vs. 5% Narbon vetch, no differences were found. In addition, no significant difference existed in the panelists' intention to buy V0 or V5 loins. Further research should investigate whether inclusion at levels higher than 5% will result in differentiated scores.

The results do not suggest that pork products from pigs fed different levels of Narbon vetch have the potential to be sold as a differentiated product based on their

sensory characteristics. Alternatively, consumers' interest in locally produced food is steadily increasing and consumers are willing to pay a higher price for animal products produced with local feed resources (Feldmann & Hamm, 2015; Profeta & Hamm, 2019). For example, Wägeli *et al.* (2016) concluded that the use of local feeds could be an option for successful product differentiation in the organic animal products market. Therefore, the potential of differentiated market opportunities based on local feed resources in Duroc × Iberians pigs might be investigated.

Conclusions

Substitution of different levels of soybean meal with Narbon vetch showed little to no effect on the pork quality traits considered in this study. Although taste panelists were able to distinguish loins from V20 from those of V0, no difference in intensity of the texture, marbling, aroma and color of dry-cured loin was found between V0 and V5 loins. Therefore, this study found no negative effect of inclusion of Narbon vetch on meat quality or sensory attributes of pork, but no indication that would support product differentiation based on improved consumer perception. Alternatively, the possibility of product differentiation based on a 'locally produced' label should be further investigated.

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