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SHORT COMMUNICATION

Feeding finishing heavy pigs with corn silages: effects on backfat fatty acid composition and ham weight losses during seasoning

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ABSTRACT
The effect of diets containing corn silages (whole ear or high cut whole plant corn silages, WECS and HCCS, respectively) on fatty acid composition of back fat and the weight loss of thighs during the seasoning process were examined in Italian heavy pigs (from 90 to 160 kg of live weight). Two trials were conducted in the same farm, following an identical experimental protocol. In both trials, a control diet, based on dry corn, barley, wheat, extracted soybean meal, wheat bran and supplement (47, 23, 10, 9, 8 and 3% dry matter (DM), respectively) was compared with a diet containing 30% DM of WECS (trial 1) or 20% DM of HCCS (trial 2) in substitution of bran and part of the corn. The initial fresh weight of thighs was very homogeneous between the two trials and only at the end of seasoning the hams from pigs fed the corn silage diets were slightly lighter (of about 0.5 kg, $p < .05$). The dietary inclusion of corn silages determined a significant increase of the saturated fraction of the back fat (from 40.6 to 41.9%, $p < .05$), mainly due to the increase of the C 18:0 fatty acid (from 14.3 to 15.2%, $p < .05$). Overall, the calculated iodine value was favourable for the fat of pigs fed silages (62.63 vs. 64.24, $p = .05$). In conclusion, feeding corn silages to heavy pigs has limited impact on seasoning ham losses and can slightly improve backfat quality, in terms of fatty acid composition.

Abbreviations: HCCS: high cut whole plant corn silage; LW: live weight; NDF: neutral detergent fibre; WECS: whole ear corn silage.

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Introduction

The great part of pigs born in Italy is reared and fattened for a period of about 9 months to reach live weights (LW) of 160–170 kg and provide several meat cuts suitable for the processing industry. The fresh thigh is the most valuable cut and is used for a long seasoning process to obtain appreciated dry-cured hams labelled with the Protected Designation of Origin (PDO, e.g. 'prosciutto' brands such as Parma, San Daniele, Toscano, etc., Bosi & Russo 2004). Within the PDO regulations the list of permitted feeds includes the silages obtained from the corn plant, such as the whole ear corn silage (WECS) and the high cut whole plant corn silage (HCCS, growing phase only). Corn silages are farmland grown resources, which do not need drying energy consumptions and therefore support farm sustainability. Moreover, they have potential dietetic benefits thanks to their fibre content, which favours the satiety of animals and reduces the gastric mucosa damages (Mason et al. 2013). Despite these positive aspects, both WECS and HCCS are not commonly used in fattening pigs since they are considered too coarse and fibrous. Moreover, they can depress growth and feed conversion, as reported by Scipioni and Martelli (2001) for diets with high contents of whole plant corn silage (50% DM) fed during the whole growth period.

However, our recent studies (Capraro et al. 2014; Zanfi et al. 2014; Galassi et al. 2017) demonstrated that corn silages can be included at moderate levels (e.g. 20–40% dry matter, DM) in diets for finishing heavy pigs without, or with limited detrimental effects (in the case of HCCS), both on growth and the main slaughtering traits.

These results encouraged us to further develop our studies by examining possible effects of diets containing coarse WECS and HCCS on the fatty acid composition of fat and the weight loss of thighs during the 'prosciutto' processing.

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Materials and methods

The experimental data were obtained from two feeding trials, which were detailed descripted in previous published papers (Zanfi et al. 2014; Galassi et al. 2017). All animals were cared for in agreement with the current law (Legislative decree No. 116/1992) and here we give only a synthetic description of the trials.

The two trials were conducted in the same farm and followed an identical experimental protocol. In both trials, 'Italian Large White × Italian Duroc' barrows (about five months of age and 90 kg of LW) were grouped into pairs, homogeneous for LW and kept in pens (1.2 × 3 m, partially-slatted) equipped for a free access to drinking water and with two separate troughs to avoid feed intake competitions between the two pigs. Within trials, each experimental diet was fed to a group of 7 pens (for a total of 14 pigs) on a restricted feeding scale (about 75-80 g DM/Kg $LW^{0.75}$) and the daily ration was divided into two equal portions at 08.00 and 16.00. Animals were weighted every 2-weeks periods to monitor growth and adjust the intake.

In both trials, a control diet (C), based on dry corn, barley, wheat, extracted soybean meal, wheat bran and supplement (47, 23, 10, 9, 8 and 3% DM, respectively) was compared with a diet containing WECS (30% DM, WECS30, trail 1) or 20% DM of HCCS (HCCS20, trial 2) in substitution of wheat bran and part of the corn. The metabolisable energy intake resulted similar for C diets (39.3 and 38.3 MJ/d, respectively for trial 1 and 2) and slightly higher for WECS30 than HCCS20 diet (38.5 vs. 35.7 MJ/d).

The animals were slaughtered by electrical stunning at an average LW of 167 (±3.6) and 163 (±1.9) kg, in trial 1 and 2 respectively, and then were exsanguinated. The carcasses were weighted and dissected into commercial cuts.

Thigh weights

The left thigh of each pig was weighed immediately after slaughter, chilled (0–2 °C) for 24 h, trimmed to obtain the typical round-shape ham and then sent to the factory located in the municipality of 'San Daniele del Friuli, Udine, Italy' (two different factories, one for each trial) for seasoning. The thighs were weighed at the arrival and then five times during the 'prosciutto' curing process in correspondence with its main phases (i.e. after salting, before resting, after drying, during and at the end of dry curing, see Table 1, MIPAAF 2007).

Table 1. Main phases of the ham process for the *Prosciutto di San Daniele* production (MIPAAF, 2007).

Preliminary phase (length: 1–5 d after the slaughtering). At the slaughter house the fresh thighs (weight higher than 11 kg) are refrigerated (from −1 to +4 °C), some superficial parts of skin and fat and lean tissues are removed to endow the typical shape to the ham and then transferred to the ham factory.
Salting phase (length: a number of days equal to the thighs weight in kg). Thighs, after a further trimming treatment, are covered with sea salt, in horizontal position and are maintained at a temperature from 0 to 3 °C.
Resting phase (length: 60–90 d, according to thighs size). Thighs are maintained at a relative humidity of 70–80% and at 4–6 °C.
Dry curing preparation phase (length: 7–8 d, water rinsing and drying). Thighs are maintained at a relative humidity of 80–90% and at 15–24 °C.
Dry curing phase (length: 8–9 months, according to thighs size). Thighs are maintained at ambient temperature and humidity in curing halls without any treatment a part from the application (one or two times) of a grease mixture (named 'stuccatura' or 'sugnatura') to the superficial portion of the ham not covered by the skin.
Overall dry curing length from the thighs arrival at the ham factory to the end of dry curing process: 11–12 months (according to thighs size)

Fatty acid profiles

Fatty acid profiles were analysed on 56 samples of back fat (28 for each trial). Samples of 150 to 200 g of tissue were collected right after slaughter from the back fat at loin (approx. between the third and the fourth last ribs) and minced; two aliquots of 2.5 g per sample were used for lipid extraction. Lipids were extracted according to the methanol–chloroform method of Folch et al. (1957) and fatty acid methyl esters (FAME) were prepared according to Christie (1993). Then FAME were separated by gas chromatography according to Renaville et al. (2013) and quantified using C19:0 as internal standard. Data were expressed as g/100 g of total fatty acids.

Iodine value was calculated according to AOCS (1998) equation: (C16:1*0.95) + (C18:1*0.86) + (C18:2*1.732) + (C18:3*2.616).

Statistical analysis

The statistical analysis of the data was performed according to the following two factorial designs by using the pen as the experimental unit (average data of two animals):

$$Y_{ijk} = \mu + D_i + T_j + (D * T)_{ij} + e_{ijk}$$

where: Y_{ijk} = dependent variable; μ = general mean; D_i (i = 1,2) dietary treatment effect; T_J (J = 1,2) trial effect; $(D^*T)_{ij}$ interaction; e_{ijk} = residual error.

Results and discussion

The four experimental diets (Zanfi et al. 2014; Galassi et al. 2017) had similar contents of crude protein, neutral detergent fibre (NDF) and ether extract (e.g. ranges of 13–15, 15–16 and 3–4% DM, respectively), with the only exception for a higher NDF content of the HCCS diets (18–19% DM). Both WECS and HCCS were not milled and maintained their original coarse physical form with an average dimension of particles of about 3 and 8 mm, respectively.

The weight loss of the fresh thigh during the whole manufacturing ham process consists of material and water losses. To assure a suitable shape and conformation to the thighs some superficial parts of skin, fat and lean tissues are removed from the internal and upper surface of the refrigerated thigh at the slaughterhouse. Then, thighs are further trimmed on arrival at the ham factory (Table 1). However, the greatest part of the weight loss of the fresh thigh is a physical process, consisting of a progressive dehydration of the thigh. This phenomenon is helped by the salt penetration into the thigh meat, which determines a reduction of water activity and consequently a loss of water thanks to osmosis conditions. The initial fresh weight of thigh (Table 2) was very homogeneous between the two trials (range 17.3–17.7 kg), given the similar weight of animals at slaughter and the same genetic type used in both trials. During seasoning, the weights were not different between treatments and only at the end of the process the hams from pigs fed on corn silage diets were slightly lighter (of about 0.5 kg, $p < .05$). The whole seasoning weight loss (range 30–31%) are in line with the values (28–31%) reported for four genetic types of heavy pigs by Piasentier et al. (2011) and are moderately higher than those recently reported by Della Casa et al. (2009), Mordenti et al. (2012) and Cecchinato et al. (2013). However, the hams obtained from pigs fed silages showed weight losses not significantly different from those of animals fed control diets.

It is well known that the intensity of dehydration is inversely related to the depth of fat covering the thigh (Gou et al. 1995), which, in turn, is highly related to the back fat depth at loin (Cecchinato et al. 2013). The moderate reduction of ham weight associated to silage feeding is only partially explained by the variation of fat deposition measured in the trials. In fact, the results of our previous trial 2 indicate that HCCS reduced the fat deposition, in terms of backfat weight ($p < .05$) and depth at loin (not significant). Instead, in trial 1, the WECS inclusion entailed less evident differences in fat deposition, with no impact on backfat weight and a small increase in fat depth. Overall, the silage feeding had a very limited effect on weight losses during the dry-curing of hams.

Fresh and whole seasoning weight losses were similar between trials, while some intermediary weights differed, probably because of some differences in seasoning procedure in the two factories where the thighs were processed.

The preferred fatty acid profile of meat fat depends on the quality criteria adopted. In fact, in terms of consumer health it would be preferable to

Table 2. Weights of thighs after slaughtering and during the dry curing process.

	Diets[a] (D)		Trial (T)		Effect			
	Control	Corn silages	1	2	D	T	D × T	RMSE
Thigh weights, kg								
Warm[b]	17.76	17.23	17.31	17.68	0.13	0.30	0.92	0.90
Cold[c]	15.09	14.61	15.23	14.46	0.11	0.01	0.87	0.78
After salting[d]	14.11	13.86	14.64	13.27	0.46	<0.01	0.46	0.87
Before resting[e]	13.27	12.82	13.80	12.22	0.20	<0.01	0.88	0.77
After drying[f]	11.86	11.51	12.09	11.27	0.17	<0.01	0.97	0.70
During dry curing[g]	10.81	10.35	10.73	10.40	0.21	0.18	0.90	0.63
End of dry curing[h]	10.46	9.97	10.47	9.92	0.04	0.03	0.88	0.64
Weight losses, %								
Preliminary phase[i]	14.98	15.22	12.04	18.17	0.53	<0.01	0.99	1.00
After salting[j]	6.49	5.13	3.89	7.82	0.18	<0.01	0.32	2.91
Before resting[j]	12.06	12.26	9.41	15.13	0.99	<0.01	0.63	1.81
After drying[j]	21.14	21.21	20.64	21.75	0.91	0.14	0.56	1.90
During dry curing[j]	28.28	29.06	29.56	27.75	0.23	0.02	0.38	1.86
End of dry curing[j]	30.64	31.73	31.31	31.10	0.17	0.79	0.36	1.98

[a]Control: control diets; Corn silages: diets containing WECS or HCCS; RMSE: Root Mean Square Error.
[b]About 30 min after the slaughtering.
[c]The day after the slaughtering at the ham factory.
[d]At the end of the salting phase.
[e]At the beginning of the resting phase.
[f]120 days from the start of the ham curing.
[g]180 days from the start of the ham curing.
[h]390 days from the start of the ham curing.
[i]Weight loss calculated between the thigh weights (2) and (3).
[j]Progressive weight losses as percentage of thigh cold weight (3).

Table 3. Fatty acid profiles in back fat of heavy pigs.

	Diets[a] (D)		Trial (T)		Effect			
	Control	Corn silages	1	2	D	T	D × T	RMSE
Fatty acid, %[b]								
C12:0	0.07	0.07	0.08	0.06	0.18	<0.01	0.80	0.01
C14:0	1.30	1.34	1.36	1.27	0.15	<0.01	0.82	0.10
C15:0	0.04	0.05	0.03	0.06	0.28	<0.01	0.39	0.02
C16:0	24.54	24.95	24.48	25.01	0.18	0.08	0.92	0.84
C16:1	1.74	1.77	1.78	1.73	0.49	0.37	0.46	0.22
C17:0	0.32	0.31	0.26	0.37	0.78	<0.01	0.52	0.06
C18:0	14.32	15.16	14.10	15.37	0.02	<0.01	0.32	1.21
C18:1 n-9	41.25	40.45	42.24	39.46	0.09	<0.01	0.86	2.10
C18:1 n-7	2.18	2.21	1.89	2.50	0.74	<0.01	0.37	0.20
C18:2 n-6	13.62	13.07	13.26	13.43	0.21	0.69	0.70	1.57
C18:3 n-3	0.63	0.62	0.52	0.73	0.97	<0.01	0.22	0.08
SFA	40.58	41.88	40.31	42.15	0.03	<0.01	0.52	1.79
MUFA	45.17	44.42	45.90	43.69	0.16	<0.01	0.75	2.23
PUFA	14.25	13.70	13.78	14.16	0.23	0.41	0.67	1.63
Calculated iodine value	64.24	62.63	63.97	62.90	0.05	0.17	0.51	2.29

[a]Diets: Control, control diets; Corn silages, diets containing WECS or HCCS. RMSE: Root Mean Square Error.
[b]Percentage of total determined fatty acids.
SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids.

have a decrease of saturated fatty acid (SFA) to reduce several risks, primarily represented by coronary disease (Wolfram 2003). On the contrary, from a technological and sensorial perspective of quality, a high proportion of polyunsaturated fatty acids (PUFA) causes the formations of oxidation complex, which alter the flavours and reduce the firmness and cohesiveness of fat.

As can be seen form Table 3, the fatty acid composition of back fat is similar to that reported from others (Corino et al. 2002; Sardi et al. 2006; Piasentier et al. 2009) in the Italian heavy pigs, with a partition of 40:45:15 between SFA, mono-unsaturated (MUFA) and PUFA respectively. The 'trial effect' was significant for the majority of fatty acid contents. This result can be affected by several experimental conditions because the two trials were carried out in two different periods. However, some general trends can be highlighted. The dietary inclusion of silages determined a significant increase of the saturated fraction (41.88 vs. 40.58%, $p < .05$), mainly due to the increase of the C 18:0 fatty acid (15.16 vs. 14.32%, $p < .05$) and a tendency of reduction of the C 18:1 n-9 (40.45 vs. 41.25%, $p = .09$). Overall, the calculated iodine value was favourable for the fat of pigs fed silages (62.63 vs. 64.24, $p = .05$).

It is well known the impact of dietary fat composition on fats deposited in pig tissues (Wood et al. 2003). However, in our trials the levels of dietary fat were low and very close among the experimental diets, given that corn silages mainly substituted the dry corn. On the contrary, diets differed for the dimension of feed particles, because the silages were included in diets in coarse form. In trial 1, the diet inclusion of WECS determined a lower faeces pH that was attributed to the passage of undigested material in the gut and to its consequent fermentation in the lower digestive tract. This phenomenon could have some implications on fatty acid composition. In particular, a high proportion of short chain fatty acids produced by fermenting bacteria could be absorbed in the lower digestive tract. In a recent metabolic experiment on pigs, a colonic fermentation was stimulated by diets containing indigestible starch (resistant starch or arabinoxylans; Ingerslev et al. 2014). In comparison with diets based on cereal meals, the measured concentrations of volatile fatty acids were approximately double in the different sites of measure (mesenteric artery, portal and hepatic vein) as well as in the net portal flux.

Data available from present trials do not allow us to investigate the reasons of the observed backfat fatty acid variations. It could be possible that the inclusion of coarse corn silages stimulates the fermentation activity in the lower tract of the intestine and the supply of volatile fatty acids, which can partly be used for the lipid synthesis. However, the increase of C 18:0 fatty acid and the concomitant tendency of C 18:1 n-9 reduction in subcutaneous tissue might also be attributed to an inhibitory effect on the enzyme delta 9 desaturase.

Conclusions

In conclusion, feeding corn silages to heavy pigs has a limited impact on seasoning ham losses and can slightly improve backfat quality, in terms of fatty acid composition.

Disclosure statement

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this article.

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