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Effect of the inclusion of dry pasta by-products at different levels in the diet of typical Italian finishing heavy pigs: Performance, carcass characteristics, and ham quality

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ABSTRACT

The effect of pasta inclusion in finishing pig diets was evaluated on growth performance, carcass characteristics, and ham quality. Pigs (144) were assigned to 4 diets with different pasta levels: 0 (control, corn-based diet), 30, 60, or 80%. Pigs fed pasta had greater (linear, $P < 0.01$) feed intakes than controls. Pasta increased (quadratic, $P < 0.01$) carcass weight and dressing percentage reaching the highest values at 30% inclusion level, and reduced (linear, $P < 0.01$) the *Longissimus thoracis et lumborum* thickness. Pasta decreased (linear, $P < 0.01$) linoleic acid and polyunsaturated fatty acid levels in subcutaneous (fresh and seasoned hams) and intramuscular (seasoned hams) fat, and enhanced saturated fatty acid content in subcutaneous fat (fresh hams: quadratic, $P < 0.01$; seasoned hams: linear, $P = 0.03$). Proteolysis index, colour, weight losses, and sensory properties (excepted extraneous taste) of the hams were unaffected by the pasta. Pasta could be considered as an ingredient in the diet for typical Italian finishing heavy pigs.

1. Introduction

The Italian heavy pig breeding (from 150 to 170 kg BW) provides fresh thighs for Protected Designation of Origin (PDO) ham production (Bosi & Russo, 2004). Parma and San Daniele hams are the most representative typical seasoned ham products in Italy (Laureati et al., 2014). Traditionally, corn is the cereal grain most used in heavy pig diets because of its high starch content (Della Casa et al., 2010). Nevertheless, there is an interest for the use of alternative ingredients because of the high levels of linoleic acid and carotenoid pigments present in the fat component of corn, which may yield yellow-coloured ham from thighs with soft subcutaneous fats prone to oxidative modifications. Therefore, corn can be included in pig diets at the maximum level of 55% (on a dry matter basis) as established by the Parma and San Daniele hams' Consortia (Consorzio del Prosciutto di Parma, 2015; Consorzio del Prosciutto di San Daniele, 2015).

Wheat containing food by-products such as dry pasta by-products are often available to pig producers for diet formulation. Pasta is a food rich in starch (68.1%), low in fats (1.4%), and with an average protein content of 10.9%, on an as-fed basis (Istituto Nazionale di Ricerca per gli Alimenti e la Nutrizione, 2009). In Italy, pasta can only be made with durum wheat as legally established (Decreto del Presidente della Repubblica, 2013). Since the lower contents of linoleic acid (NSNG, 2010) and yellow pigments of wheat compared with corn (Abdel-Aal, Akhtar, Zaheer, & Ali, 2013), dry pasta by-products could represent an alternative ingredient to corn in diet formulation for heavy pigs for the production of Italian PDO ham products. However, nowadays the rules of the Parma and San Daniele hams do not admit pasta as an ingredient in the diet for fattening pigs.

The aim of the study was to evaluate the effect of the inclusion of dry pasta by-products at different levels as an alternative ingredient in diets for finishing pigs on growth performance, carcass characteristics, and fresh and seasoned Parma ham quality.

2. Materials and methods

The experiment was performed at the CERZOO Research Center (San Bonico, Piacenza, Italy). Animal care and use practices during this trial conformed to the guidelines of the European Parliament and Council (2010/63/EU Directive).

2.1. Animals, housing, and experimental design

One hundred and forty-four Italian Duroc × PIC pigs (72 females and 72 castrated males; initial BW: 103 ± 3 kg), coming from commercial breeding, were used as experimental animals. The pigs were initially weighed and allotted to 4 homogeneous groups for sex (castrated males and females) and initial BW. Then, pigs were randomly allotted to 1 of 4 dietary treatments. There were 6 pens per treatment (3 females

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and 3 castrated males) for a total of 24 pens (6 pigs per pen; 1.5 m^2/pig). Animals were kept under controlled environment (temperature and ventilation) and the temperature and relative humidity were within 19 ± 2 °C and 60 ± 5%, respectively. The lighting was natural throughout the study.

2.2. Dietary treatments

Four experimental diets (Table 1) were formulated to contain 4 levels of dry pasta by-products (0, 30, 60, 80%). Diets were the following: 1) control corn-based diet (CTR) where corn was within the maximum level allowed by regulation of the PDO Parma ham (Consorzio del Prosciutto di Parma, 2015); 2) diet with 30% of dry pasta by-products (P30); 3) diet with 60% of dry pasta by-products (P60); and 4) diet with 80% of dry pasta by-products (P80). The pasta by-products were supplied by Rummo S.p.A. (Benevento, Campania, Italia). The diets were formulated to be iso-nutritive according to the requirements for high performing pigs (Manini et al., 1997). All the diets were prepared and pelleted by a feed company (Ferrari SRL, Sarmato — Piacenza, Emilia Romagna, Italy). The pigs had access to feed and water for ad libitum consumption. The experimental diets were fed for 91 consecutive days (experimental period), after a 6 day pre-experimental period of adaption. No medicated feeds were used throughout both the periods. Before the pre-experimental period, the pigs were fed with a commercial diet.

Table 1
Ingredients and chemical composition of the experimental diets.[a]

	CTR	P30	P60	P80
Ingredients (%)				
Corn meal	60.00	30.00	–	–
Dry pasta by-products[b]	–	30.00	60.00	80.00
Barley meal	15.00	15.00	15.00	–
Soybean meal (50% crude protein)	11.77	7.80	3.54	3.60
Soft wheat bran	5.00	11.50	15.00	6.19
Soft wheat meal	3.34	–	0.14	–
Dried beet pulp	2.00	3.00	4.00	4.00
Soybean hulls	–	–	–	4.00
Tallow	0.63	0.50	–	–
Calcium carbonate	0.98	0.98	0.93	0.81
Sodium chloride	0.50	0.39	0.35	0.35
Bicalcium phosphate	0.25	0.25	0.25	0.25
Premix[c]	0.20	0.20	0.20	0.20
Phytase[d]	0.10	0.10	0.10	0.10
Endo-1,4-β-xylanase[e]	0.05	0.05	0.05	0.05
Lysine HCl (78%)	0.17	0.17	0.33	0.34
Threonine L	0.01	0.05	0.09	0.09
Methionine DL	–	0.01	0.02	0.02
Chemical composition (% as-fed basis)				
Dry matter	89.21	90.04	90.55	90.51
Crude protein	13.33	13.56	13.65	13.67
Ether extract	3.54	2.93	1.62	1.07
Crude fibre	3.27	3.31	3.37	3.49
Ash	3.59	3.56	3.54	3.27
Total starch	49.85	52.22	54.05	54.96
Rapidly digested starch (% of total starch)	48.51	68.02	87.18	91.17
Slowly digested starch (% of total starch)	45.04	26.69	10.88	8.46
Resistant starch (% of total starch)	6.45	5.29	1.94	0.37
Predicted glycemic index[f]	68	82	97	105
Linoleic acid	1.59	1.11	0.80	0.44
Lysine	0.72	0.73	0.73	0.72
Methionine	0.22	0.22	0.22	0.22
Methionine + cystine	0.46	0.48	0.49	0.49
Threonine	0.50	0.50	0.50	0.49
Tryptophan	0.14	0.15	0.16	0.16
Digestible energy (MJ/kg)	14.35	14.47	14.54	14.52
Net energy (MJ/kg)	10.76	10.86	10.90	10.90

[a] CTR: control corn-based diet; P30: diet with 30% of dry pasta by-products (P30); P60: diet with 60% of dry pasta by-products; P80: diet with 80% of dry pasta by-products.
[b] Supplied by Rummo S.p.A. (Benevento, Campania, Italia).
[c] Provided (per kg of premix): vitamin A, 4,166,500 UI; vitamin D_3, 479,190 UI; vitamin E, 9523 mg; vitamin B_1, 595 mg; vitamin B_2, 1190 mg; vitamin B_6, 714 mg; vitamin B_{12}, 7 mg; D-pantothenic acid, 2975 mg; biotin, 35 mg; vitamin K_3, 952 mg; niacin, 4760 mg; folic acid, 119 mg; Co, 95 mg; Fe (ferrous sulphate), 74,428 mg; I, 357 mg; Mn (manganous oxide), 16,666 mg; Cu (copper sulphate), 39,285 mg; Se (sodium selenite), 47 mg; Zn (zinc oxide), 59,523 mg; calcium and magnesium carbonate to 1000 g.
[d] Phytase by *Aspergillus niger* (Alko Ltd., Biotechnology, Rajamaki Finland).
[e] Endo-1,4-β-xylanase by *Bacillus subtilis* (Vetagro, Reggio Emilia, Italy).
[f] Calculated with the equation proposed by Giuberti et al. (2012b) using white bread as a reference.

2.3. Growth performance and carcass measurements

The pigs were individually weighed on days 0 and 91. The feed consumption was recorded daily on a pen basis during the experiment to calculate average daily gain (ADG), average daily feed intake (ADFI), and gain to feed ratio (G:F).

The pigs were electrically stunned at slaughter. The carcasses (without head) and trimmed thighs were weighed, and then the dressing percentages and trimmed thigh yields were calculated. The thicknesses of the back fat and *Longissimus thoracis et lumborum* muscle (LTL) were recorded using a Fat-O-Meat'er in accordance with Commission Implementing Decision (2014) authorizing methods for grading pig carcasses in Italy. Then, the carcass lean percentage was estimated (Commission Implementing Decision, 2014). The pH was also measured at 45 min and 24 h post mortem on *Biceps femoris* on cooled thighs.

2.4. Fresh and seasoned ham quality

Samples of subcutaneous fat were collected from 24 left thighs (6 per treatment) and analysed for fatty acid composition. Then, the fresh thighs were initiated to the processing of seasoned Parma ham according to the PDO protocol (Consorzio del Prosciutto di Parma, 2015).

At the end of ripening (12 months), the hams were weighed and weight losses due to seasoning were obtained. Then, samples of covering fat were collected and analysed for fatty acid composition. The fatty acid composition of intramuscular fat, and proteolysis index and colour of *Biceps femoris* muscle were also determined. The L* (lightness), a* (redness), and b* (yellowness) colour values were measured on the hams using a Konica Minolta CM-700d spectrophotometer (Konica Minolta Sensing, Inc., Osaka, Japan) and operating with a D65 illuminant, di:8°/de:8° geometry (diffused illumination, 8° viewing angle), 11 mm aperture diameter for illumination and 8 mm for measurement, and 10° observer angle. Following general guidelines for descriptive testing (ISO 13299, 2010), the sensory analysis was performed on ham slices by an eight-member expert panel in 6 sessions [4 hams (1 per dietary treatment)/session]. The sensory evaluation was based on visual and taste descriptors (13 attributes in total) commonly used to evaluate the Italian ham sensory profile (Benedini, Parolari, Toscani, & Virgili, 2012; Laureati et al., 2014). The attributes were rated by numeric scales ranging from 0 (devoid of attribute) to 9 (maximum perception).

2.5. Chemical analyses

Diet and dry pasta by-product samples were ground through a 1 mm screen using a Retsch type ZM100 centrifugal grinding mill (Retsch, Haan, Germany) and stored until analysis. The samples were then analysed according to AOAC (2012) for moisture (method 945.15), crude protein (method 984.13), ether extract (method 920.29), crude fibre (method 962.09), and ash (method 942.05). The total starch was determined according to Masoero, Gallo, Zanfi, Giuberti, and Spanghero (2010). The starch components (i.e. rapidly digestible starch, slowly digestible starch and resistant starch) of the diets were characterized according to the procedure described by Englyst, Veenstra, and Hudson (1996). The in vitro starch digestion over time of the diets was performed with an enzymatic method simulating gastric and pancreatic phases occurring in the pig gastrointestinal tract (Giuberti, Gallo, Cerioli, & Masoero, 2012a). Milled white