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Effect of the inclusion of food waste in pig diets on growth performance, carcass and meat quality

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Food waste from fish and fruit shops was used as an alternative to the grain in grower-finisher pig diets. Two diets were formulated on an iso-nutrient basis (14 MJ digestible energy per kg, 160 g crude protein per kg on a dry-matter basis) to contain 0 g of food waste per kg in the control diet and 50 g of fish-shop waste per kg and 120 g of fruit-shop waste per kg in the experimental diet. In the study, 28 pigs per diet (seven pigs per pen) were fed ad libitum *from 20 kg to 100 kg, then, they were slaughtered and the carcass characteristics determined. The inclusion of food waste in the diet had no significant effect ($P > 0.05$) on average daily feed intake (2.12* v. *2.20 kg/day), average daily gain (0.74* v. *0.78 kg/day), or gain/feed (0.35* v. *0.35 kg per kg). In the case of the experimental diet, backfat thickness was significantly lower (18.0* v. *21.3 mm, $P < 0.01$). The results of the taste test indicated that the meat from food waste-fed pigs had acceptable organoleptic quality although a very light aroma to fish was observed in the bacon ($P < 0.01$).*

It was concluded that food waste from the fish and fruit shops could be included in grower-finisher pig diets without any detrimental effect on growth performance and only minor effects on carcass characteristics and meat quality.

Keywords: feed composition, food waste, meat quality, pigs

Introduction

In order to alleviate environmental burdens from solid waste, the Landfill Directive of the European Community (1999/31/EC) requires a progressive reduction in the land filling of biodegradable municipal solid waste (BMW), which decomposes and produces pollutants when land filled. In these circumstances, the magnitude of the food-waste disposal problem cannot be understated. According to Carty (2003), biodegradable municipal waste in the European Union contributes with 135 million tonnes per annum and about 50% of this total is food waste (Kiely, 1999).

Food waste used to be utilised as pig feed. The use of food waste, however, declined due to the introduction of commercial concentrate feed and to a change of producer strategy in pursuing a greater efficiency of production. The quantity and quality of food waste also changed due to the change of lifestyle. The system in the past cannot be simply applied currently. Relatively low prices for animal feed have also been disturbing the efficient use of food waste as pig feed.

While some food industry by-products, whose quality and quantity do not fluctuate, are used as a part of concentrate feed after drying, the nutritional quality of most of food waste fluctuates considerably and its safety is another concern (González *et al.*, 1984; Boda, 1990; Maylin *et al.*, 1991).

Under the present legislative system, many projects have been initiated but most of the activities are related to the production of compost (European Environment Agency, 2002). As acceptance by farmers is limited, the waste, which can be safely utilised as feed for pigs, should be processed into feed. The high nutrient content of food waste makes it a potential pig feed. Analyses show food waste have high protein and fat contents both in excess of 150 g/kg on dry-matter (DM) basis (Westendorf, 2000).

In order to change the feeding system from a system based on commercial concentrate feed to a food waste recycling system, it is necessary to develop a series of technologies as follows: (1) feed evaluation, (2) processing, (3) feeding system, (4) feed safety and (5) meat quality. Our results on the stages of feed evaluation and processing for food waste have been previously published (Sancho *et al.*, 2004; García *et al.*, 2005; Pinacho *et al.*, 2006; Esteban *et al.*, 2007). In these studies biodegradable municipal

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wastes from different sources were evaluated and vegetable and fruit wastes were selected as potential animal feedstuffs after a dehydration processes because both types of wastes ensured the required microbiological quality for feed, contained all necessary nutrients to feed pigs and their composition did not depend on the place where they were generated and their seasonal variation. Now, we present the results of the feeding system, feed safety and meat quality for pig production using these types of wastes.

Material and methods

Animals and management

Fifty-six pigs (seven pigs per pen), intact males of the Landrace breed, were weighed, individually identified and assigned to eight pens (1.3 m^2 per pig).

At 29 kg live weight until slaughter, the pigs were fed with two dietary treatments randomly assigned to each pen. Pigs were weighed and feed intake measured every 4 weeks for the 12-week trial to determine average daily feed intake (ADFI) and average daily gain (ADG), from which gain/feed (G:F) was calculated. Feed was withdrawn from the hogs 17 h prior to slaughter. Pigs were slaughtered at an approximate age of the 180 days.

Diets

Two growing-finishing dietary treatments were formulated on an iso-nutrient basis (14 MJ digestible energy (DE) per kg, 160 g crude protein (CP) per kg on a DM basis) (Wiseman, 1987) to contain 0 g fresh food waste per kg (control diet; CD) and 170 g fresh food waste per kg (experimental diet, ED) as shown in Table 1. ED and CD were used in pig feeding for 3 months.

Fresh food waste was obtained from fish and fruit shops (Esteban *et al.*, 2007; García *et al.*, 2005). The nutritional value of the waste was described in a previous paper (Esteban *et al.*, 2007) where values of 15 MJ/kg fish waste and 12 MJ/kg fruit waste are indicated for DE, and a content of 487 g/kg fish waste and 71 g/kg fruit waste appears for digestible protein. A high content of water was also observed for the food waste (about 750 to 900 g water per kg). For trial, the food waste was minced and dehydrated. Drying temperature was about 110°C so that the product temperature reached 65°C (Pinacho *et al.*, 2006). The dehydrated waste was blended with a dry feedstock as shown in Table 1: ED contained, on a DM basis, 120 g of fruit waste per kg and 50 g of fish waste per kg and CD did not contain any food waste.

Each of the diets utilised in this trial was a pelleted, tan to dark brown-coloured product that was slightly greasy to the touch. The CD colour was lighter than that noted for ED. The products had a mild odour.

ED and CD (manufactured in the Dibaq-Diproteg facilities, Segovia, Spain) were analysed for DM, CP, ether extract, ash and crude fibre in accordance with specific

Table 1 *Ingredient and nutrient content of diets given to pigs*

	Experimental diet	Control diet
Ingredients (g/kg DM)		
Barley	331.2	499.6
Wheat	200.0	200.0
Soya-bean	157.0	201.0
Maize	89.0	51.0
Lard	35.0	21.0
$Ca_3(PO_4)_2$	7.7	12.2
$CaCO_3$	3.1	7.5
Salt	3.0	3.0
Average mix P−312[†]	2.0	2.0
L−Lysine HCl	0.9	1.4
Megabinder[‡]	0.5	0.5
Choline chloride 50	0.307	0.272
DL−Methionine	0.260	0.540
Fruit waste	120.0	0.0
Fish waste	50.0	0.0
Composition (g/kg)		
Moisture	105.2	106.4
Crude protein	165.0	163.9
Digestible protein	109.2	136.7
Crude fibre	70.6	57.4
Nitrogen-free extract	541.7	568.5
Ash	61.0	55.5
Crude fat	56.4	48.1
Digestible energy (MJ/kg)	13.96	14.05

[†] Mineral and vitamin mixture.
[‡] Glaze gel used as amalgam.

methods (Madrid *et al.*, 1995); nitrogen-free extract was calculated by difference. Fatty acid profile in experimental and control diets was also analysed. Analyses were carried out by gas chromatography standard methods (Association of Official Analytical Chemists (AOAC), 2000) in the Meat Technologic Centre of the Junta de Castilla y León (Salamanca, Spain). Microbiological characterisation of the diets was performed as indicated by Pascual (1992) in the Microbiology and Genetics Department of the University of Salamanca, analysing total aerobic mesophiles, *Enterobacteria,* moulds and yeasts, *Salmonella, Escherichia coli* and *Staphylococcus aureus*.

Slaughter and carcass evaluation

All pigs were weighed immediately before slaughter. The carcass was split down the mid line and the hot carcass weight was recorded. Carcasses were placed in a chiller (5°C) approximately 2-h *post mortem* where they were kept overnight. At 24 h *post mortem*, cold carcass weight was recorded, and carcass measurements were obtained.

Meat quality measurements

At 2 h *post mortem*, pH was measured on both hams in each carcass; the pH Star probe (Matthäus) was inserted in the ham some centimetres from the end of the spine. Back

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fat was determined by a Fat-O-Meter optical probe; it measured backfat longitudinally 6 cm from the mid line in the region of the third fourth last rib. At 24 h *post mortem*, ultimate pH measured in ham and fatty acid profile of subcutaneous fat were determined. Analyses of fatty acid profile were carried out by gas chromatography standard methods (AOAC, 2000) in the Campofrío I + D department (Burgos, Spain).

The taste of meat from pigs fed either the ED or the CD was compared in a consumer taste panel. This panel was set up as a blind test (none of the samples was identified in any way) and reflected the perceptions of 10 participants. For sensory measurements, the loins were vacuum-packed and frozen to save all the flavour inside and around the meat until the panellist evaluated the sample. Each loin was thawed, sliced into 2-cm thick chops and cooked at 480 K until done. Cooked loin was then offered to consumers. Each person tasted two pork loin samples, one from each experimental group, without knowledge of origin. Loin was evaluated for the following attributes: juiciness, texture, flavour, colour and smell. Bacon was vacuum-packed and frozen separately from the loin. The bacon was sliced into 0.5-cm thick chops and scored for taste in the same way as for the loin. The sensory traits were measured on a scale from 1 to 5 (1 = poor, 5 = very good).

Statistical analysis

Statistical analysis for studied parameters was conducted by one-way analysis of variance (ANOVA). Probability values of 0.05 or less were considered statistically significant. For the experiments four repetitions (= pens) per treatment were used; no pigs were discarded.

Results and discussion

Experimental and control diets

For comparative purposes, the composition of the major chemical components of the ED and CD was analysed and results are given in Table 1. The chemical analyses of the diets indicated that the ED was low in nitrogen-free extract, high in fat, fibre and ash, and similar in protein and moisture. The chemical analyses of the different batches of ED used in the trial were in general agreement. One of the problems with feeding food waste is the variation in types and sources that results in variation of composition. The food waste used in the trial was taken at different times but from the same sources and processed similarly, and differences between the different batches were not observed. The detailed results about the no variation of the nutritional composition of the food waste were previously described by Esteban *et al.* (2007).

Microbiological similarities between ED and CD as well as their safety according to the bacteriological specifications for the products destined for animal feed (Ministerio de Agricultura, Pesca y Alimentación, 1988) were shown in detail by Sancho *et al.* (2004).

The fatty acid analysis of the fat in the ED an the CD showed a profile for the diets mainly composed of palmitic acid [16 : 0] (22.2 and 22.0 g per 100 g total fatty acids for ED and CD, respectively), oleic acid [18 : 1] (30.2 and 29.8 g per 100 g total fatty acids for ED and CD, respectively) and linoleic acid [18 : 2] (18.7 and 23.7 g per 100 g total fatty acids for ED and CD, respectively). The ratio of total unsaturated to saturated fatty acids in the fat of the ED (ratio = 1.5) was similar to that found in the CD (ratio = 1.6). However, the percentage of polyunsaturated fatty acids was higher in CD (percentage in ED = 20.4, percentage en CD = 25.6), due to the partial replacement of the soya bean in CD (polyunsaturated fatty acids in soya bean = 11.3 g per 100 g total fatty acids) by fish waste in ED (polyunsaturated fatty acids in fish waste = 4.3 g per 100 g total fatty acids).

Growth performance

Initial weights for pigs fed control and experimental diets were 29.2 (s.d. 4.3) kg and 28.7 (s.d. 4.1) kg respectively, ($P > 0.05$). The growth performance of the pigs is given in Table 2.

During the initial period, pigs fed the experimental diet had a decrease in ADFI and ADG ($P < 0.05$), probably due to a change in the taste of the feed at the start of the study (all pigs were fed with CD until the beginning of the

Table 2 *Mean (with s.d.) performance of pigs fed experimental and control diets*

	Average daily gain (kg/day)				Average daily feed intake (kg/day)				Gain:feed (kg/kg)			
	Experimental diet		Control diet		Experimental diet		Control diet		Experimental diet		Control diet	
	Mean	s.d.	Mean	s.d.	Mean	s.d.	Mean	s.d.	Mean	s.d.	Mean	s.d.
Weeks												
1–4	0.50*	0.02	0.64	0.07	1.74*	0.11	1.96	0.28	0.29	0.03	0.32	0.02
5–8	0.87	0.06	0.89	0.06	2.01	0.12	2.29	0.10	0.44	0.05	0.39	0.01
9–12	0.91	0.13	0.89	0.18	2.77	0.43	2.53	0.22	0.33	0.02	0.35	0.06
Overall	0.74	0.05	0.78	0.05	2.12	0.15	2.20	0.10	0.35	0.01	0.35	0.02

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study). For subsequent time periods, the response decreases in significance ($P > 0.05$), which could be attributed to the adaptation of the pigs to the new feed. However, overall there was no difference in feed efficiency between treatments ($P > 0.05$). No significant effect of waste inclusion in the diet was detected on G:F ($P > 0.05$).

This resulted in no significant ($P > 0.05$) difference in the average final weight for pigs on CD or ED (99.6 (s.d. 7.8) *v.* 96.6 (s.d. 7.5) kg).

Carcass characteristics

The pH measured at 2 and 24 h for pigs fed both diets (Table 3) showed similar ($P > 0.05$) values, corresponding not to pale, soft and exudative meat (pH at 2 h <5.8) or dark, firm and dry meat (pH at 24 h >6) but red firm and non-exudative meat (pH at 24 h <6) (Kauffman *et al.*, 1993; Toldra and Flores, 1999).

Hot carcass weight for pigs on CD was higher ($P < 0.05$) than for pigs on ED and dressing percentage (carcass hot weight/live final weight) was better ($P < 0.05$) for CD (78.10%) than for ED (75.47%) (Table 3). Although these results seem to disagree with the no significant difference observed in the final weight, it is proved that a fatter animal (like pigs on CD) have a higher dressing percentage than a lean animal (like pigs on ED) (Wulf, 1999).

Carcass fat depth tended to decrease ($P < 0.01$) in pigs on ED (Table 3). These data indicate that the addition of food waste into a standard grain and soyabean based feed has no hindrance on growth performance and may decrease backfat thickness, increasing carcass value. There are quantifiable economic benefits to pig farmers in reducing the amount of backfat, as the price paid to the farmer for the carcass is dependent on backfat.

Samples of subcutaneous fat from each pig were collected and pooled for fatty acid analysis. A clear influence of fatty acid profile in diets on fatty acid profile in subcutaneous fat (Table 4) was observed. Just like diets, subcutaneous fat was mainly composed of palmitic, oleic and linoleic acids.

No significant differences ($P > 0.05$) were detected in saturated and monounsaturated fatty acid composition between pigs on ED and CD (Table 4). However, a higher percentage of polyunsaturated fatty acids was detected in subcutaneous fat of pigs on CD ($P < 0.05$) according to the higher percentage of polyunsaturated fatty acids in CD.

Table 3 *Carcass characteristics of pigs fed experimental and control diets*

	Experimental diet		Control diet	
	Mean	s.d.	Mean	s.d.
Hot weight (kg)	73.2*	7.0	77.8	6.4
Dressing (%)	75.5*	0.5	78.1	0.5
pH at 2 h	6.3	0.2	6.3	0.2
pH at 24 h	5.7	0.2	5.7	0.2
Fat depth (mm)	18.0**	3.8	21.3	4.0

Table 4 *Fatty acid profile of subcutaneous fat of pigs fed experimental and control diets*

	Experimental diet		Control diet	
	Mean	s.d.	Mean	s.d.
Acid (g per 100 g total fatty acids)				
14:0 (myristic)	1.4	0.1	1.3	0.0
16:0 (palmitic)	22.5	0.8	22.3	1.1
18:0 (stearic)	10.7	2.8	11.1	0.0
Saturated fatty acids	35.0	2.5	35.1	1.2
16:1 (palmitoleic)	3.2	0.9	3.0	0.3
18:1 (oleic)	45.4	1.9	42.9	0.9
Monounsaturated fatty acids	49.4	1.8	46.7	1.6
18:2 (linoleic)	13.6*	0.6	16.1	1.0
18:3 (linolenic)	1.3	0.1	1.2	0.0
Polyunsaturated fatty acids	15.6*	0.5	17.7	0.4
Unsaturated-saturated ratio	1.9	0.2	1.8	0.1

Meat quality

The results (Table 5) of the taste test indicated that the meat from pigs fed food waste had acceptable organoleptic quality.

The panel liked loin from pigs fed food waste and preferred it to loin from pigs on CD ($P < 0.01$ for overall preference). The consumers rated loin from food waste-fed pigs as having a better colour ($P < 0.01$) and smell ($P < 0.05$) but rated juiciness, texture and flavour similar ($P > 0.05$) between the two groups.

Results also indicated that there was not much difference ($P > 0.05$) for juiciness, texture, flavour and colour between bacon from pigs on ED and pigs on CD. The lowest odour score ($P < 0.001$) for the former is due to a very light aroma to fish. In spite of this score, the overall preference above 2.5 means that bacon from pigs on ED is acceptable to consumers.

Conclusion

The results of this study suggest that diets with 120 g of fruit waste per kg DM and 50 g of fish waste per kg DM can be used successfully in pig growing-finishing diets obtaining similar growth performance, carcass characteristics and meat quality to control diets. This application for food waste will allow a decrease in disposal to landfill according to the European environmental regulations.

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Table 5 *Taste panel results for meat of pigs fed either experimental diet or control diet*

	Loin				Bacon			
	Experimental diet		Control diet		Experimental diet		Control diet	
	Mean	s.d.	Mean	s.d.	Mean	s.d.	Mean	s.d.
Attributes								
Juiciness	3.28	0.49	2.71	0.95	3.83	1.17	3.71	0.75
Texture	3.22	0.61	2.81	0.98	2.33	1.50	2.59	1.32
Flavour	3.00	0.75	2.92	0.76	2.54	0.78	3.09	0.89
Colour	3.71**	0.49	2.50	0.55	3.30	0.67	3.55	0.53
Smell	3.83*	0.41	3.00	0.63	2.11***	0.33	3.78	0.44
Overall preference	3.30**	0.65	2.81	0.83	2.69*	1.14	3.19	1.01

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