Influence of high levels of beet pulp in the diet on endocrine/metabolic traits, slaughter dressing percentage, and ham quality in Italian heavy pigs

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Paper received May 26, 2008; accepted September 5, 2008

ABSTRACT

Seventy two Landrace x Large White barrows were divided into three groups and fed different diets: a control traditional diet based on cereals (C) and two with 15 or 30% dried sugar beet pulp (BP15 and BP30, respectively). Animals weighed 106 kg at start and 167 kg at the end of the experiment. Feeding was restricted (2.5 kg DM/head, on average).

The aim of the present experiment was to investigate the influence of high levels of beet pulp in the diet of fattening heavy pigs on some endocrine/metabolic traits, on the slaughter dressing percentage and on some parameters related to meat quality, composition and on the ham quality, after 14 months of seasoning.

During the experimental period, jugular vein blood samples were collected from C and BP30-fed pigs and plasma was analysed for several metabolic traits. BP30 diet initially increased the plasma glucose level and decreased free amino acids ($P<0.05$), but this difference disappeared at the end of the experimental period, when insulin level was decreased ($P=0.06$) by beet pulp administration. During the entire period, 30% beet pulp diet increased total protein and albumin levels ($P<0.001$) and decreased urea ($P<0.05$) without affecting plasma leptin.

At slaughter, pigs fed BP30 diet were lighter ($P<0.001$) and with a lower dressing percentage ($P<0.001$) in comparison with the other two treatments. Pigs fed BP30 diet also had lower ham and loin weights ($P<0.05$) (but similar ham and loin percentages) and higher liver weight ($P<0.05$), liver/carcass ratio ($P<0.001$), gastrointestinal-tract weight ($P<0.001$) and gastrointestinal-tract/carcass ratio ($P<0.001$). Pigs fed C diet had a higher dressing percentage in comparison with pigs fed BP15 diet ($P<0.01$), but no other significant difference was found between pigs fed diets C and BP15.

At slaughter, liver samples were taken from C and BP30-fed pigs in order to evaluate the effect of the diet on liver composition. BP30 diet increased dry liver weight ($P<0.05$) and liver fat content ($P<0.01$).

The iodine value and the fatty acid composition of the backfat revealed no significant difference between pigs fed the control diet and those fed the high fibre diets.

Finally, considering the economic importance of ham production, the characteristics of the seasoned hams were evaluated. No difference was observed on ham quality.

In conclusion, feeding a diet with a high percentage of dried sugar beet pulp alters protein and energy metabolism and slaughter parameters, without affecting the quality of the seasoned ham.

Key words: Pig, Ham, Beet Pulp, Metabolites, Hormones.

RIASSUNTO

INFLUENZA DELLA SOMMINISTRAZIONE DI ELEVATE QUANTITÀ DI POLPE DI BIETOLA ESSICCATE SU PARAMETRI ENDOCRINO/METABOLICI, RILIEVI AL MACELLO E QUALITÀ DEL PROSCIUTTO NEL SUINO PESANTE ITALIANO.

Settantadue suini Landrace x Large White sono stati suddivisi in tre gruppi e alimentati con differenti diete: una dieta di controllo tradizionale a base di cereali (C) e due diete contenenti il 15% e il 30% di polpe di bietola essiccate (BP15 e BP30, rispettivamente). Il peso medio dei suini era di 106 kg a inizio prova e di 167 kg il giorno della macellazione. L'alimentazione è stata razionata e pari in media a 2,5 kg SS/capo/giorno.
Lo scopo del lavoro è stato quello di valutare l'influenza dell'inclusione nella dieta per suini all'ingrasso di alti livelli di polpe di bietola essiccate su alcuni parametri endocrino/metabolici, sulle rese di macellazione e su alcuni parametri relativi alla qualità e composizione della carne e dei prosciutti stagionati.
Durante il periodo sperimentale sono stati prelevati campioni di sangue dagli animali dei gruppi C e BP30. Sul plasma ottenuto è stata determinata la concentrazione di diversi parametri metabolici. La dieta BP30 ha inizialmente aumentato (P<0,05) i livelli plasmatici di glucosio (4,26 vs *4,95 mmol/l per i gruppi C e BP30, rispettivamente, SE=0,32), riducendo (P<0,05) la concentrazione di amminoacidi liberi (6,18* vs *5,50 mmol/l, SE=0,36). Tale differenza è svanita alla fine del periodo sperimentale, quando i livelli plasmatici di insulina negli animali del gruppo BP30 si sono ridotti (205* vs *161 pmol/l, SE=23,8, P=0,06). Durante l'intero periodo sperimentale, gli animali del gruppo BP30 hanno mostrato maggiori (P<0,001) livelli plasmatici di proteine totali e albumina.*
Alla macellazione i suini del gruppo BP30 hanno mostrato i minori (P<0,001) peso e resa. Inoltre, dagli animali del gruppo BP30 sono stati ottenuti prosciutti e lombi di peso inferiore (P<0,05). Tuttavia la loro resa non ha mostrato differenze. Gli animali del gruppo BP30 avevano fegati di peso superiore (1,74 vs *1,74 e 1,94 kg, per gli animali dei gruppi C, BP15 e BP30, rispettivamente, SE=0,06, P<0,05), più alto rapporto fegato/carcassa (1,25%* vs *1,27% e 1,49%, SE=0,04, P<0,001), maggior peso del digerente (12,3* vs *12,5 e 16,1 kg, SE=0,45, P<0,001) e più alto rapporto digerente/carcassa (8,8%* vs *9,1% e 12,4%, SE=0,31, P<0,001). I suini del gruppo C hanno avuto una maggior resa rispetto agli animali del gruppo BP15 (83,3%* vs *81,9%, SE=0,36, P<0,01), ma nessun altra differenza statisticamente significativa.*
Dagli animali dei gruppi C e BP30, al macello, sono stati prelevati campioni di fegato, la cui analisi ha evidenziato un aumento del peso secco (P<0,05) e del contenuto di grassi (P<0,01) nel fegato degli animali alimentati con dieta BP30.
Il numero di iodio e la composizione acidica del grasso dorsale non hanno fatto registrare differenze significative tra gli animali del gruppo di controllo e quelli alimentati con le diete ad alto contenuto di fibra.
Infine, nessuna differenza significativa è emersa per le caratteristiche qualitative dei prosciutti dopo 14 mesi di stagionatura.
In conclusione, la somministrazione di diete ricche di polpe di bietola essiccate altera il metabolismo energetico e proteico e la resa alla macellazione senza influenzare la qualità dei prosciutti per i parametri osservati.

Parole chiave: *Suini, Prosciutto, Polpe di Bietola, Metaboliti, Ormoni.*

Introduction

In the diet formulated for the Italian fattening heavy pig, 8-9% of fibrous feeds (mostly wheat bran) are normally included to compensate for the lack of fibre of maize which is traditionally the cereal used in the plain farming systems of the Po Valley.

Higher proportions of fibrous raw materials are not usually fed, because their digestibility and nutritional value, generally determined on light growing pigs, are low and therefore there is the fear that high proportions of fibrous feeds might excessively decrease the energy concentration of the diet. However, in a recent experiment (Galassi *et al.*, 2007b) on pigs averaging 150 kg BW, fibre digestibility of diets with high levels of beet pulp was high and similar to that previously registered in sows (Noblet and Bourdon, 1997; Le Goff and Noblet, 2001). In fact, it is known that dietary fibre is hardly digested by the piglet, but it is quite well utilized by the adult pig (Noblet and Shi, 1994; Le Goff *et al*., 2002).

Therefore, it seems interesting to evaluate the convenience of including high proportions of fibrous ingredients in diets fed to fattening heavy pigs (BW>100 kg). Moreover, fibrous pig diets are known to shift the N excretion from urine to faeces, without changes in global N excretion, but with a reduction of ammonia emission from slurries due to the decreased urea content of urine which, in turn, has to be ascribed to the higher utilization of ammonia for the synthesis of microbial protein in the caecum-colon tract (Bach Knudsen *et al*., 1991; Galassi *et al*., 2005; Hansen *et al*., 2006; Galassi *et al*., 2007b).

Among fibrous feeds, beet pulp resulted significantly more digestible than wheat bran in the heavy pig (Galassi *et al*., 2004, 2007b) and the net energy content of wheat bran and beet pulp destined to fattening heavy pigs resulted in 7.60 and 8.07 MJ NE/kg DM, respectively (Galassi *et al*., 2007a).

It must also be taken into consideration that the guidelines of production of the Parma Ham and San Daniele Ham Consortia (the most important and representative consortia for PDO ham production in Italy) stipulate that pigs for ham must be slaughtered at over 9 months of age and at a bodyweight of 160 kg±10%. This leads to an average daily gain of 0.6 kg, implying the restriction of feed and energy intake to mature the animals sufficiently without excessive fattening.

Therefore, the inclusion of dried beet pulp in the diets for fattening heavy pigs at higher rates than the 4% on DM, which is the maximum inclusion level presently permitted by the guidelines of the Parma Ham and San Daniele Ham Consortia, seems to be interesting.

Experiments on heavy pigs fed high-fibre diets showed a low methane emission when the fibrous fractions were scarcely digestible (e.g. wheat bran) (Crovetto *et al.*, 2001; Galassi *et al*., 2004). On the contrary, diets containing fibrous ingredients with a highly digestible fibre (e.g. beet pulp) enhanced methane production. This is due to a higher microbial growth rate in the large intestine (Bach Knudsen *et al.*, 1991) which in turn determines lower ammonia emission from slurries of light and heavy pigs (Canh *et al*., 1998a, 1998b; Galassi *et al*., 2007).

Nitrogen balance and ammonia emission from slurries have been registered also in this research project and data were presented at the 16th ASPA Congress (Galassi *et al*., 2005).

The aim of the present experiment was to investigate the influence of high levels of beet pulp in the diet of fattening heavy pigs on some endocrine/metabolic traits, on the slaughter dressing percentage and on some parameters related to meat quality and composition. Moreover, considering that ham quality is crucial in the production of the Italian heavy pig (on average, hams represent 25% of carcass weight but almost 60% of the economic value of the pig), we also evaluated the influence of high levels of beet pulp in the diet on the ham quality, after 14 months of seasoning.

Material and methods

Altogether 72 Italian Landrace x Large White barrows were divided into three groups and fed different diets. The three tested diets were: a control traditional diet based on cereals (C) and two with 15 or 30% dried sugar beet pulp (BP15 and BP30). The overall composition and analysis of the three diets, fed as dry mash, are shown in Table 1. BP15 and BP30 included 1 and 2% vegetable oils respectively, to facilitate pelleting and balance the energy value of the diets. Chemical analyses of feeds were performed following the indications of ASPA (1980). The gross energy (GE) of feeds was determined in an adiabatic bomb calorimeter (IKA 4000).

The animals of each group were allotted to 4 pens of 6 pigs each. On average the animals weighed 106 kg at the beginning of the trial, 170 kg at the end of the experiment and 167 kg at slaughter (after 12 hours fasting and transport). More precisely, the live weights at the beginning of the experiment were, on average, 105, 105 and 108 kg for pigs fed diets C, BP15 and BP30, respectively.

Table 1. Composition and analysis of the experimental diets.

		C	BP15	BP30
Maize	%	54.0	43.0	27.0
Barley	"	30.0	30.0	30.0
Beet pulp, dried	"	-	15.0	30.0
Wheat bran, coarse	"	5.0	-	-
Soybean meal	"	8.0	8.0	8.0
Sugar cane molasses	"	0.87	0.87	0.87
Vegetable oil	"	-	1.0	2.0
$CaCO_3$	"	1.17	1.17	1.17
$Ca(H_2PO_4)_2$ hydr.	"	0.40	0.40	0.40
NaCl	"	0.25	0.25	0.25
L-Lys HCl	"	0.25	0.25	0.25
Vit./min. supplement	"	0.13	0.13	0.13
OM	% DM	85.6	85.7	85.0
Ash	"	4.7	5.4	6.1
CP	"	13.2	12.7	12.5
EE	"	2.7	3.9	4.4
Crude fibre	"	4.7	6.7	9.2
NDF	"	14.2	15.8	20.9
ADF	"	5.4	7.7	11.6
ADL	"	1.4	1.8	2.1
Starch	"	55.1	46.0	34.4
Lysine	"	0.79	0.81	0.85
Gross energy	MJ/kg DM	18.03	17.96	17.92
Metabolisable energy	"	14.75	14.35	13.77

Feeding was restricted and, on average, the dry matter fed was 2.5 kg/d. For personnel availability all the animals were fed at 7.30 a.m. and 5.00 p.m. each day. Drinking water was always available.

Two hours after the first meal of the day, jugular vein blood samples were collected from 12 pigs of C group and from 12 pigs of BP30 group, twice: when mean liveweight was 115 kg (8 months of age) and 165 kg (10 months of age, just before slaughtering). After the blood sample was taken it was immediately centrifuged at 2000 x g, for 15 minutes and then stored at -20°C until analysis. Plasma was analysed for glucose (Wako Chemicals GmbH, Neuss - Germany), free amino acids (Goodwin, 1968), total protein, urea, creatinine (Giesse Diagnostics Snc, Colle Prenestino - Roma, Italy), albumin and globulin (Boehringer Mannheim GmbH, Mannheim, Germany) with spectrophotometric methods, leptin (Multispecies Leptin RIA Kit, Linco Research Inc, St. Charles – MO, USA) and insulin (Insik-5, Dia Sorin Spa, Saluggia – VC, Italy) by radio-immuno-assays.

At the end of the experiment, after 12 hours of fasting, all the pigs were taken to the slaughterhouse, to register the following parameters:

- carcass, hams, loins, cured neck, liver and gastro-intestinal tract (including tongue, pancreas and urinary bladder) weight and dressing percentage;
- total dressing percentage and specific dressing percentages of hams, loins, and cured neck;
- backfat and *m. longissimus dorsi* thickness, proportion of the lean meat, liver/carcass ratio, and gastro-intestinal tract/carcass ratio.

Backfat and *m. longissimus dorsi* thickness was determined using the Fat-O-Meater (FOM), equipped with a probe of 6 mm diameter.

Lean meat proportion was computed using the following equation for the heavy pig (method authorized by the EU Commission on 8th June 2001 (2001/468/EU):

$$\hat{y}=45.371951-0.221432x_1+0.055939x_2+ +2.554674x_3$$

where:

$\hat{y}$=predicted content (%) of lean meat in the carcass;

x_1=backfat (including the pigskin) thickness (mm) measured at 8 cm aside from the central line of the carcass between the 3rd last and the 4th last rib;

x_2=*m. longissimus dorsi* thickness (mm) simultaneously and at the same point as backfat;

$x_3 = x_2/x_1$

Carcass weight was also determined following the procedure indicated by the EU Commission on June 8^{th}, 2001 (2001/468/EU).

In order to evaluate the effect of the high fibre diet on liver composition, liver samples from C and BP30-fed animals were taken and immediately stored at -80°C until analysis for dry matter (AOAC, 1990a) and ether extract (AOAC, 1990b).

In order to estimate the total amount of unsaturated fatty acids in the subcutaneous backfat, the iodine value was determined according to the Wijs method and the fatty acid composition was gas-chromatographically determined with an instrument equipped with a flame ionisation detector.

Methyl esters were identified by their retention time in comparison with a reference standard and expressed as percentage of total detected methyl esters.

The influence of high levels of beet pulp in the diet on the ham quality was also evaluated. Twelve 14 month-seasoned hams per dietary treatment were judged for meat consistence, muscle colour uniformity, marbling, globosity, muscle colour intensity, subcutaneous veining defect, and for a global evaluation, on a 5-point scale, by a technician of the curing factory.

Data obtained were statistically analysed by GLM procedure of SAS. For the dependent variables live weight at slaughter and carcass weight the statistical analysis was performed including the covariance for the initial bodyweight. The model applied was the following:

$$y_{ij}=\mu+t_i+\beta(x_{ij}-x)+e_{ij}$$

where:
y_{ij}=dependent variable;
μ=general mean;
t_i=effect of the i-diet;
$\beta(x_{ij}-x)$=effect of the covariate initial BW;
e_{ij}=residual error.

The effect of the "pen" variable within treatment was excluded from the model since not significant.

Results and discussion

Endocrine and metabolic parameters

Analysis of endocrine/metabolic traits are reported in Table 2.

During the first part of the experimental period, when pigs weighed 115 kg, beet pulp administration increased plasma glucose ($P<0.05$). This result is consistent with those of other researchers, who observed that administration of a high non-starch polysaccharides (NSP) diet could produce an enhancement of fermentation in the hindgut, leading to a more gradual and prolonged supply of energy throughout the day (Schrama *et al.*, 1996). Soluble fibre fermentation by the intestinal microflora produces short chain fatty acids (SCFA), which are rapidly absorbed and may prevent transient declines in plasma glucose levels between meals (Rerat, 1996).

The higher glucose level observed in BP30 pigs, two hours after feeding, could be the consequence of a delayed post-prandial rise, due to the high fibre diet. In non pregnant first-parity sows fed a low NSP diet, blood glucose level has a clear post-prandial peak just 30 min after feeding and turns to basal level 2 hours after meal, whereas in high NSP diet fed animals, glucose level has a gradual post-prandial rise, without a clear peak (De Leeuw *et al.*, 2004). This delayed post-prandial rise could be ascribed to the delayed nutrient absorption, since high fibre diets are eaten more slowly and chewed longer than low fibre diets (De Leeuw *et al.*, 2004) and also because high soluble fibre diets are known to slow down gastric emptying of digesta in pigs (Johansen *et al.*, 1996).

No difference between diets was observed in plasma insulin levels in the growing pigs (115 kg) according to what has been reported for non-pregnant sows. This result could be the consequence of a reduced response in pancreatic insulin synthesis due to diets with a low amount of glucose supply (as starch) (De Leeuw *et al.*, 2004).

In 115 kg animals, BP30 diet reduced plasma level of free amino-acids ($P<0.05$). Along with a stabilizing effect on blood glucose, 30% beet pulp diet is reported to decrease protein digestibility and N absorption, as already observed in previous studies (Ramonet *et al.*, 2000; Galassi *et al.*, 2004; Hansen *et al.*, 2006). These two effects could explain the decrease of free amino acids in plasma level, observed in pigs fed the BP30 diet.

Dietary treatment increased total protein level ($P<0.01$) in plasma of the 115 kg pigs. This result is probably due to an increase in the level of albumin required for the transportation of the fatty acids derived from NSP fermentation, since albumin is the main carrier of lipids in blood (Spector, 1975).

In 115 kg pigs, BP30 diet decreased plasma level of urea ($P<0.05$). Since SCFA production in the large intestine represented a gradual and prolonged supply of easily me-

Table 2. Postprandial levels of metabolites and hormones (n=24).

		BW (kg)	C	BP30	SE	C *vs* BP30	115 *vs* 165 kg
Glucose	mmol/l	115	4.26	4.95	0.32	*	*
		165	4.34	4.14		ns	
Free Aminoacids	"	115	6.18	5.50	0.36	*	**
		165	6.63	6.59		ns	
Total Protein	g/l	115	69.3	76.0	2.69	**	***
		165	66.3	70.7		*	
Albumin	"	115	37.3	40.9	1.72	**	***
		165	40.3	42.8		*	
Globulin	"	115	32.0	35.1	3.06	ns	**
		165	26.0	27.9		ns	
Urea	mmol/l	115	3.61	3.08	0.35	*	ns
		165	4.08	3.33		*	
Creatinine	μmol/l	115	171	180	10.3	ns	**
		165	198	199		ns	
Insulin	pmol/l	115	145	146	23.8	ns	**
		165	205	161		0.06	
Leptin	"	115	268	260	25.9	ns	*
		165	302	292		ns	

**=P<0.05; **=P<0.01; ***=P<0.001.*

tabolizable energy throughout the day, it is possible that the BP30 pigs did not need to use free amino-acids for glucose production. In fact, amino-acid oxidation for glucogenic purpose is considered the most important cause of the variation of plasma level of urea (Campanile *et al.*, 1998). It must also be emphasised that a reduction in the urea content in blood of pigs fed the BP30 diet has to be ascribed to the higher microbial growth in the large intestine with a consequent higher absorption of urea by the blood as source of N. The lower plasma levels of urea might also explain the lower ammonia emission from slurries, previously recorded (Galassi *et al.*, 2005).

In finishing pigs (165 kg), plasma levels of total protein, albumin and urea showed the same difference presented in the previous part of the present study, while the differences in glucose and amino acid levels disappeared. These results could be ascribed to the adaptation to the diet by the BP30 animals. In fact, pigs improve their digestive efficiency as they grow and this improvement is greater for fibre, as previously determined (Galassi *et al.*, 2004). Moreover, it is worth remembering that the quality guidelines of the Parma Ham and San Daniele Ham Consortia stipulate that pigs must be slaughtered at over 9 months of age and at a bodyweight of 160 kg ±10%. Thus, Italian heavy pig feeding must aim to mature the animals sufficiently without excessive fattening and this implies feed restriction, which is usually forced just before slaughtering. This feed restriction could contribute to reducing differences between groups.

Moreover, although in growing pigs (115 kg) 30% beet pulp diet increased plasma glucose, without influencing insulin, in finishing pigs (165 kg) the same diet decreased plasma level of insulin (P=0.06), without affecting glucose. Our result is in accordance with what has been observed in pregnant sows (Ramonet *et al.*, 2000; Farmer *et al.*, 2002).

BP30 diet did not affect plasma level of leptin, during the entire period. Leptin is a peptidic hormone primarily synthesized by white adipose cells (Kershaw and Flier, 2004), which has an important role in the regulation of body weight (Prolo *et al.*, 1998). As neither body weight nor subcutaneous fat thickness - measured at slaughtering - differed between the experimental groups, we did not expect any difference in plasma leptin between groups.

Slaughter performances

All the pigs were slaughtered at the average weight of 167 kg. Slaughter parameters are shown in Table 3.

Considering the overall slaughter data, it appears that the concentration of 15% of beet pulp in the diet (correspondent to 15.8% NDF on DM) did not hamper the quality parameters of the pigs, in accordance with results found by Scipioni and Martelli, 2001. By contrast, the inclusion level of 30% of beet pulp in the diet (correspondent to 20.9% NDF on DM) showed a significant decrease in many parameters considered.

Pigs fed diet BP30 resulted lighter (P<0.05) than the pigs fed diets C and BP15 (162 *vs* 169 kg; P<0.05).

Pigs fed diet BP30 also had a far lower (P<0.001) dressing percentage (79.1%) than the other experimental animals (83.3 *vs* 81.9%, for C and BP15, respectively). In comparison with diet C, dressing percentage with diet BP15 was lower (P<0.01). However, a dressing percentage of almost 82% for a heavy pig is normally considered satisfactory.

Considering the weights of hams and loins and their dressing percentages, no difference was revealed between C and BP15, but BP30 had lower values (P<0.05) in comparison to treatment C. Loin weights of pigs fed diet BP30 resulted significantly lower than those fed diet BP15.

Backfat and *m. longissimus dorsi* thickness did not show any difference among treatments. The same holds true for the lean meat proportion.

Cured neck weight (10.6 kg on average) and dressing percentage (7.8% on average) were similar for the three dietary treatments.

The mean values obtained in the present experiment for the different cuts (hams, loins, cured neck) are consistent with those reported in literature for the Italian heavy pig (Lo Fiego *et al.*, 2000; Martelli *et al.,* 2005).

Liver weight (P<0.05) and its percentage on the carcass (P<0.001) were significantly higher for diet BP30 as compared to the other two diets. The same holds true for the gastro-intestinal tract weight and incidence on carcass: diets C and BP15 were similar, but diet BP30 determined a strong increase (P<0.001) of both weight (+3.7 kg, on av.) and percentage (+3.5 percent units, on av.).

The analysis of liver samples from C and BP30 animals displayed higher dry weight for NSP fed pigs (P<0.05), as shown in Table 4. This latter result could be the consequence of the increase in liver activity both for the synthesis and secretion of albumin into the systemic circulation and for the metabolism of the SCFA deriving from the soluble fibre fermentation. The major production of free fatty acids could also be responsible for the higher lipid content found

Table 3. Slaughter parameters of the pigs fed the diets with 15% (BP15) or 30% (BP30) beet pulp in the diet, in comparison with control (C) (n=72).

		C	BP15	BP30	SE	C *vs* BP15	C *vs* BP30	BP15 *vs* BP30
Liveweight at slaughter [1, 2]	kg	169	169	162	2.24	ns	*	*
Carcass weight [1]	"	141	139	128	1.95	ns	***	***
Dressing percentage	%	83.3	81.9	79.1	0.36	**	***	***
Backfat thickness	mm	26.7	27.2	27.4	1.17	ns	ns	ns
M. longissimus dorsi thickness	"	64.1	64.6	61.8	1.30	ns	ns	ns
Lean meat (predicted by F-o-M)	%	44.5	44.0	42.8	1.26	ns	ns	ns
Hams weight	kg	35.6	34.9	33.8	0.64	ns	*	ns
Hams percentage	%	25.6	25.3	26.0	0.17	ns	ns	ns
Trimmed hams weight	kg	28.1	27.5	26.6	0.51	ns	*	ns
Trimmed hams percentage	%	20.2	20.0	20.5	0.13	ns	ns	*
Loins weight	kg	22.2	22.4	21.1	0.44	ns	*	*
Loins percentage	%	16.0	16.3	16.2	0.17	ns	ns	ns
Cured neck weight	kg	10.7	10.7	10.3	0.22	ns	ns	ns
Cured neck percentage	%	7.7	7.8	7.9	0.10	ns	ns	ns
Liver weight	kg	1.74	1.74	1.94	0.06	ns	*	*
Liver/carcass	%	1.25	1.27	1.49	0.04	ns	***	***
Gastro-intestinal tract weight [3]	kg	12.3	12.5	16.1	0.45	ns	***	***
Gastro-intestinal tract/carcass	%	8.8	9.1	12.4	0.31	ns	***	***

**=P<0.05; **=P<0.01; ***=P<0.001.*

[1] *Analysis of variance using liveweight at slaughter as covariate.*

[2] *Liveweight registered on the day of slaughter.*

[3] *Including tongue, pancreas and urinary bladder.*

in livers of BP30 animals (P<0.01) (Table 4): liver is considered to have a crucial role in the synthesis of endogenous plasma triglycerides starting from free fatty acids and in the removal of exogenous lipids from blood (Kern *et al.*, 1965).

Table 5 reports the data on the iodine values and the fatty acid percentage composition of the backfat for the pigs fed the different experimental diets.

No significant difference was found for any parameter between treatments. The mean values of both the Iodine numbers and the acid profile are similar to the data reported in literature for pigs of the same genotype and bodyweight (Lo Fiego *et al.*,

Table 4. Liver analysis at slaughter (n=24).

		C	BP30	SE	C *vs* BP30
Dry Weight	g/g fresh liver	0.60	0.70	0.03	*
Dry Matter	%	29.4	28.3	0.41	0.06
Ether Extract	g/kg fresh liver	16.7	22.7	1.54	**
Ether Extract	g/kg dry tissue	57.2	79.9	5.48	**

*=P<0.05; **=P<0.01.*

Table 5. Iodine value and fatty acid composition of the backfat (n=72).

		C	BP15	BP30	SE
Iodine value	g	62.6	64.8	61.3	2.79
Myristic	%	0.9	0.8	1.0	0.13
Palmitic	"	25.0	23.5	24.8	1.28
Palmitoleic	"	1.3	1.6	1.7	0.28
Stearic	"	10.0	9.4	11.8	2.02
Oleic	"	47.8	47.1	44.5	2.70
Linoleic	"	13.2	14.1	14.4	1.01
Linolenic	"	1.6	1.3	1.4	0.22
Arachidonic	"	0.4	0.5	0.4	0.09

2005; Martelli *et al.*, 2005). The data obtained suggest that even high levels of beet pulp in pig diets do not change or worsen the fatty acid composition of pig fat.

The evaluation of the ham quality (Table 6) revealed no substantial difference between the dietary treatments for all the parameters considered. Therefore, high levels of beet pulp in pig fattening diets do not seem to hamper ham quality. The final weight of the twelve 14 month-seasoned hams per dietary treatments were 10.3, 10.1 and 10.0 kg for diets C, BP15 and BP30, respectively.

Conclusions

The data obtained suggest that feeding a diet with 30% of dried sugar beet pulp can increase the plasma level of glucose and decrease free amino-acids in growing pigs (115 kg), as a consequence of the increase in polysaccharides fermentation (as fibre) and of the reduction of protein digestibility and N absorption. However, this difference disappears in heavy pigs (165 kg), in which beet pulp administration can decrease the insulin level without affecting plasma leptin.

Feeding a 30% sugar beet pulp diet increases total protein, in response to an increase in the plasma level of albumin required for the transportation of the fatty acids deriving from NSP fermentation. By contrast, BP30 diet decreases plasma urea as a possible consequence of an increase in microbial growth in the large intestine.

Table 6. Expert-based evaluation of the ham characteristics.

	C	BP15	BP30	SE
Meat consistence	2.7	2.6	2.3	0.52
Muscle colour uniformity	1.9	2.0	1.8	0.19
Marbling	1.6	1.8	1.6	0.13
Globosity	2.0	2.0	1.6	0.46
Muscle colour intensity	2.5	2.4	2.6	0.18
Adipose cover (mm)	25.9	27.6	28.3	2.58
Subcutaneous veining defect	2.7	2.6	2.4	0.34
pH	5.5	5.6	5.6	0.07
Global evaluation	3.8	3.8	3.5	0.39

Legend of Table 6.

Score	Meat consistence	Muscle colour uniformity	Marbling and globosity	Muscle colour intensity	Subcutaneous veining defect	Global evaluation
1	Ideal	Ideal	Ideal	Very pale	Not present	Ideal
2	Good	Slightly different	Hardly evident	Pale	Hardly visible	Very good
3	Mean	Fairly different	Fairly evident	Ideal	Visible	Good
4	Poor	Different	Evident	Dark	Evident	Fairly good
5	Negative	Very different	Highly evident	Very dark	Very evident	Sufficient

BP30 diet can also increase dry liver weight and liver fat content. These results could be due to an increase in liver activity both for synthesis of albumin into the systemic circulation and for the metabolism of the SCFA deriving from the soluble fibre fermentation.

A diet with 15% beet pulp does not change the slaughter parameters and the quality of the seasoned ham except for a slight decrease of dressing percentage.

A diet with 30% beet pulp heavily worsened the dressing percentage and some slaughter parameters. Also for this treatment no difference was registered for the quality parameters of the seasoned ham in comparison with the control subjects.

In conclusion, feeding a diet with a high percentage of dried sugar beet pulp alters protein and energy metabolism, without affecting the ham quality for the considered parameters.

The authors wish to thank Davide De Angeli and Paolo Roveda for their precious assistance in conducting the trial.

This experiment was financially supported by Regione Lombardia, Italy.

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