Volatile fatty acids and meat composition

Hernández-Matamoros A., Paniagua Breña M., Izquierdo Cebrián M., Tejeda Sereno J.F., González Sánchez E.

in

De Pedro E.J. (ed.), Cabezas A.B. (ed.).
7th International Symposium on the Mediterranean Pig

Zaragoza : CIHEAM
Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 101

2012
pages 169-173

Volatile fatty acids and meat composition

A. Hernández-Matamoros*, M. Paniagua Breña, M. Izquierdo Cebrián**, J.F Tejeda Sereno*, and E. González Sánchez***

*Escuela de Ingenierías Agrarias, Dpto. de Producción Animal y Ciencia de los Alimentos, Universidad de Extremadura, Ctra. de Cáceres s/n, 06007 Badajoz (Spain)
**Centro de Investigación La Orden, Junta de Extremadura, Badajoz (Spain)

Abstract. The digestion of fiber in the diet of pigs is mainly the large intestine. Volatile fatty acids (mainly acetic, propionic and butyric acids) are produced as a result of fermentation and are used metabolically after being absorbed through the intestinal wall. Linear odd-chain fatty acids (C15: 0 and C17: 0) can be synthesized de novo from propionate in adipose tissue. The aim of this study was to determine whether the presence of odd-chain fatty acids in the subcutaneous tissue is influenced by the production of propionic because fiber fermentation in the large intestine. A total of 20 Iberian pigs divided into five lots was used. The sugar beet pulp and cereal straw were incorporated as the major fiber sources in diets with levels of incorporation of 300, 450 and 600 $g{\cdot}kg^{-1}$. The subcutaneous fatty acid composition was determined at beginning of period (by biopsy) and at slaughtered. The FA composition varies depending on the type of diet given to pigs. Volatile fatty acids production does not change the composition of the odd-chain fatty acids.

Keywords. Volatile fatty acids – Fiber – Subcutaneous adipose tissue.

Acides gras volatils et composition de la viande

Résumé. *La digestion des fibres dans l'alimentation des porcs se fait surtout dans le gros intestin. Les acides gras volatils (principalement les acides acétique, propionique et butyrique) sont produits à la suite de la fermentation et sont utilisés après avoir été métaboliquement absorbés par la paroi intestinale. Les acides gras linéaires à chaîne impaire (C15:0 et C17:0) peuvent être synthétisés de novo à partir du propionate dans le tissu adipeux. L'objectif de cette étude était de déterminer si la présence d'acides gras à chaîne impaire dans le tissu sous-cutané est influencée par la production d'acide propionique, en raison de la fermentation des fibres dans le gros intestin. Un total de 20 porcs Ibériques divisés en cinq lots ont été utilisés. La pulpe de betterave sucrière et la paille de céréales ont été intégrées en tant que sources majeures de fibres dans l'alimentation selon des niveaux d'incorporation de 300, 450 et 600* $g \bullet kg^{-1}$*. La composition sous-cutanée en acides gras a été déterminée en début de période (par biopsie) et à l'abattage. La composition en AG varie selon le type d'alimentation donnée aux porcs. La production d'acides gras volatils ne modifie pas la composition en acides gras à chaîne impaire.*

Mots-clés. *Acides gras volatils – Fibres – Tissu adipeux sous-cutané.*

I – Introduction

The digestion of fiber in the diet of pigs is mainly the large intestine. The rate of degradation of dietary fiber depends on dietary fiber characteristics such as the chemical composition, the degree of lignification, particle size, or the water solubility. Volatile fatty acids (mainly acetic, propionic and butyric acids) are produced as a result of fermentation and are used metabolically after being absorbed through the intestinal wall. Propionate is involved in the synthesis of linear odd-chain fatty acids (C15:0 and C17:0) by two metabolic pathways: (A) by lengthening of the carbon chain by micro-organisms (Fulco, 1983; Kaneda, 1991), followed by absorption and uptake of these exogenous and circulating fatty acids by the tissues, (B) by fatty acid synthesis and incorporation of propionyl-CoA instead of acetyl- CoA during the synthesis of these endogenous fatty acids in milk secretion (Loor *et al*., 2005; Vlaeminck *et al*., 2004) and in adipose tissue (Berthelot *et al*., 2001). Whereas, regression analysis suggested cis-9 C17:1 to be a desaturation product of C17:0 (Fievez *et al*., 2003; Kay *et al*., 2005). However, all these studies have been conducted on ruminants (Berthelot *et al*., 2001) or rabbits (Papadomichelakis *et al*, 2010) but not in pigs.

The aim of this study was to determine whether the presence of odd-chain fatty acids in the subcutaneous tissue is influenced by the production of propionic acid because fiber fermentation in the large intestine.

II – Materials and methods

A total of 20 Iberian pigs divided into five lots was used. Sugar beet pulp SBP (as soluble fiber) and cereal straw CS (as insoluble fiber) commercially available were incorporated as the major fiber sources in diets according to the scheme presented in the Table 1. The diets were milled to pass through a 2 mm screen diameter and offered as granule. The chemical composition of the diets is presented in Table 1. The diets contained similar crude protein contents and total amino acids, calcium and phosphorus levels and were balanced for metabolizable energy (ME). The pigs started the experiment with an average live weight of 84 kg and remained there for 28 days, up to 102 kg of live weight and were then slaughtered.

Table 1. Content of fiber sources on the experimental diets (g·kg^{-1}) and chemical composition (g·kg^{-1} dry matter)

Diets	1	2	3	4	5
Sugar beet pulp	150	300	150	225	300
Cereal straw	150	150	300	225	300
Crude fat	23.5	20.7	38.0	27.7	49.5
∑Saturated	7.6	6.2	12.6	8.8	18.6
∑Monounsaturated	7.7	5.9	15.7	9.6	22.8
∑Poliunsatured	8.0	8.5	9.4	9.1	7.7
∑Odd-chain fatty acid	0.2	0.1	0.3	0.2	0.4

It were taken samples from subcutaneous fat at beginning of period (by biopsy) and at slaughtered. The fatty acid (FA) composition of the lipids were determined by gas chromatography after acidic-trans-esterification in the presence of sulfuric acid (5% sulfuric acid in methanol) (Cava *et al*., 1997). The gas chromatograph, model Hewlett-Packard 4890 Series II, was equipped with a split/splitless injector and a flame ionization detector. FAs were separated on a nitroterephthalic acid modified polyethylene glycol semicapillary fused silica column (30 m long, 0.53 mm i.d., 1 μm film thickness).

To determine volatile fatty acids (VFA) concentration (acetic, propionic, butyric, isobutyric, isovaleric and valeric acid), samples from the caecum and proximal colon were centrifuged. The supernatant fraction was analyzed chromatographically for VFA essentially by the method of Brighenti (1997) (using 2-ethyl butyrate as an internal standard, rather than isovaleric acid).

Statistical analyses were performed using SPSS (version 15.0, 2008). One-way ANOVA determined significant differences between groups. Differences between means were tested by Tukey's least significant difference. Dates are presented as means and standard error of the means (SEM) and the animal was the experimental unit. It was performed a simple regression analysis to relate the differences caused in the fatty acid composition with the fatty acids consumption and total production of volatile fatty acids in *caecum* and proximal colon.

III –Results and discussion

In Table 2 the FA composition of subcutaneous fat and difference between initial and final period of experiment is shown. FA composition was not significantly different between diets when the experiment begins, but it was significantly different after 28 days the diets ingestion. In the total of saturated and polyunsaturated is where can be appreciate these differences.

Table 2. Fatty acid composition (g·100g^{-1} fat) of the subcutaneous adipose tissue and the difference between the fatty acid composition the initial and final experimental time

Diets	1	2	3	4	5	SEM	p-value
Subcutaneous							
∑Saturated	38.3 ^{b}	36.7 ^{ab}	34.6 ^{a}	36.0 ^{ab}	35.8 ^{a}	0.353	0.004
∑Monounsaturated	52.3	52.9	53.5	53.0	52.7	0.225	0.549
∑Polyunsaturated	8.7 ^{a}	9.4 ^{ab}	11.0 ^{c}	10.3 ^{bc}	10.6 ^{bc}	0.239	0.002
∑Odd-chain fatty acids	0.8	0.9	0.9	0.7	0.9	0.031	0.519
Difference							
∑Saturated	0.18 ^{b}	0.67 ^{b}	-1.95 ^{a}	-1.00 ^{ab}	-2.35 ^{a}	0.384	0.031
∑Monounsaturated	2.04	1.90	2.44	2.67	3.14	0.192	0.254
∑Polyunsaturated	-2.17 ^{ab}	-2.56 ^{a}	-0.51 ^{b}	-1.62 ^{ab}	-0.87 ^{ab}	0.242	0.017
∑Odd-chain fatty acids	-0.05	0.00	0.02	-0.04	0.07	0.019	0.239

Means with the different letters on the same line are significantly different.

Results of total volatile fatty acid and molar proportion in the caecum and proximal colon are shown in Table 3. Total VFA concentrations in the caecum and colon of pigs have been reported to be between 80 and 240 mmol·l^{-1} in several studies (Pierce *et al*., 2005; Reilly *et al*., 2010). Although the volatile fatty acids production is high (both total and propionic acid) there is no relation to odd-chain fatty acids composition (Table 4).

Table 3. Effect of experimental diets on total volatile fatty acid (mmol·l^{-1}) and on the molar proportion (%) in the caecum and proximal colon†

Diets	1	2	3	4	5	SEM	p-value
Caecum							
Total VFA (mmol•l^{-1})	299	291	249	228	295	10.41	0.090
Acetic acid	71.4ab	74.2b	69.7a	71.9ab	74.4b	0.54	0.011
Propionic acid	19.5ab	17.1a	22.1b	19.0ab	16.4a	0.57	0.003
Butyric acid	8.1	8.0	7.0	8.0	7.9	0.23	0.568
Proximal colon							
Total VFA (mmol•l^{-1})	317b	296ab	251ab	235a	308ab	9.93	0.011
Acetic acid	70.3	71.4	68.4	70.1	71.4	0.47	0.246
Propionic acid	18.3ab	18.2ab	21.7b	19.1ab	17.4a	0.50	0.045
Butyric acid	9.8	9.3	8.2	9.3	9.4	0.28	0.497

†Acetic, propionic, butyric, isobutyric, isovaleric and valeric acid. Means with the different letters on the same line are significantly different.

Fievez *et al*. (2003) suggested that cis-9 C17:1 was endogenously produced from C17:0 by Δ9-desaturase activity, consistent with a product/precursor relationship. In our case, the ratio of odd-chain fatty acids is narrow, with the adipose fat concentration of cis-9 C17:1 and C17:0 closely related (r^2=0.763).

The fat composition is determined by feed, either by direct diet lipids deposition or by de novo synthesis from carbohydrates ingested. For the monounsaturated and saturated, the fatty acids intake influences the composition. The correlation coefficients in the regressions analyses reflect the relation between consumption and differences in FA composition (Table 4). In the case of monounsaturated FA, this relationship is positive and negative in saturated.

Table 4. Regression analysis with correlations coefficients

	Difference			
	Saturated	**Monounsaturated**	**Polyunsaturated**	**Odd-chain**
Consumption†	-0.65*	0.49*	-0.10	0.42
Total VFA *caecum* (mmol/l)	0.37	-0.21	-0.42	-0.07
Total VFA colon (mmol/l)	0.22	-0.12	-0.27	0.24
Propionic *caecum* (mmol/l)	0.49*	-0.47*	-0.39	-0.21
Propionic colon (mmol/l)	0.34	-0.28	-0.33	0.14

†Total consumption of each fatty acid per day, respectively.
* Marked correlations are significant at $p < 0.05$

IV – Conclusions

The subcutaneous fatty acid composition varies depending on the type of diet given to pigs. Volatile fatty acids production not changes the composition of the odd-chain fatty acids.

Acknowledgments

The research was supported by the Regional Government Junta de Extremadura and the European Social Fund. Research (Project PRI08B091). The authors gratefully acknowledge to workers the farm Valdesequera for their technical assistance in animal management and Fanny Senie for her help in the laboratory.

References

Berthelot V., Bas P., Schmidely P. and Duvaux-Ponter C., 2001. Effect of dietary propionate on intake patterns and fatty acid composition of adipose tissues in lambs. In: *Small Ruminant Research* 40: 29-39.

Brighenti F., 1997. Simple method for quantitative analysis of short chain fatty acids in serum by gas–liquid chromatography. In: *Profibre: Plant Polysaccharides in Human Nutrition*: *Structure, Function, Digestive Fate and Metabolic Effects. Guillon*, F., Abraham, G., Amadò, R., Andersson, H., Asp, N.G.L., Bach Knudsen, K.E., Champ, M., Robertson, J.A. (Eds.). INRA, Nantes, p. 114–119.

Cava R., Ruiz J., López-Bote C.J., Martín L., García C., Ventanas J. and Antequera T., 1997. Influence of finishing diet on fatty acid profiles of intramuscular lipids, triglycerides and phospholipids in muscles of the Iberian pig. In: *Meat Science* 45: 263-270.

Fievez V., Vlaeminck B., Dhanoa M.S. and Dewhurst R.J., 2003. Use of principal component analysis to investigate the origin of heptadecenoic and conjugated linoleic acids in milk. In: *J. Dairy Sci*. 86: 4047–4053.

Fulco A.J., 1983. Fatty acid metabolism in bacteria. In: *Prog. Lipid Res*. 22: 133–160.

Kaneda T., 1991. Iso- and anteiso-fatty acids in bacteria: biosynthesis, function, and taxonomic significance. In: *Microbiol. Rev*. 55: 288–302.

Kay J.K., Kolver E.S., Thomson N.A., Roche J.R. and Baumgard L.H., 2005. The effect of Vitamin E supplementation on production and fatty acid profiles. In: *J. Dairy Res*. 72: 1–11.

Loor J.J., Doreau M., Chardigny J.M., Ollier A., Sebedio J.L., and Chilliard Y., 2005. Effects of ruminal or duodenal supply of fish oil on milk fat secretion and profiles of trans-fatty acids and conjugated linoleic acid isomers in dairy cows fed maize silage. In: *Anim. Feed Sci. Technol*. 119: 227–246.

Massart-Leen A.M., Roets E., Peeters G., and Verbeke R., 1983. Propionate for fatty acid synthesis by the mammary gland of the lactating goat. In: *J. Dairy Sc*i. 66,: 1445–1454.
Vlaeminck B., van Vuuren A.M., Demeyer D., and Fievez V., 2004. Origin of starch in dairy concentrates provokes differences in milk fatty acids related to lifestyle diseases. In: *Comm. Appl. Biol. Sci*. 69,: 341–344.
Papadomichelakis G., Karagiannidou A., Anastasopoulos V. and Fegeros K., 2010. Effect of high dietary digestible fibre content on the fatty acid composition of two muscles in fattening rabbits. In: *Livestock Science*. 129, : 159-165.