EFFECT OF INTRODUCING DIFFERENT N-3 FATTY ACIDS INTO PIG FEED ON THE NUTRITIONAL QUALITY OF THE MEAT AND PROCESSED PRODUCTS

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Abstract - The introduction of n-3 essential fatty acids (FA) into the pig diet can increase the level of these fatty acids in the meat. Numerous studies have been carried out with the incorporation of the n-3 fatty acid precursor, C18:3 n-3 (ALA). But the human diet also needs the long chain fatty acid as C22:6 n-3 (DHA). The objective of this study is to compare the effects of the ingestion of ALA (from extruded linseed) and/or of DHA (from microalgae) on the metabolism of fatty acids, their deposit in the meat and in processed products. Four batches of ten pigs received diets weighing between 50 and 110 kg, and composed respectively of rapeseed oil, extruded linseed (GLE), microalgae (MAG) or a GLE-MAG mixture. In all batches, the ALA or DHA content in the meat increases according to the diet. This study shows that 100 g of cooked ham can provide approximately 400 mg of ALA or 250 mg of DHA with the diets GLE or MAG respectively or 250 mg of ALA and 100 mg of DHA with an ALA-DHA mixed diet. The use of microalgae in animal feed is thus very promising to obtain a pork product with an interesting nutritional value.

key word : linolenic acid, DHA, microalgae, pork meat, rapeseed oil

I. INTRODUCTION

Introducing linseed, a source of C18:3 n-3 (ALA) into pig feed increases the content of this fatty acid in pork and processed products [1]. The nutritional value of these products is increased both by the presence of n-3 fatty acids considered to be good for human health and by the reduction in saturated fatty acids [2]. But the human diet also needs long-chain n-3 derivatives such as C20:5 n-3 (EPA) and C22:6 n-3 (DHA). The *de novo* synthesis of EPA and DHA from the ALA precursor is weak because of competition between the n-6 and n-3 fatty acids for desaturase activities. The transformation of the precursor into its DHA derivative is estimated at between 1 and 2%. Introducing C18:3 n-3 into the pig diet significantly increases this fatty acid and EPA, whereas the increase in DHA is low and insignificant [1].

The known source of DHA for human consumption is primarily oily fish. This source seems limited in the future because of reduced fish resources. Other sources of long-chain n-3 fatty acids in human food must be sought without delay to preserve fish stocks. The incorporation of DHA-rich microalgae into the feed of monogastric animals may be a possible solution. Numerous studies have been made into the effect of ALA in feed and the consequences on deposition in the meat, but the effects of DHA in feed are not yet very well known. The objective of this study is to compare the effects of ALA input by extruded linseed and DHA input by microalgae on deposition in pork, and their fate in processed products.

II. MATERIALS AND METHODS

Forty castrated crossbreed pigs and gilts (Piétrain × (Landrace × Large White)) were divided into 4 batches of 10, and after 50 kg of live weight and for a period of 2 months received an isolipidic diet with a varied lipid source. The fat content was provided either by rapeseed oil (HC) or by extruded linseed (Tradi-Lin®), a source of ALA (GLE), or by microalgae (MAG) selected for their DHA content (Schizochytrium *sp* strain) or a 50/50 GLE-MAG combination. The total lipid content was from 4.1 to 4.5% according to diet. The ALA content (g/kg feed) was 2.27g for HC, 9.88 for GLE, 5.49 for GLE-MAG and 0.82 for MAG. The DHA contents were at the limit of detection for HC and GLE, 3.42g for GLE-MAG and 6.05 for MAG. All the diets contained 80 ppm of vitamin E. The animals were housed individually, their daily consumption was measured and they were weighed once a week. At slaughter, the carcasses were cut up and samples from various fat tissues and muscles were taken and kept at -20°C in a vacuum pack pending analysis. Prepared meat products were made from this meat by the industrial partner according to their usual manufacturing processes.

From the samples, the lipids were extracted by a cold method with a methanol-chloroform blend [3]. The fatty acid profile was carried out by gas chromatography after derivation with BF3 [4]. The results were tested by global analysis of variance with the diet effect as principal factor, and then they were compared two by two using the Bonferonni test.

III. RESULTS AND DISCUSSION

There was no significant difference between the growth performances and the carcass composition of the pigs.

Fatty acid composition of the back fat and the pork rib

The lipid contents in the back fat were 69.4% for HC, 67.2 for GLE, 67.7 for GLE-MAG and 67.9 for MAG, but the variations were not significant. The percentage of saturated fatty acids was identical in the back fat of the animals in the 4 batches (Table 1). Expressed in quantity, the total saturated fatty acid content was lower in batch GLE (23.4 g/100 g) compared to 29.6 g for HC, 25.3 g for GLE-MAG and 27.4 g for MAG ($p<0.001$). The polyunsaturated fatty acid (PUFA) content was significantly higher for batch GLE ($p<0.001$). The variations of ALA or DHA went along with the inputs of these fatty acids in the diets. For ALA, these results were expected, but for DHA *via* microalgae, few comparisons are available. A previous study with extracts of DHA-rich microalgae had shown that DHA was deposited nearly 50 times less well than ALA [5]. In this study, the DHA deposition was therefore more effective.

Table 1 - Comparison of classes of fatty acids (%) and of the main unsaturated fatty acids in the back fat according to the animals' diets

Diet	HC	GLE	GLE-MAG	MAG	Rsd	*p*.value
SFA	37.85	36.60	38.37	38.25	2.73	NS
MUFA	47.00a	41.53b	41.70b	43.13b	1.70	< 0.001
PUFA	15.15a	21.86bc	19.93bc	18.63c	2.36	< 0.001
C18:2n-6	11.92ab	12.73a	10.93ab	10.18b	1.62	< 0.004
C18:3n-3	1.58ab	6.59c	3.81d	1.08b	0.54	< 0.001
C22:6n-3	0.05a	0.06a	2.07b	3.69c	0.29	< 0.001
n-6/n-3	5.76a	1.59b	1.69b	2.08c	0.13	< 0.001
LA/ALA	7.54a	1.92b	2.88b	10.41c	1.27	< 0.001

The inline values with a different letter were significantly different at the 5 % threshold
MUFA : Monounsaturated fatty acid

The total lipid contents of the pork rib do not differ significantly between the animals. The ALA and DHA contents (Figure 1) differ according to the animals' diets and they vary according to the inputs in the feed. It should be noted that 100 g of pork rib from batch GLE cover nearly one third of the ALA requirements recommended for the human diet.

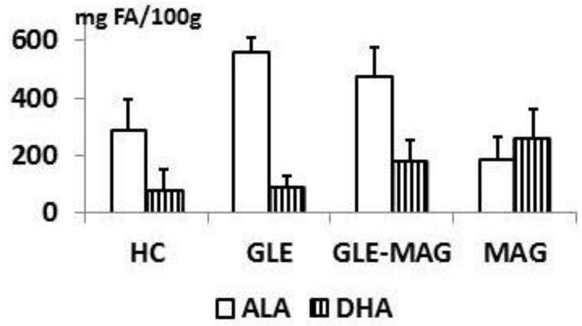

Figure 1 - n-3 fatty acid content in pork rib (mg of fatty acid/100 g of rib)

n-3 fatty acid content in processed products

The processed products were cooked ham and country paste. The country paste mixture was compared before cooking with the cooked product.
The cooked ham slices were analyzed with the pork rind. The total lipid contents were significantly higher in animals from batch MAG (value from 11 to 15%). These variations seemed related more to a ham effect than to a diet effect. Six hams per batch selected at random at the slaughter-house were processed. Analysis was carried out on six slices from each ham taken randomly at the time of cutting. All this increased the variability. The evolution of the n-3 fatty acid deposition was in line with the inputs in the diet (Table 2). The ham slices from the pigs in batch GLE provided more than a quarter of human needs in ALA, and for DHA, the animals from batch MAG covered the totality of the recommendations for this fatty acid.

Table 2 - Effect of diets on the content of total lipids and fatty acids of the cooked ham (expressed in mg of fatty acid/100 g of ham)

Diet	HC	GLE	GLE-MAG	ALG	Rsd	*p*.value
Total lipids (%)	11,70ab	10,97ab	10,96ab	14,68a	3,36	0,01
SFA	3285ab	3260ab	3141ab	4393b	838	<0,02
MUFA	5624ab	4678ab	4613ab	6834a	1315	<0,002
PUFA	1373	1681	1701	1619	500	NS
Total n-6	1131	1064	1133	1153	336	NS
C18:2 n-6	1064	1017	1099	968	310	NS
C20:4 n-6	29ab	21b	38ab	46a	12	<0,02
Total n-3	190a	567b	512b	416b	161	<0,007
C18:3 n-3	125ab	442c	280bc	80a	106	<0,001
C20:5 n-3	9	11	19	8	7	NS
C22:5 n-3	9a	18ab	29bc	42c	11	<0,001
C22:6 n-3	5a	4a	106b	239c	52	<0,001
LA/ALA	8.5a	2.3b	3.9b	12.1c	2.1	<0,001
n-6/n-3	5.9a	1.9b	2.2b	2.8b	2.1	<0,001

The inline values with a different letter were significantly different at the 5 % threshold

The total lipid content of the country paste did not differ between batches (Table 3). The saturated fatty acid content (SFA) was lower with the pigs which received linseed in their diet ($p<0.01$). The content of PUFA is the lowest with pigs with the rapeseed diet ($p<0.001$). The quantities of ALA were the highest in pigs receiving extruded linseed, whereas DHA quantities were higher in pigs ingesting microalgae ($P<0.001$). The 18:2 n-6/18:3 n-3 ratio was lower than 5 for the batches with GLE and all of the values of these ratios were different from each other.

Table 3 - Effect of diets on the total lipid and fatty acid content of the country paste (expressed in mg of fatty acid/100 g of paste)

Diet	HC	GLE	GLE-MAG	ALG	Rsd	*p*.value
Total lipids (%)	33,09	32,52	30,92	34,21	1,87	NS
SFA	11489a	10607b	10378b	11399ab	522	<0,01
MUFA	14169a	12863ab	12232b	13990a	762	<0,001
PUFA	4732a	6513b	5996b	6109b	348	<0,001
Total n-6	3827	4066	3856	4073	229	NS
C18:2 n-6	3533ab	3842a	3409b	3347b	205	<0,002
C20:4 n-6	197a	141c	16bc4	194a	16	<0,001
Total n-3	727a	2273b	1998c	1891c	11	<0,001
C18:3 n-3	473a	1752b	1057c	341d	62	<0,001
C20:5 n-3	20a	85b	85b	117c	7	<0,001
C22:5 n-3	64a	109b	114b	171d	7	<0,001
C22:6 n-3	59a	33a	543c	1129e	34	<0,001
LA/ALA	7.5	2.1	1.7	9.8	1.7	<0,001
n-6/n-3	5.2a	1.8b	1.9b	2.1b	1.7	<0,001

The inline values with a different letter were significantly different at the 5 % threshold

Comparison between the mixture before cooking and the finished product highlighted an increase in the total lipid content of approximately 2 to 3 points of total lipids because of evaporation during cooking.

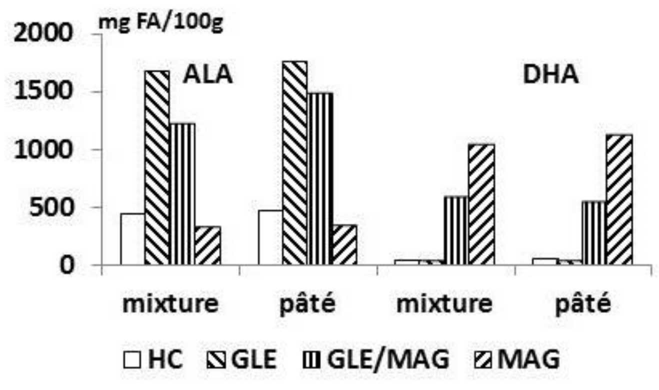

Figure 2 - Comparison of the n-3 fatty acid content of the country paste before and after cooking

The fatty acids of the n-3 family were not affected during processing. Their contents increased along with those of the total lipids (Figure 2).

IV. CONCLUSION

This study confirmed that pigs receiving fatty acids of interest for human health in their feed made it possible to find them in the dish of the consumer. The processing of the pork into prepared meat products did not deteriorate the n-3 fatty acid composition.

In this study, the quantities of DHA added to the pig feed were certainly too high. The objective was not to provide the consumer with all his fatty acid requirements in just one product. This study has to continue with lower DHA inputs to reconcile both the nutritional and organoleptic qualities and the higher cost of the product.

By this study, we show that meat products with added health value really do have their place in our everyday food. The use of DHA-rich microalgae in pig feed makes it an interesting source of DHA for humans, helping to preserve fishery resources.

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