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Effect of dietary conjugated linoleic acid supplementation on the technological quality of backfat of pigs

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ABSTRACT

Pigs were fed diets containing 0, 0.25, 0.5 and 1% conjugated linoleic acid (CLA). Compared to controls, backfat from CLA fed pigs was firmer and extracted lipid contained increasing amounts of CLA, but a ±11% overall decrease in unsaturated fatty acids and a ±5% overall increase in each of C16:0 and C18:0 saturated fatty acids were noted. This resulted in a change in the melting properties of fat. The onset setting temperature increased from ±14 °C to ±18 °C for lipid of backfat of pigs from the 0.25 and 0.5% CLA supplementation groups, and to ±26 °C for lipid from the 1% CLA supplementation group. The final melting temperatures increased from ±37 °C to ±43 °C and ±45 °C, respectively. The presence of β′-crystals of C18:0–C16:0–C18:1c9 triacylglycerides in fat from CLA fed pigs and β-crystals in fat from 1% CLA fed pigs was observed. Fatty acid and melting point results explained the improvement in the technological quality of backfat as a result of dietary CLA supplementation.

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1. Introduction

Fat is an important part of the pig carcass for both the consumer and the meat processing industry (Hallenstvedt, Kjos, Øverland, & Thomassen, 2012). Wood (1984) defined a good quality fat in pigs as firm and white, while a poor quality fat is soft, oily, wet, grey and floppy. Lipid characteristics are important for the technological quality of pork (Hugo & Roodt, 2007). Meat products containing soft fat may show quality defects, such as insufficient drying, oily appearance, rancidity development and lack of cohesiveness between muscle and adipose tissue on cutting (Bailey, Cutting, Enser, & Rhodes, 1973; Maw, Fowler, Hamilton, & Petchey, 2003).

Meat with a more saturated fatty acid (SFA) profile is therefore more suitable for the meat processing industry, while fat with a lower degree of saturation is associated with superior health properties (Hadorn, Eberhard, Guggisberg, Piccinali, & Schlictherle-Cerny, 2008; Hugo & Roodt, 2007). This illustrates the great dilemma between technology and human health that the meat producers and the meat industry have to deal with (Wood et al., 2003). In other words, the nutritional and technological qualities of backfat are inversely related (Hugo & Roodt, 2007; Ospina-E, Cruz-S, Perez-Alvarez, & Fernandez-Lopez, 2010).

A possible solution to this problem may be the supplementation of pig diets with conjugated linoleic acid (CLA). In pigs and other monogastric animals, the fatty acid composition of the fat tissue triglycerides can be changed by altering the fatty acid composition of dietary fat, which are absorbed intact from the small intestine and incorporated directly into the fat tissue (Rhee, Davidson, Cross, & Ziprin, 1990). It has been reported that dietary CLA supplementation increased the saturated/unsaturated fat ratio of fat tissue, and improved belly fat firmness (Dugan, Aalhus, Jeremiah, Kramer, & Schaefer, 1999; Eggert, Belury, & Schinckel, 1998; Joo, Lee, Ha, & Park, 2002; Wiegand, Parrish, Swan, Larsen, & Baas, 2001). This implies that an unsaturated fatty acid (UFA) can be used to improve the technological properties of fat tissue.

In general, triacylglycerides do not differ only in fatty acid composition, but also in their stereospecific arrangement on the three *sn*-positions of the glycerol (Christie, 1983). While the overall fatty acid composition amongst mammalian fats may differ, the stereospecific arrangement shows common features. For pig fat, most of the UFAs are located in the *sn*-1 and *sn*-3 positions (Breckenridge, 1978). Although the stereospecific distribution sets some limits to the amount of different possible molecular triglyceride species that can be formed, a large number is still possible. Simple fats with single or limited types of fatty acids regularly form β crystals, which are the most stable form, or they may be transformed to the less stable β′ and least stable α crystals (Hagemann, 1988; Mortensen, 1983). In complex fats, such as animal fats, the combination of different triglyceride molecule species leads to complicated crystallization patterns. Polymorphism is observed during

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crystallization, i.e. more than one crystal type is formed due to different patterns of molecular packing in the crystal.

The crystallization and melting of fat from pig lard have been studied to some extent (Sasaki, Mitsumoto, Nishioka, & Irie, 2006; Svenstrup, Brüggemann, Kristensen, Risbo, & Skibsted, 2005). Due to the large number of triglyceride molecule species present, the crystallization is very complex, resulting in the formation of compound crystals. It is not possible to relate specific molecules to the formation of these crystals, however, six major crystal types have been identified in pig fats. The melting points observed by differential scanning calorimetry (DSC) were found to be in agreement with the results from a study of particle size distribution in lard fat, which was prepared by fractional crystallization at different temperatures (Wang & Lin, 1995).

As mentioned earlier, pig fat composition may be altered with nutritional intake, which may affect the textural properties (Corino, Spark, Parrish, & Zimmerman, 2003; D'souza & Mullan, 2002; Wiegand, Spark, Parrish, & Zimmerman, 2002). Differences in fatty acid composition of pig fat also affect the crystallization properties of the fat, as was shown for fat from lard and leaf fat (Svenstrup et al., 2005). The effect of nutritional intake on fat crystallization properties, irrespective of the location in the pig carcass, has not yet been determined.

The aim of this research was to determine how dietary CLA supplementation of pigs affects the physical properties, fatty acid composition and melting and crystallization behaviour of fat in an attempt to explain the effect of elevated CLA levels on technological properties of backfat.

2. Materials and methods

2.1. Animal feeding experiment

Forty eight Large White × Duroc gilts, weighing on average ±35 kg, were randomly divided into four groups of twelve pigs each. The groups were then randomly assigned to each of the four dietary treatments that consisted of a control diet containing 1% sunflower oil (SFO), a diet containing 0.75% SFO + 0.25% CLA-60, a diet containing 0.5% SFO + 0.5% CLA-60 and a diet containing 1% CLA-60. The pigs were individually penned and provided ad libitum access to feed and water. Pigs were fed until their average live weight was ±95 kg. The experiment was approved by the Control Committee on Animal Experiments of the University of the Free State (Animal Experiment Number 05/2010).

2.2. Diets

The formulation and nutrient composition of the diets are shown in Tables 1 and 2. Diets were formulated to be isocaloric and isonitrogenous (Table 2). Fresh sunflower oil was obtained from Chipkins, Bloemfontein, South Africa. Luta-CLA® 60, manufactured by BASF, was imported from BASF in Germany by Advit (Johannesburg, South Africa). The CLA mixture contained 60% total CLA, consisting mainly of the two active ethyl-ester isomers, *cis*-9, *trans*-11 and *cis*-10, and *trans*-12. Conjugated linoleic acid can be included at levels of 0.5–1% in complete pig feeds and received GRAS status in the USA in 2004 (Dr R Ruehle, BASF, Personal Communication, 30 September 2013). All experimental diets were mixed in 2000 kg batches at Nutrifeeds, Viljoenskroon. A commercial antioxidant, Oxiban® P, (a mixture of BHA, BHT, ethoxyquin and trisodium citrate) was included in all diets at a concentration of 0.0125%, to protect against oxidation during storage. Feed was packaged in 50 kg bags and transported to Bloemfontein, where it was stored in the dark, at room temperature, until used.

Proximate analysis on the feed was performed by the laboratories of Nutrifeeds in Viljoenskroon, South Africa. Lipid extraction and fatty acid methyl ester (FAME) analysis of the sunflower oil, CLA of all the four diets, as well as individual fat containing feed ingredients, were determined as described by Folch, Lees, and Sloane-Stanley (1957) and Park, Albright, Cai, and Pariza (2001). Analysis on the feed was performed on samples from 12 randomly selected bags from each treatment.

Table 1
Composition (%) of experimental diets on an air dry basis based on % CLA inclusion.

Component	Control (CL)	0.25% CLA	0.5% CLA	1% CLA
Yellow maize/fine	67.87	67.87	67.87	67.87
Maize gluten/20%	3.00	3.00	3.00	3.00
Soybean oilcake	20.00	20.00	20.00	20.00
Sunflower oilcake	3.00	3.00	3.00	3.00
Fish meal	2.00	2.00	2.00	2.00
Limestone powder/fine	1.45	1.45	1.45	1.45
Mono-calcium phosphate	0.47	0.47	0.47	0.47
Fine salt	0.42	0.42	0.42	0.42
Natuphos 500 (phytase 500-high inclusion)	0.10	0.10	0.10	0.10
Liquid choline	0.02	0.02	0.02	0.02
Lysine	0.14	0.14	0.14	0.14
L-Threonine	0.01	0.01	0.01	0.01
Premix L	0.40	0.40	0.40	0.40
Oxiban® P	0.02	0.02	0.02	0.02
Mycosorb	0.10	0.10	0.10	0.10
Sunflower oil	1.00	0.75	0.50	0.00
Luta-CLA® 60	0.00	0.25	0.50	1.00
Total	100.00	100.00	100.00	100.00

2.3. Slaughter and carcass measurements

At an average live weight of ±95 kg, the pigs were weighed and their feed removed approximately 12 h before slaughter. The pigs were transported to the Bloemfontein abattoir, where they were electrically stunned (400 V at 60 Hz), stuck, scalded (61 °C) and dressed, following commercial procedures. The Hennessey Grading Probe was used to measure the backfat thickness, 4.5 cm off the carcass midline, between the second and third last ribs, within 30–40 min of stunning.

After a 24 h chilling period in a cold room at 2 °C, carcasses were transported to the meat technology laboratory of the University of the Free State. Heads were removed, and carcasses halved and split between the second and third last ribs. After the fat was shaved and smoothed, the firmness of the subcutaneous fat was measured with a Bristol Fat Hardness Meter MK2 on the cross sectional surface, at the position between the second and third last ribs. These values were obtained from the average of three readings, adjusted to 1 °C, using the equation: Fat hardness measurement = M − 18(1 °C − T°C), with fat hardness measurement being the temperature-corrected meter reading, M the actual reading and T the actual fat temperature (Sather, Jones, Robertson, & Zawadski, 1995). Backfat colour (L*, a* and b* values) was determined at the same position after a 30 min bloom time, with a Minolta CR-200 tristimulus colour analyzer.

2.4. Tissue sampling

A core (±1 g) sample of both layers of backfat was taken, 45 mm from the mid-dorsal line, between the second and third last ribs, on the left side of the carcass. It is known that the lipid saturation between backfat layers differs (McDonald & Hamilton, 1976). Since both layers of backfat are used in processed meat products and because the emphasis

Table 2
Calculated and analysed nutrient composition of the experimental diets on an air dry basis.

Composition	Unit	Control (CL)	0.25% CLA	0.5% CLA	1% CLA
Calculated values					
Net energy (NE)	MJ/kg	9.63	9.63	9.63	9.63
Lysine	(g/kg)	10.2	10.2	10.2	10.2
Lysine/NE (g/MJ)	%	1.06	1.06	1.06	1.06
Analysed values					
Dry matter	%	89.31	89.29	89.06	89.39
Crude protein	%	19.42	19.55	19.49	19.56
Total lipid content	%	4.02	4.04	4.04	4.01

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