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The influence of thermal processing on the fatty acid profile of pork and lamb meat fed diet with increased levels of unsaturated fatty acids

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ABSTRACT

The research was carried out on 32 crossbred pigs of Polish Large White × Danish Landrace with Duroc and 80 rams, crossbreds of the Prolific-Dairy Koludzka Sheep with the Ile de France, a meat sheep. The fodder for the animals was enriched with the unsaturated fatty acids originated mainly from linseed and rapeseed oils. The fatty acid profile was determined in cooked *longissimus lumborum*, roasted *triceps brachii* and raw ripened rump from pigs as well as in grilled lambs' legs and their corresponding raw materials. Roasting caused the most pronounced increase of the saturated fatty acids and decrease in the polyunsaturated fatty acids of heated pork muscles. The smallest changes were observed in grilled lamb legs. The heating processes applied in this study, in most cases, did not cause essential changes in the indices of pro-health properties of fatty acid, therefore meat in the majority fulfil the latest recommendations of EFSA and FAO/WHO according to human health.

1. Introduction

From the physicians and dieticians point of view, meat, as a healthy food, should contain a small amount of fat with a proper fatty acid (FA) profile, especially with regard to the ratio of omega 3 (n − 3) and omega 6 (n − 6) long chain polyunsaturated acids (LC-PUFA). Within the group of n − 3 FA the most important are α-linolenic acid (ALA; C18:3 n − 3), eicosapentaenoic acid (EPA; C20:5 n − 3) and docosahexaenoic acid (DHA; C22:6 n − 3) (Simopoulos, 2002; Corino, Rossi, Cannata, & Ratti, 2014). Meat can be a good source of them. As it arises from the paper of McAfee et al. (2010) the consumption of total meat and meat products may contribute to 43% of the total dietary intake of LC n − 3 PUFA compared to 48% from oily fish in Australian adults. The reason such a high contribution, is a high meat intake, which is 6 times higher than that of fish (Howe, Meyer, Record, & Baghurst, 2006; Howe, Buckley, & Meyer, 2007). Meat contains also a meaningful amount of monounsaturated fatty acids (MUFA). They oxidize significantly slower in comparison to PUFA (Wood et al., 2008, Webb & O'Neill, 2008). Interesting features are also related to the stearic acid, which, despite the fact, that it belongs to the saturated fatty acids (SFA), according to some papers (Li, Siriamornpun, Wahlqvist, Mann, & Sinclair, 2005; Hunter, Zhang, & Kris-Etherton, 2010) it lowers the LDL cholesterol level, is neutral or even decrease HDL cholesterol level, and tends to lower the ratio of total and HDL cholesterol.

A lot of studies have been carried out indicating the possibility of a modification of intramuscular fat in meat leading to an increase in the proportion of unsaturated fatty acids (UFA) and therefore the pro-health properties of meat (see the reviews of Wood et al., 2008 and McAfee et al., 2010; Zhang, Xiao, Samaraweera, Lee, & Ahn, 2010; McNeill & Van Elswyk, 2012).

The limiting factors of such changes are the sensory and technological properties of meat (Rentfrow, Sauber, Allee, & Berg, 2003; Nuernberg et al., 2005; Guillevic, Kouba, & Mourot, 2009; Watkins et al., 2014), although growth performance and carcass characteristics are often not affected (Mas et al., 2011; Morel, Leong, Nuijten, Purchas, & Wilkinson, 2013).

The meat FA profile of fat can also be changed using different methods of processing; such as trimming (Gerber, Scheeder, & Wenk, 2009), production of the raw cuts, ripened with or without curing and the smoking step (Martín, Córdoba, Ventanas, & Antequera, 1999; Saloko, Darmadji, Setiaji, & Pranoto, 2014), inclusion of thermal treatment or storage with a chilling or freezing regime (Alfaia et al., 2010; Campos et al., 2013; Botsoglou, Govaris, Ambrosiadis, Fletouris, & Botsoglou, 2014) and production of sausages with a mixture of antioxidants or without (Juárez et al., 2009; Piotrowska, Świąder, Waszkiewicz-Robak, & Świderski, 2012).

The proportional changes in FA compositions are associated with lipid losses during heating. Lipids contain mainly triacylglycerols of

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the adipose tissues, which are relatively more saturated than UFA and the last ones are part of the membrane structure (Igene, Pearson, & Gray, 1981; Ramamurti, 1986). As an effect of this situation UFA, especially PUFAS, are less affected by cooking than SFA (Gerber et al., 2009; Jiang et al., 2010; Campo et al., 2013) and consequently, higher losses of SFA compared to PUFA can be observed in meat after cooking. From the study of Kouba, Benatmane, Blochet, and Mourot (2008) appears that n − 3 PUFA are less susceptible to alterations by cooking than n − 6. This may explain why no significant differences have been found in any individual n − 3 FA or in the group of all n − 3 FA when various methods of lamb meat cooking e.g. stewing, grilling or roasting (Campo et al., 2013) were compared and why PUFA n − 6 and PUFA n − 3 ratio decreased after cooking in processed beef steaks (Jiang et al., 2010). Opposite results were obtained by Maranesi et al. (2005), where the microwaving and broiling of lamb meat in a preheated electric grill led to a decrease of n − 3 PUFA however without changes in the ratio of n − 6/n − 3.

The above study presents different results on the influence of thermal processing on the FA profiles mainly in pork and lamb meat. To some extent they might be connected with the meat of the various animal species and also the fat content in meat. In many countries, pork is a very popular meat; however it has often been criticized due to the high fat content. New hybrids make it possible to get leaner cuts and a very lean meat. Lamb meat, a bit more fatty, is rather sparingly used and is mainly a meat for culinary purposes.

Thermal processing in connection with other pre-culinary treatment may shape new functional properties of meat and change its pro-health properties. In the majority, previous experiments were usually performed on meat with high amounts of fat. Recommendations of EFSA (2012) and FAO/WHO (2008) limit the consumption of fat or fatty meat products.

Therefore, the aim of this study was to investigate the influence of the most often used thermal processes for a culinary purposes on the FA profile of very lean (*LL* and *TB* muscles) and a bit more fatty pork and lamb meat from the hind leg (ham in the case of pig's and leg from lamb carcasses). The FA profile of pork and lamb meat was changed through the diet given to animals, which was enriched in unsaturated FA through the addition of linseed and rapeseed oils.

2. Materials and methods

2.1. Pigs, their rearing conditions and carcass value

The study was performed on 32 crossbred pigs, 50% gilts and 50% young hogs. The crossbreeding was based on sows (Polish Large White x Danish Landrace) and Duroc boars. The pigs were kept in the same environmental conditions and fed with a restricted feeding system and with a diet enriched in UFA. The proximate composition (g/kg) of the diet was as follows: barley (360), wheat (360), corn (100), rapeseed meal (40), soybean meal grain (80), linseed (15) and rapeseed (15) oils and vitamin-mineral premix (30).

After slaughter, the lean meat content of the carcasses was estimated using the Ultra Fom 300 ultrasound device (Borzuta, 1998). The average dressing percentage was high and reached the value of 79.87%. The pork muscles *longissimus lumborum* (*LL*) and *triceps brachii* (*TB*) were cooked using different methods of heating. Ham, which formed a rump (main muscles: *gluteus medius* and *biceps femoris*), after a special technology process, was finally cured and smoked, what is described below.

2.2. Lambs, their rearing conditions and carcass value

The research material consisted of 80 lamb crossbreds based on ewes of the Prolific–Dairy Koludzka Line (PDKS) and ram crossbreds of mutton sheep of Ile de France x PDKS. The lambs were fed with a diet composed (g/kg) as follows: barley (250) wheat middling (170), dried grass (100), dried sugar beet pulp (180), rapeseed cake (255), linseed (50), and vitamin-mineral premix (10). All of the lambs were slaughtered at the age of 16 weeks and at a weight of approx. 35 kg (± 3 kg). The dressing percentage was in the range of 42–45%. After cooling and cutting, from the middle of the leg, sample which mainly consists of *semimembranosus* and *biceps femoris* muscles was cut.

2.3. Meat quality measurements

The quality of pork and lamb meat was estimated through the measurements of the pH value, the electrical conductivity (EC), the L*, a*, b* colour values and drip and cooking loss in selected muscles at various post-mortem time according to the methods, which allowed to identified muscle defects and their rejection from further investigations (Garrido, Pedauyé, Bañon, López, & Laencina, 1995; Pospiech, Borzuta, Łyczyński, & Płókarz, 1998). Samples with pH_{45} (45 min post-mortem) lower than 5.8 were rejected as well as those with pH_{24} (24 h post-mortem) greater than 6.0. The EC value shall not be higher than 8.0 by measurements made in these both terms of study, when muscles are still in carcass (Pospiech et al., 2002). Two pork and none lamb carcasses were rejected from experiment.

2.3.1. pH and electrical conductivity measurements

In the pigs the pH value measurements were done in the *LL* muscle between the 1st and 2nd lumbar vertebra at 45 min (pH_{45}) and 24 h (pH_{24}) *post-mortem*. In the lamb meat samples and in the *TB* muscle the pH measurements were taken 24 h post-mortem. The pH value measurements were performed using the Danish pH-meter type Radiometer PHM 80 Portable with integrated electrode type Mettler Toledo LE427. The electrical conductivity of the meat was measured 24 h post-mortem in the hanging carcass only in the *LL* muscle using the apparatus type LF-Star Model 340 from the company Mettler-Toledo GmbH in Schwerzenbach, Switzerland.

2.3.2. Instrumental and subjective colour and marbling evaluation

In the pig meat samples the instrumental evaluation of meat colour was performed 24 h post-mortem on the cross-section of the *LL* muscle at the same place where measurements of the pH value were conducted. Measurements were taken using a Minolta Chronometer CR-400, and the values of L* (lightness), a* (redness) and b* (yellowness) were determined (CIE, 1986). The subjective meat colour evaluation was performed by a team of five people using a 5 point scale for a colour standard (1 — pale, pinkish grey, whereas 5 — dark, purplish red) (NPPC, 1991; Kauffman, Cassens, Scherer, & Meeker, 1992). Lamb meat colour was evaluated objectively 24 h post-mortem on the leg using the same method and equipment as in the case of pork muscles. Meat marbling was estimated on the same cross-section of both pork muscles (*LL* & *TB*) where measurements of the pH value were conducted using a 5 point scale of a marbling standard, where 1 meant devoid to practically devoid, and 5 — moderately abundant or greater (Kauffman et al., 1992).

2.3.3. Drip, cooking, roasting and grilled losses

In order to determine the drip loss value of the pork *LL* and *TB* muscles and lamb leg muscles, samples of these muscles weigh approx. 100 g were placed in plastic bags and left for 48 h at a temperature of 4 °C. The samples of the *LL* muscle for the determination of cooking loss were weighed, packed in a plastic bag and then heated in water until they reached 72 °C in the sample centre. After cooling the samples were weighed again. A similar procedure was used to determine the roasting loss of the *TB* muscle, however in this case the weighed sample was placed not in water, but in an electric oven and heated to 80 °C in the meat centre. Grilling of lamb meat was performed using the apparatus Expo Service type GR 100. Slides of approx. 1.5 cm were grilled for 5 min from each side to the final temperature of 75 °C.