Oxidative Stability and Texture Properties of Fermented Sausage Produced from Pork Differing in Fatty Acid Composition

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Background and objectives: The composition of pork fat, which is an important constituent of many meat products, is very susceptible to nutritional influences (e.g. Bee and Wenk, 1994; Warnants et al. 1996) and also dependent on genetic disposition (Schwörer et al., 1988). From the point of view of high processing quality and product stability, firm lard, low in polyunsaturated fatty acids, is desired.
To prevent the trend towards a more and more undesirable lard quality due to production of very lean pork carcasses or using unsuitable feed compounds, a rapid method to quantify the amount of double bonds in the back fat of pigs was established on Swiss slaughterplants (Häuser and Prabucki, 1990). This study forms part of a project aiming to evaluate the relationship between the composition of dietary lipids, chemical and physical properties of pork fat and selected characteristics of processed meat products. Fermented sausage was chosen as one product to be examined for reasons of its texture traits and shelf-life being susceptible to differences in pork fat quality.

Methods: A total of 12 x 4 siblings of Swiss Landrace and Large White breed (25.4 ± 3.9 kg) where assigned to one of four feeding treatments, fully balanced according to sex, breed, and genetic origin and fattened to an average weight of 105 ± 3,7 kg. The pigs were fed either the basic diet consisting of barley, wheat, soya bean meal and supplemented minerals and amino acids (control) or the basic diet containing a replacement of either pork fat, olive oil or soya bean oil (7.0, 4.95, 3.17 %). The added amount of each fat was calculated to achieve a similar amount of double bonds per kg feed as monoenoic or polyenoic fatty acids.
One day after slaughter the left shoulder of each animal was deboned, trimmed of superficial fat, vacuum packed and, as well as the back fat, kept frozen until all animals had been slaughtered. Then, two batches of lean pork and back fat were produced from each experimental group, one batch from six lean animals with a high proportion of premium cuts and one batch from six fatter animals. Thereby, the balanced design was maintained within each experimental subgroup. To achieve the same fat content, for all batches 19 kg lean meat and 6.25 kg back fat were used. Meat and fat were ground through a 3 mm plate and starter culture *(Staphylococcus carnosus, Lactobacillus plantarum;* rudolf müller, D-35415 Pohlheim) as well as spices, ascorbic acid, sodium ascorbate, rosemary extract, nitrate and sugars were added according to a recipe of the manufacturer. The batter was stuffed in collagen casings of 50 mm diameter and dipped into a suspension of *Penicillium nalgiovense*. Ripening started at a room temperature of 24 °C dropping to 16 °C within one week. Then, the sausages were kept at a temperature of 12 °C and a relative humidity of 85 %. Duplicate samples were taken from the freshly prepared mince and at day 7, 34 and 77. Additionally, samples from a commercially produced salami were taken at the same ripening stages.
The firmness of the sausages was recorded using a texture analyzer (TA-XT2; Stable Micro Systems, Haslemere, Surrey, U.K.). A 12 mm diameter punch was driven after the first contact for another 2 mm on the surface (1) lateral in the middle of the intact salami and (2) on the cross-section of a cut end. On the cross-section, measurements were taken from the center and 5 as well as 1 mm from the edge. The lipids were extracted with hexane/iso-propanol (2:1 v/v) by homogenizing small cut cubes of the salami in the solvent mixture. An aliquot of the filtered solution was used to determine the fat content. Fatty acid profile was determined by GLC from methyl esters (FAME) of the extracted lipids. The oxidative stability was measured as induction time using the Rancimat method (Läubli et al., 1988), where 1 g of the extracted lipid and 2 g paraffin oil as inert carrier substance were weighed into the reaction vessels. At a later stage of ripening, on day 112, the release of oil from the sausages was measured by placing a cut end on a layer of five filter paper circles (70 mm, Schleicher & Schuell) in a petri dish and weighing the amount of fat soaked into the filters. Replicate measurements were done for all analyses; for lateral firmness four measurements were performed.
The data from each of the two sausages per batch and storage time were statistically analyzed performing the GLM procedure and Scheffe's multiple comparison (SAS, Release 6.12).

Results and Discussion: Fat content was, as intended, similar for all treatments (Tab. 1). The slightly higher contents in the sausages produced from the fatter animals might have resulted from the somewhat higher inter- and intramuscular fat of these animals. As expected, the variation of the fatty acid composition was highly significant. Fat of the control animals, which probably derived mainly from *de novo* synthesis, was highest in palmitic and stearic acid. The high amount of oleic acid in the olive oil treatment and of linoleic and linolenic acid in the soya bean treatment well reflected the fatty acid profile of the supplemented oils. Besides, the extraordinary low amount of saturated fatty acids in the olive oil treatment must be stressed. The amount of so called conjugated linoleic acid (CLA) was highest in the pork fat supplemented treatment and in the commercial sausages, indicating the use of beef, which is relatively rich in CLA. Within treatment, the fat of the lean subgroups was generally higher in polyunsaturated fatty acids, emphasizing the negative genetic correlation between the proportion of linoleic acid and the amount of superficial fat, as was pointed out by Schwörer et al. (1988).
The shortest induction time and therefore oxidation stability was found in control and soya bean oil treatment. Regarding the highly unsaturated fat of the latter compared to the control, it can be assumed that some of the tocopherol from the supplemented oil might have been transferred to the body fat being able to act as antioxidant even in the processed products. The Olive oil treatment showed a rather high oxidation stability, despite the high amount of oleic acid. This may be partly explained by the lower susceptibility of the monoenoic compared to the polyenoic acids. Nevertheless, an additional effect may arise from antioxidative activity of olive oil constituents (Visioli et al., 1995). The extended induction time of the commercial sausage may be led back at least in part to the differing recipe, perhaps including elevated amounts of antioxidants.

Table 1: Carcass characteristics of the animals from which the different batches were formed and some chemical and physical properties of the sausages produced

Treatment	Control		Olive oil		Pork fat		Soya bean oil		Commercial	*std.err.*
subgroup	fat	lean	fat	lean	fat	lean	fat	lean		
Carcass characteristics										
Primal cuts[1] [%]	55.4	57.5	54.7	57.9	54.3	57.5	54.7	57.4	–	
Superficial fat[2] [%]	14.0	12.1	14.0	11.2	14.1	12.2	14.1	12.1	–	
Properties of the sausages										
Fat content [g/100g]	32.4 ^{a}	30.2 ^{a}	33.2 ^{a}	31.0 ^{a}	32.4 ^{a}	30.4 ^{a}	30.3 ^{a}	31.8 ^{a}	34.4 ^{a}	*0.68*
Selected fatty acids[3]										
16:0	23.9 ^{a}	23.7 ^{a}	20.6 ^{c}	18.9 ^{d}	22.0 ^{b}	21.6 ^{b}	21.6 ^{b}	20.4 ^{c}	22.3 ^{b}	*0.12*
18:0	14.1 ^{a}	13.8 ^{a}	9.9 ^{d}	8.5 ^{e}	12.6 ^{b}	11.3 ^{c}	11.7 ^{c}	11.5 ^{c}	12.7 ^{b}	*0.12*
18:1	43.7 ^{d}	42.0 ^{e}	51.2 ^{a}	51.7 ^{a}	45.1 ^{c}	45.1 ^{c}	41.0 ^{f}	36.4 ^{g}	46.4 ^{b}	*0.17*
18:2	9.9 ^{e}	11.7 ^{cd}	10.6 ^{de}	12.8 ^{c}	11.3 ^{d}	12.5 ^{c}	16.3 ^{b}	22.3 ^{a}	8.5 ^{f}	*0.19*
18:3	0.9 ^{f}	1.1 ^{de}	0.9 ^{ef}	1.1 ^{cd}	1.1 ^{cd}	1.2 ^{c}	1.6 ^{b}	2.2 ^{a}	1.1 ^{cd}	*0.02*
18:2 conjugated	0.07 ^{cd}	0.08 ^{cd}	0.06 ^{d}	0.08 ^{cd}	0.18 ^{b}	0.22 ^{b}	0.12 ^{c}	0.12 ^{cd}	0.37 ^{a}	*0.01*
Induction Time [h]	6.3 ^{b}	7.0 ^{b}	10.2 ^{b}	9.9 ^{b}	10.4 ^{b}	10.7 ^{ab}	7.8 ^{b}	5.4 ^{b}	17.1 ^{a}	*1.17*
Firmness [kg]										
Lateral	3.5 ^{b}	2.8 ^{c}	1.7 ^{de}	1.6 ^{de}	2.1 ^{d}	1.8 ^{de}	2.0 ^{de}	1.6 ^{e}	4.3 ^{a}	*0.07*
Cross section	2.2 ^{b}	1.4 ^{c}	0.9 ^{c}	0.9 ^{c}	1.2 ^{c}	1.0 ^{c}	1.4 ^{c}	1.0 ^{c}	3.3 ^{a}	*0.10*
Oil release[4] after 20 h	109 ^{a}	102 ^{a}	310 ^{a}	493 ^{a}	112 ^{a}	183 ^{a}	133 ^{a}	322 ^{a}	77 ^{a}	*115*

1)Trimmed shoulder, loin and ham as percentage of carcass weight; 2) Fat and hide trim of primal cuts; 3) g/100g identified FAME; 4) measured at day 112 only
Means within one row lacking a common superscript differ significantly (Scheffé, $p<0.05$)

Although the differences in released oil after 20 h are not significant – due to the small number of observations and the high variation in this trait – the high values for the olive oil and the lean subgroup of the soya bean treatment coincide well with the fatty acid profiles. Also in accordance with the fatty acid composition is the low firmness of these treatments. In contrast, the control treatment showed the highest firmness of the experimental groups and the highest proportion of saturated fatty acids.

Table 2: Fat content and composition as well as oxidation stability and firmness of the sausages at different storage times

	Day 1	Day 7	Day 34	Day 77	*std.err.*
Fat content [g/100g]	23.7 ^{a}	27.3 ^{b}	34.9 ^{c}	40.1 ^{d}	*0.45*
Fatty acids [g/100g]					
16:0	21.8 ^{a}	21.3 ^{c}	21.3 ^{bc}	21.7 ^{ab}	*0.09*
18:0	11.9 ^{a}	11.5 ^{b}	11.3 ^{b}	11.8 ^{a}	*0.08*
18:1	44.9 ^{a}	44.0 ^{b}	44.6 ^{a}	44.5 ^{ab}	*0.12*
18:2	12.7 ^{c}	14.1 ^{a}	13.7 ^{ab}	13.2 ^{bc}	*0.14*
18:3	1.2 ^{c}	1.3 ^{a}	1.3 ^{ab}	1.3 ^{b}	*0.02*
18:2 conjugated	0.12 ^{a}	0.11 ^{a}	0.11 ^{a}	0.11 ^{a}	*0.01*
Induction Time [h]		13.0 ^{a}	6.1 ^{b}	9.2 ^{c}	*0.71*
Firmness [kg]					
Lateral		0.6 ^{a}	2.1 ^{b}	4.3 ^{c}	*0.07*
Cross section		0.4 ^{a}	1.3 ^{b}	2.7 ^{c}	*0.06*

Means within one row lacking a common superscript differ significantly (Scheffé, $p<0.05$)

As expected, the sausage became firmer during ripening, and the induction time was shorter on day 34 and 77 than on day 7. On day 1, the induction time was 41 ± 10 h on average, but, as only one measurement per treatment was taken under these conditions, these data were excluded from statistical analysis.

No sound explanation can be given for the nonlinear behavior of the oxidative stability and the small, nevertheless significant, differences in fatty acid composition between storage times.

Conclusions: Concerning oxidative stability, the fatty acid profile of the pork fat may be only one of several determining factors. The texture properties seem to be closely related to the fat composition. Observations during the processing of the sausages reveal, that the characteristics of the pure fat and its behavior during processing might be even more important than the effects on the quality of the sausages.

Pertinent literature:

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