

# **DOCTORAL (PhD) THESIS**

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**EFFECT OF THE MODIFIED FATTY ACID  
COMPOSITION ON THE QUALITY OF THE  
PÁRIZSI (COLD-CUT)**

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## **1. BACKGROUND OF RESEARCH, OBJECTIVES**

We live in a rushing world, which requires healthy people. For this we need a life style that considerably contributes to the preservation of our health, and it not only includes regular physical exercise, but it also means the consumption of healthy food that support and preserve health. This points to the fact that the food industry became an innovative industry which produces new products year by year to increase consumer satisfaction and to realize the above mentioned objectives.

The functional food is intended to satisfy the above mentioned expectations. This food is able to considerably contribute to achieve and preserve healthy status. Functional food mostly contains components with positive effect that by getting into the organism have a positive effect on its functioning. The improvement and production of this type of food has grown into the most dynamically developing area in the past decade.

Meat and meat products have an important role in the nutrition of modern society. Meat is particularly valuable as  $\omega$ -3 fatty acid, vitamin B<sub>12</sub>, protein and iron source (BENDER 1992), therefore meat itself is also functional food. However, as all food, meat and meat products also have components that under certain conditions (may) have negative effect on our health. Thus, the goal is also to produce healthier meat and meat products, in some cases the development of functional meat and meat products in such a way that the harmful components (substances of natural origin or being present for other reasons) shall

be completely excluded, or at least to reduce them, nevertheless it shall be possible to increase the amount of components having a positive effect on the organism.

To achieve these goals, several methods may be used. The components of meat can be modified (fatty acid content, protein content, level of vitamin E, fatty acid composition) by genetical selection, by combination of the nutrient and feeding, by changing the growth tendency or by different genetic modifications to improve the immunological status of the animal (BASS ET AL., 1990; BYERS ET AL., 1993; HAYÉS PRESTON, 1994). The modification of meat composition is a long and difficult process. Meat product can be modified in the most effective way if during the food industry production, at mixing, the changing happens, for example the amount of a substance having negative effect or of a component with negative judgment is reduced, or component having a positive effect is added to the mix. There are several opportunities to produce different types of functional food (JIMENEZ-COLMENERO, 2000).

Fat is the main component of pork meat products. In order to obtain the optimal fatty acid content different methods are applied to increase the proportion of unsaturated fatty acids (UFA). Mainly animal nutrition is modified to increase the amount of unsaturated fatty acids in animal products. The other procedure is that during the product manufacture the amount of unsaturated fatty acids is increased in the end product. The goal is to increase the UFA/SFA (saturated fatty acids) proportion and to reduce the  $\omega$ -6/ $\omega$ -3 proportion but by increasing the amount of unsaturated fatty acids the sensory property

and the shelf life of the product may also change (WOODS ÉS FEARON, 2009) which usually appears as a problem.

The recommendations for fat intake nowadays applies not only to its amount but, from the aspect of quality, its composition has also become important. Food that have a higher  $\omega$ -3 and  $\omega$ -6 content should be consumed in greater amounts (VOEDINGSAANBEVELINGEN VOOR BELGIË, 2000). Therefore the number of those researches that aims at optimizing, improving the fatty acid content of meat and meat products has increased sharply in the past decades (WOOD ET AL., 2002).

In case of functional pork meat products, several factors shall be considered. First of all, if talk about meat products, by this we mean the reduction of the amount of fat and obtaining the optimal fatty acid profile. By reducing the amount of fat, we not only have an effect on the chemical composition but there is a risk of changing the physical and sensory properties of the end product. If the fatty acid composition is modified through animal nutrition, then due to the higher proportion of unsaturated fatty acid, the backfat will be more tender which may constitute a serious problem during the production of meat products. It is important to mention that as a result of the increasing unsaturated fatty acid content, it becomes reasonable to add antioxidants in order to delay the fatty acid oxidation.

On the whole numerous experiments have been performed to modify the fatty acid composition for different meat products. This is the reason why I have considered that it is important to examine the modification possibilities of the fatty acid composition in párizsi, one of the most popular meat product of Hungary.

**Objectives** of the experiments are the followings:

- I. Comperision of the párizsi products from different price category and with different quality level, which are available on the market. The statistical analysis of examined parameters.
- II. Develop the basic recipe which can be the base for the further examinations and which may have the role of control sample.
- III. The preparation of the first modified párizsi samples with different types and concentrations of liquid lecithin, and their comparison regarding the chemical, physical and sensory aspects.
- IV. The preparation of the second model product with solid, powder based lecithin and flaxseed supplementation, and their comparison regarding the chemical, physical and sensory aspects.
- V. The preparation of the third model product with soybean and flexseed oil based supplementation (soybean and linseed oil), and their comparison regarding the chemical, physical and sensory aspects.
- VI. Comperision the model products with 3 and 6 % supplementation levels with the commercial product from different price category and with different quality level.

## **2 MATERIAL AND METHODS**

The experiments were conducted in the Technological Laboratory of the Department of Agricultural Product Processing and Qualification, at the Faculty of Agricultural and Environmental Sciences, at Kaposvár University and the Physiology Department of the Research Institute for Animal Breeding and Nutrition, Herceghalom.

### **2.1 Examination of cold cut (Párizsi) samples purchased from the market**

I purchased the five different párizsi samples from local shops. It was an important aspect to choose samples of different price and quality. I bought the párizsi in bar (in full, with complete wrapping) to get the information on the composition. From the each brand I bought 2-2 bars. The ingredients of the samples were definitely similar, differenc was just in the amount of the ingredients and in the type of the additives (thickeners, fructose, acidity regulators, etc.)

### **2.2 Development of the basic recipe**

In the first step, I had to develop the basic recipe for the experimental products in order to provide the comparability inside each experimental units and between them. I experimented with the changing of the amount of the components (backfat, pork loin, spices). During the preparation of the test párizsis, I examined the effect of the amount of backfat, pork loin and spice mix on the sensory properties

of the product (color, taste, odour, consistency). The process of production was as follows: directly after purchasing the backfat and the meat, I ground them and frosted them in doses (table 1). On the day of mixing, I diced the half frozen ingredients and put them into the cutter. In the second phase of mixing, when the meat and backfat dices had properly mixed, I added the ice, the spice (ProFood kft.) and the nitrite curing salt (ProFood kft.). After this I was stirring the mass until I got a homogeneous unit.

In order to reach the texture and homogeneity, I had to measure continuously the temperature of the mass, since if it rises above 14 °C, phase separation may occur in the end product which results in separation of fat. So I stopped the cutter every 2 minute and I checked the temperature of the mass with a stab probe thermometer at the following measurement points:

- alongside the wall of the mixing vessel,
- next to the supporting axis of the mixing knife,
- and between the two points.

We filled the ready-made mass into water-vapor-permeable casing having the diameter of 55 mm and 20 cm long, then I applied heat treatment in a cabinet that cooks and smokes at 85 °C until reaching the core temperature (for 60 minutes) of 72 °C. In the end I cooled down the samples to 4 °C and I stored them in this temperature till 1-28 days, with continuous temperature verification.

**Table 1:** Amount of ingredients

Sample code	Backfat (g)	Pork loin (g)	Ice (g)	Spices (g)	Nitrite curing salt (g)
<b>1</b>	400	450	150	10	20
	(40 %)	(45 %)	(15 %)	(1 %)	(2 %)
<b>2*</b>	450	400	150	10	20
	(45 %)	(40 %)	(15 %)	(1 %)	(2 %)
<b>3</b>	500	350	150	10	20
	(50 %)	(35 %)	(15 %)	(1 %)	(2 %)
<b>4</b>	400	450	150	20	20
	(40 %)	(45 %)	(15 %)	(2 %)	(2 %)
<b>5</b>	400	450	150	40	20
	(40 %)	(45 %)	(15 %)	(4 %)	(2 %)

### 2.3 Supplementation with liquid soybean and sunflower lecithin

I performed the first supplementation with soybean and sunflower lecithin (Cargill Ltd.). The samples contained (0% (control), 1.5 %, 3 %, 6 %) the lecithin used for the supplementation in different percentages compared to the quantity of the complete backfat (1200 g=100%) (Table 2). It is important to note that in the recipe, I reduced the quantity of backfat by the quantity of added lecithin, so the quantity of fat stayed constant in the end product but its (fatty acid) composition changed. For preparing it, I used the recipe and the production process developed in **section 2.2**.



**Table 2:** Amount of ingredients for the supplementation by liquid soybean- and sunflower lecithin

Sample code	Pork loin (g)	Backfat (g)	Ice (g)	Soybean lecithin (g)	Sunflower lecithin (g)	Spices (g)	Nitrite curing salt (g)	Percent of supplementation * (%)
1 (Control)	1350	1200	450	0		30	60	0
	(45 %)	(40 %)	(15 %)	(0 %)		(1 %)	(2 %)	
2	1350	1182	450	18		30	60	1.5
	(45 %)	(39,4 %)	(15 %)	(0,6 %)		(1 %)	(2 %)	
3	1350	1164	450	36		30	60	3
	(45 %)	(38,8 %)	(15 %)	(1,2 %)		(1 %)	(2 %)	
4	1350	1128	450	72		30	60	6
	(45 %)	(37,6 %)	(15 %)	(2,4 %)		(1 %)	(2 %)	
5 (Control)	1350	1200	450		0	30	60	0
	(45 %)	(40 %)	(15 %)		(0 %)	(1 %)	(2 %)	
6	1350	1182	450		18	30	60	1.5
	(45 %)	(39,4 %)	(15 %)		(0,6 %)	(1 %)	(2 %)	
7	1350	1164	450		36	30	60	3
	(45 %)	(38,8 %)	(15 %)		(1,2 %)	(1 %)	(2 %)	
8	1350	1128	450		72	30	60	6
	(45 %)	(37,6 %)	(15 %)		(2,4 %)	(1 %)	(2 %)	

\*only refer to the fat substitution, not the whole product

## 2.4 Supplementation by soybean lecithin powder and ground flaxseed

The liquid lecithin supplementation was followed by the solid supplementation in which case I applied soybean lecithin powder (Cargill Ltd.) and ground flaxseed (Cargill Ltd.) to substitute fat. In table 3 the composition of the samples can be seen.

**Table 3:** Amount of ingredients for the supplementation with soybean lecithin and linseed powder

Sample code	Pork loin (g)	Backfat (g)	Ice (g)	Soybean lecithin powder (g)	Linseed powder (g)	Spices (g)	Nitrite curing salt (g)	Percent of supplementation *
1 (Control)	1350	1200	450	0		30	60	0
	(45 %)	(40 %)	(15 %)	(0 %)		(1 %)	(2 %)	
2	1350	1182	450	18		30	60	1.5
	(45 %)	(39,4 %)	(15 %)	(0,6 %)		(1 %)	(2 %)	
3	1350	1164	450	36		30	60	3
	(45 %)	(38,8 %)	(15 %)	(1,2 %)		(1 %)	(2 %)	
4	1350	1128	450	72		30	60	6
	(45 %)	(37,6 %)	(15 %)	(2,4 %)		(1 %)	(2 %)	
5 (Control)	1350	1200	450		0	30	60	0
	(45 %)	(40 %)	(15 %)		(0 %)	(1 %)	(2 %)	
6	1350	1182	450		18	30	60	1.5
	(45 %)	(39,4 %)	(15 %)		(0,6 %)	(1 %)	(2 %)	
7	1350	1164	450		36	30	60	3
	(45 %)	(38,8 %)	(15 %)		(1,2 %)	(1 %)	(2 %)	
8	1350	1128	450		72	30	60	6
	(45 %)	(37,6 %)	(15 %)		(2,4 %)	(1 %)	(2 %)	

\*only refer to the fat substitution, not the whole product

## 2.5 Supplementation by soybean- and linseed oil

Finally I carried out the liquid linseed and soybean oil supplementation. In this case I prepared the samples with the supplementations of 3 %, 6 % and 9 % (Table 4).

**Table 4:** Amount of ingredients for the supplementation with soybean- and linseed oil

Sample code	Pork loin (g)	Backfat (g)	Ice (g)	Soyoil (g)	Linseed oil (g)	Spices (g)	Nitrite curing salt (g)	Percent of supplementation *
1 (Kontroll)	1350	1200	450	36		30	60	0
	(45 %)	(40 %)	(15 %)	(1,2 %)		(1 %)	(2 %)	
2	1350	1164	450	72		30	60	3
	(45 %)	(38,8 %)	(15 %)	(2,4 %)		(1 %)	(2 %)	
3	1350	1128	450	108		30	60	6
	(45 %)	(37,6 %)	(15 %)	(3,6 %)		(1 %)	(2 %)	
4	1350	1092	450	36		30	60	9
	(45 %)	(36,4 %)	(15 %)	(1,2 %)		(1 %)	(2 %)	
5 (Kontroll)	1350	1200	450		0	30	60	0
	(45 %)	(40 %)	(15 %)		(0 %)	(1 %)	(2 %)	
6	1350	1164	450		36	30	60	3
	(45 %)	(38,8 %)	(15 %)		(1,2 %)	(1 %)	(2 %)	
7	1350	1128	450		72	30	60	6
	(45 %)	(37,6 %)	(15 %)		(2,4 %)	(1 %)	(2 %)	
8	1350	1092	450		108	30	60	9
	(45 %)	(36,4 %)	(15 %)		(3,6 %)	(1 %)	(2 %)	

\*only refer to the fat substitution, not the whole product

## 2.6 Fatty acid analysis

I performed the extraction of fatty acids according to the method of FOLCH ET AL. (1957). I measured ~ 300 mg of each samples into Erlenmeyer flasks then I homogenized them into 20 ml of 2:1 methanol:chloroform mixture. For the preparation of the mixture, I used ultra-pure solvents (Sigma-Aldrich, Schnellendorf, Germany) and I added butylated hydroxytoluene of 0.01 w:v % as antioxidant. I produced the fatty acid methyl esters from the fats with acid-catalyzed ( $\text{H}_2\text{SO}_4$ ) method (CHRISTIE & HAN, 2010). The method is quantitative for which I used nonadecanoic acid (C19:0) internal standard.

The gas chromatographic measurement took place at the Physiology Department of the Research Institute for Animal Breeding and Nutrition (Herceghalom). The measurements were performed with the Shimadzu 2010 gas chromatography instrument which was equipped with SP-2380 (Supelco, Bellefonte, USA) type capillary column (30 m x 0.25 mm internal diameter x 0.20  $\mu\text{m}$ ) and with flame ionization detector (FID  $2 \times 10^{-11}$ ). The gas chromatography conditions were as follows: temperature of injector: 270 °C, temperature of detector: 300 °C, helium flow: 28 cm / sec. The program was as follows: 80-205 °C: 2,5 °C / min, 5 min 205 °C, 205-250 °C-10 °C / min, 5 min at 250 °C. For the identification of the fatty acids, a fatty acid standard mixture of known composition (Mixture ME100 (90-1100 Larodan Fine Chemicals AB, Sweden) was used. We have performed also the fatty acid analysis of the raw components. I carried out the sample preparation in the Technological Laboratory of the Department of Agricultural Product Processing and Qualification, at

the Faculty of Agricultural and Environmental Sciences, at Kaposvár University

## **2.7 Texture analysis**

I performed the texture measurement by determining the texture profile analysis (TPA) and the Warner-Bratzler shear force with Wick Roell Z005 machine (Zwick Roell GmbH, Ulm, Germany). The samples were measured at 4 °C in order to assure the comparability.

### **2.7.1 Texture analysis by texture profile analysis**

I cut out of the párizsi samples a cylindrical test specimen of 2.5 cm diameter and 1 cm high which I pressed to 50 % of its height. I cut out of the párizsi samples 3 test specimens by bar. For the comparison of the samples, I used the force necessary for the 50 % compression ( $1_{st}F_{max}$ , N) and signed with  $F_{50\%}$ .

### **2.7.2 Texture analysis by Warner-Bratzler cell**

By determining the value of the Warner-Bratzler shear force ( $1_{st}F_{max}$ , N), I also allowed the characterization of the texture in which case I cut out of the párizsi bars cylindrical test specimens of 1.5 cm diameter, then I cut them until complete intersection with the help of the cell. I made 3 test specimens by bar. The length of the special moving blade is 100 mm, its width is 70 mm and its thickness is 2 mm in which an inverted V shaped cutting of 60 °vertical angle can be seen. The blade moves in the guide created on side of the fixed part of the cell and fitting into the slot at the bottom of the cell, the complete

intersection of the test specimen happens. The speed of the cross-head was 200 mm/min, the sampling frequency was 10 points/sec.

## 2.8 Colour measurement

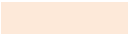




The base of the measurement was the so called CIE Lab color system (GENÉVE, 1924). In the system the color points are represented in the  $L^*-a^*-b^*$  spatial coordinate system. On the  $a^*-b^*$  plane the  $a^*$  and  $b^*$  axis mean the following shades:  $+a^*$  red,  $-a^*$  green,  $+b^*$  yellow,  $-b^*$  blue.  $L^*$  is the brightness factor which shall be defined perpendicular to the  $b^*$  plane (COMMISSION INTERNATIONALE DE L'ÉCLAIRAGE, 1976).

The color-difference ( $\Delta E^*$ ) were determined by ABRIL ET AL. (2001) (Table 5):

$$\Delta E^* = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$$

**Table 5:** Range of the colour difference

If the value of  $\Delta E^*$  is:

	0.0-0.5, then no difference,
	0.5-1.5, then slightly difference,
	1.5-3.0, then appreciable difference,
	3.0-6.0, then visible difference,
	6.0-12(<), then significant difference.

The calorimetry was performed in every case on the fresh slice of párizsi with Minolta Chroma Meter CR-300 instrument (Minolta

Corporation, Tokyo, Japan). Measurements were carried out with three repetitions on two sided of a slice of párizsi by putting the light source on it (D65).

## **2.9 Sensory analysis**

The sensory analysis of the párizsis available on the market and of the samples prepared at the development of the basic recipe were performed in the Technological Laboratory of the Department of Agricultural Product Processing and Qualification, at the Faculty of Agricultural and Environmental Sciences, at Kaposvár University where samples were prepared in a preparation room that corresponds to the Hungarian Standard (MSZ7304/2-77). 13 critics (university students and employees) assessed the sensory properties of the samples (colour, odour, taste, texture) (complete profile analysis). The critics received a bit of each samples which were samples provided with randomized codes. They had to differentiate these on a so called unstructured scale (100 mm long) from 0 to 100 based on the questionnaire compiled by us (MSZ 7304-5:1980). In addition to questions on the colour, the texture, the odour and the taste, I have also formed questions about the popularity. In case of the supplemented samples following characteristics were assessed: colour intensity of the slice, odour, the smell of spices, elasticity at chewing, moisture at chewing, fatness at chewing, salty taste, taste of cooked pickled meat pulp, spicy taste, strange odour and taste, and popularity.

## 2.10 Electronic nose

The measurements were done by An Alpha MOS  $\alpha$ Fox 4000 e-nose (ALPHA MOS, Toulouse, France) type Electronic Nose (EN). The equipment has three main parts as: an AutoSampler, which performs the samplings (64 samples can be handled in the same time), an electronic part (Fox Analyzer), which contains the sensors (18 metal oxide-MOS-sensor array) and the AlphaSoft 12.3 collected the signs via the RS232-port. The TOC generator provided the Synthetic air. The adsorption of volatile compounds onto the MOS surface generates a change in the electrical resistance of the sensors which gives the relative resistance-alteration, what is the ratio of the difference from the baseline resistance and the baseline resistance ( $\Delta R/R_0$ ). From each sample repetitions (5-10x) were performed. The 20 cm<sup>3</sup> vials contained ~1 g samples and covered with tefloncap (septum). Before the injection the EN incubated the sample on 40 °C for 2 minutes and the injected volume was 3000  $\mu$ l in 2 seconds and injection speed was 1500  $\mu$ l/s. After the two minutes session was 18 minutes regeneration period.

## 2.11 Determination of moisture content

The determination of the moisture content of the párizsi available on the market and the supplemented parizsi products were performed based on MSZ ISO 1442:2000. I dried the 100-300 mg samples in drying cabinet until 105 °C constant weight, and I measured them again.

$$\text{Moisture content (w/w \%)} = (w_1 - w_2) * 100 / w_1$$

$w_1$  = weight of measured sample (g)

$w_2$  = weight of dried samples (g)

The measurements were performed in three repetitions on the individual samples.

### **2.12 Determination of collagen content**

The collagen's special property is that its amino acids are located in an extremely regular manner, glycine-proline-X or glycine-X-hydroxyproline where X can be any amino acid. For this reason during the laboratory determination, we based on the hydroxyproline content measurement (GUBA, 1988). From the high collagen content of the product, I have been able to conclude that the given sample contains raw materials originating from "non-meat" source - like from rind of backfat - in higher quantities. The measurements were performed with MSZ ISO 3496-2000 spectrophotometry method in three repetitions.

### **2.13 Determination of fat content**

The fat content of párizsis can be maximum 23 % (CODEX ALIMENTARIUS, 2008). The fat content of the samples was determined by the method of FOLCH ET AL. (1957). After grinding, I measured ~300 mg of the samples and I noted them to 4 decimal places, then I homogenized the samples with 10 ml chloroform:methanol 2:1 vol/vol proportion mixture. After that I filtered them and I added ~ 2 ml of physiological saline solution to the samples. After vortexing, there were 10 minutes of centrifuging (1000 g) for the purpose of phase separation. After removing the aqueous phase, I evaporated the organic phase on 55-60 °C in a rotary vacuum evaporator, then I put the



samples into the drying cabinet at 65 °C and I dried them until reaching constant weight. Finally I back-tested the flasks to 4 decimals places, then I calculated the fat content based on the following equation:

$$\text{Fat content (w/w \%)} = (w_1 - w_2) * 100 / w_1$$

$w_1$  = weight of measured sample (g)

$w_2$  = weight of dried sample (g)

The measurements were performed in three repetitions on the individual samples.

## **2.14 Storage**

For the performance of the storage experiment, every sampling day I used a new bar of párizsi. During the storage experiment, I defined 5 sampling days which was performed every 7 days (day 0, day 7, day 14, day 21, day 28).

## **2.15 Data analysis**

SPSS 8.0 for Windows software was used for the statistical analysis. Before the normality test (Shapiro-Wilks test) in every case those values of primer database, which was over the 2 standard deviations, were eliminated.

Analysis of variance (GLM, *post hoc* Tukey test) was used for the storage, fatty acid profile, the texture analysis, the colour measurements, the sensory analysis, the moisture content and the fat content, where the supplementation level was a factor.

The classification of párizsi's sensory and electronic nose results

was performed by discriminant analysis (DA) and the results were tested by cross-validation (CV)

## **3 RESULTS**

### **3.1 Comparison of cold cut (Párizsi) samples purchased from the market**

During the comparison of cold cut (Párizsi) samples purchased from the market, five products of different price categories and brands were chosen as the subject of my experiment. The aim of the experiment was to characterize how the price and quality parameters influence the measurable properties of the products. The composition influenced significantly the fatty acid composition and the physical properties.

In my experiment, the fat content could be shown in the extent corresponding to the norms as well as the moisture content and the collagen content. Independently from the price and the brand, based on the values measured, the chosen samples corresponded to the norms in the dietetic aspect. Furthermore, regarding the fatty acid content, none of the products approached the optimal value of 4. This suggests that the objectives of the research I have pursued tend towards the solution of an existing problem.

Concerning the rheological characteristics, minimal difference was experienced in case of the samples originating from the market, while significant difference was experienced in case of all three chromaticity coordinates ( $L^*$ ,  $a^*$ ,  $b^*$ ). The difference was confirmed also by the calculation of the color stimulus difference.

Based on the sensory test, it was proven that the Párizsi of higher price category and at the same time of better quality are more popular

among the consumers, not only regarding the overall impression but also in respect of the taste, odour and texture. After executing the discriminant analysis, the results obtained by the electronic nose test performed in connection with the sensory assessment, are promising regarding the possibilities of application of the electronic nose.

The collagen, fat and moisture content of the purchased samples corresponded to the norms of the Codex Alimentarius but there was significant difference among the samples. Concerning the price-quality and the measured value, a regular tendency could not be observed.

### **3.2 The result and assessment of the elaboration of the basic recipe**

In this section the sensory properties were highlighted and the color was examined by instrumental measurement. Concerning the sensory properties, there was difference mostly in the color and in salty taste. The optimal recipe was chosen on the basis of the assessments given by the critics.

### **3.3 Supplementation with liquid lecithin base**

During the experiment, I examined how liquid lecithin (sunflower and soybean lecithin) influenced the characteristics of traditional Párizsi (color, texture, odour, taste, fatty acid content).

The result of the fatty acid analysis reinforces the literature data, according to which lecithin is a very good unsaturated fatty acid resource, but it is especially rich in  $\omega$ -6 fatty acids. By consuming

100 g of the Párizsi supplemented by sunflower lecithin of 6 %, 28 % of the recommended daily intake of linoleic acid (C18:2  $\omega$ -6) can be covered.

Statistically verifiable difference was experienced in the rheological properties when applying liquid lecithins. The firmness was reduced by the increase of the lecithin concentration. The colour of the slice was affected by the lecithin supplementation, the lightness and yellowness values increased significantly, while the redness value decreased.

The result of sensory assessment justified the result of the instrumental rheological test. The control sample was the most popular, and as the lecithin concentration was increased, the popularity decreased. It is interesting that the increasing lecithin concentration reduced the sensation of fattiness.

The electronic nose analysis was able to separate the two lecithin types but within these it could not confidently distinguish the levels of lecithin concentration based on the discriminant analysis. It can be stated that the higher lecithin concentration “results in greater discrimination power”.

### **3.4 Solid lecithin and ground flaxseed based supplementation**

By applying solid supplement, a minimal change of the rheological properties was expected.

The fatty acid analysis confirmed that not only the flaxseed oil but the flaxseed has also a good effect on the product’s fatty acid content.

It increased not only the linolenic acid quantity but it decreased  $\omega$ -6/ $\omega$ -3 ratio in a favourable extent. In the samples made with lecithin powder, only the quantity of  $\omega$ -6 increased significantly, but it did not influence considerably the  $\omega$ -6/ $\omega$ -3 ratio compared to the control sample.

Regarding the rheological properties, in case of the samples made with powder supplement, the decrease of the firmness value was of lower extent than in case of applying liquid lecithin. The supplementation with flaxseed powder showed minimal firming compared to the control sample but by increasing the flaxseed powder concentration, the firmness decreased.

Concerning the results of colorimetry, the soybean lecithin powder generated some decrease in the lightness value, while the flaxseed powder caused an increase. The redness value decreased simultaneously with the supplementation, and the yellowness value increased.

The sensory assessment also proved the color and texture differences between the samples supplemented by soybean lecithin and flaxseed powder. Popularity decreased also in this case as the concentration of soybean lecithin and ground flaxseed was increased. The critics found further differences in the sensation of fattiness, and also the taste and the odour were influenced by the type and the extent of the supplement.

### **3.5 Soybean and linseed oil based supplementation**

In several aspects, the most outstanding results were obtained during the experiments performed with the samples made with soybean and linseed oil supplementation. This confirms also the facts proven by literature data according to which in meat products, oil supplementation is the most effective method to increase the quantity of unsaturated fatty acids, considered to be healthy.

Regarding the fatty acid profile, with the linseed oil supplementation, in case of  $\omega$ -6/  $\omega$ -3 ratio, the value of about 4 was reached which was not accomplished completely in the previous test phases. The soybean oil supplementation was not so successful but in both cases the unsaturated fatty acid content increased compared to the control sample.

During the structural analysis, significant difference was experienced in both cases (soybean and linseed oil) compared to the control sample. Regarding the results of colorimetry, soybean oil modified the L\*, a\*, b\* values. The linseed oil supplement of 3% was the most similar to the control sample based on the color parameters.

Based on the sensory assessment, a statistically verifiable difference was also found between the two types of supplementation and the control sample. In this case it was also proven that the increasing oil concentration reduced popularity. Difference was found in the taste and the odour, but with the linseed oil supplement of 3% I managed to produce a sample that is very similar to the control sample.

Based on the measurements performed with the electronic nose, the value of the classification function, given by the discriminant

analysis, was 90 %, while the cross-validation value did not reinforce the reliability. In this case, I was not managed to achieve the outstanding result given by the purchased samples.

### **3.6 Comparison of the prepared párizsi samples and the samples originating from retail trade**

During the comparison of the prepared Párizsi samples and the samples purchased on the market, the results of four objective measurements (fatty acid, color, rheology and electronic nose analysis) were compared in case of the different supplementations and the Párizsi available on the market.

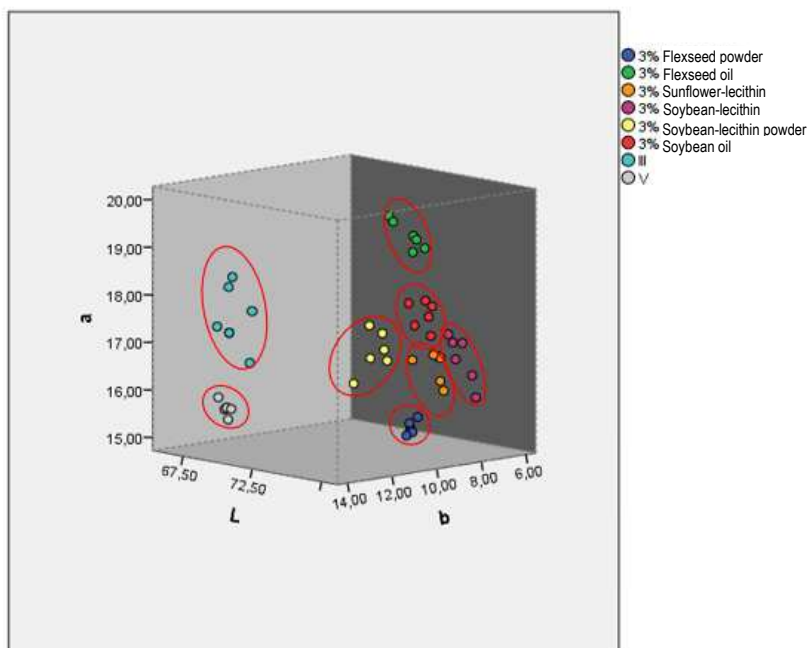
By comparing the fatty acid results, it can be stated that the quantity of unsaturated fatty acids was higher in case of each supplementation compared to the samples available on the market, but it did not have an important effect on the  $\omega$ -6/ $\omega$ -3 ratio. The exceptions are flaxseed powder and linseed oil which are the most favourable unsaturated fatty acid sources.

Based on the rheological tests, the different types of supplementation can be distinguished, and the samples made by me were far from the samples available on the market but based on this, it cannot be clearly stated that those are worse or better. Linseed oil supplementation was the most similar to the Párizsi sample of higher price category available on the market, and the lecithin supplementation was the most similar to the lower price commercial sample.

The calorimetry also proved the significant difference between the samples. The oil supplementation modified the lightness, yellowness



and redness values, too. Based on the points of  $L^*$ ,  $a^*$ ,  $b^*$  values represented in 3D coordinate system, the Párizsi available on the market are separated significantly from those made by me (figure 1).



**Figure 1:** The CIE  $L^*$ ,  $a^*$ ,  $b^*$  coordinates of the samples purchased on the market and of the 3% samples prepared by me

Based on the results obtained by the electronic nose, both oil supplementations approached the aromatic profile of the Párizsi available on the market which also proves that this supplementation is the most suitable.

## 4 CONCLUSIONS

In the series of experiments included in my dissertation, I have tested supplementations that have not been applied by this field of science so far for the purpose of the optimization of fatty acid profile and reducing the amount of fat content in respect of párizsi. My aim was to determine the optimal supplementation ratio for the different fat substitute formulas, all this in a way that the properties typical of the experimental product categories shall change as little as possible, or they shall not change at all.

In case of the samples originating from the market, the fatty acid profile was very diverse. This largely depended on what fatty acid composition had the raw materials used for the production and how many was used from the given component. The parameters examined by me compared to the values recommended by the Codex Alimentarius, in each case they corresponded to the expectations. Regarding the quality/price ratio, we can state that the more expensive products have better sensory properties, they have a better consumer perception as well, although I have not conducted tests to find out to what extent the price would influence the consumer in the judgment of the product.

The linseed oil, soybean oil, soybean lecithin powder, ground flaxseed powder, sunflower and soybean lecithin used for the supplementation of sample párizsis influenced positively in each case the quantity of unsaturated fatty acids, even if the  $\omega$ -6/ $\omega$ -3 ratio did not improved at such an extent that it approach the value of 4 considered to be optimal. The flaxseed oil and ground flaxseed proved

to be most suitable for the párizsi supplementation because in both cases the quantity of  $\alpha$ -linolenic acid increased considerably, and at 6 % of supplementation, it has already approached the optimal  $\omega$ -6/ $\omega$ -3 ratio (4).

In case of the sensory properties, the 3 % linseed oil supplementation reached better results during the sensory assessment compared to the control samples, which is an outstanding result in every aspect. Generally by the increasing concentration of each type of supplementation (component), the popularity decreased, and the differences appeared in the mouthfeel and in the taste, in the odour. As the sensory properties are the most parameters of food, the proposed supplementation form in this case also the linseed oil, even in 9 % ratio, too.

Regarding the rheological properties, also the oil supplementation proved to be the most suitable. I measured the lowest firmness values in case of the samples made with sunflower lecithin, while at the application of the flaxseed powder a more solid, more robust structure was formed. The other supplementations are minimally different from the products available on the market, therefore it seems to be employable for the replacement of fat from the rheological point of view.

In case of párizsi, colour varies widely. It is difficult to define precisely what the consumers expect in this regard, furthermore the components used influence significantly the final colour. The párizsis prepared on the basis of the recipe described in my work were considerably different from the purchased samples. Even in case of 3% of supplementation a well visible difference can be identified in respect

of the colour stimulus differences which was typical of the liquid lecithin and lecithin powder supplementations. The lightness ( $L^*$ ) and yellowness ( $b^*$ ) values increased with the increasing supplementation level, and the redness ( $a^*$ ) value decreased compared to the control sample. The increase of the yellowness value can be explained by the yellowish shade of the components used for the supplementation.

I also examined the applicability of the electronic nose measuring instrument, both for comparing the aroma profile of the samples available on the market, and for separating the supplementation concentrations and types. I reached the best results in case of the samples available on the market. In case of the purchased samples there is a difference to such an extent both in the components and in the proportion of the components that the electronic nose was able to separate the samples with due security. The same can be mentioned for the samples prepared in the same percentage but in a different way, therefore the instrument has the adequate sensitivity to separate the different supplementation types. In my series of experiment, when applying the tested supplementation types to different extent, the accuracy of the electronic nose decreased. The subject of further experiments may be to follow-up the aroma profile change occurring during the aging/storing process of supplemented párizsi with the help of the electronic nose technology.

Storage had a minimal effect to the fatty acid composition but I have experienced some changes in colour and in texture during the aging process. As a result of storing, the colour became darker, and the párizsi samples became more solid, which was evidently due to the loss of moisture. In case of the supplementation with 6 % of soybean

lecithin and 9 % of linseed oil, the rheological changes were of lower extent than in case of the other supplementations.

Altogether, the linseed oil was proved to be the most suitable supplementation also in case of párizsi. The joint application of linseed oil and flaxseed powder may be the subject of a further experiment, as it would bring a satisfactory result for the fatty acid proportion, and the flaxseed powder would adequately compensate the reduction of firmness as a result of the oil supplementation. It would also worth examining the fiber content of párizsi when applying flaxseed powder, since this way it would be possible to increase the biological value of the product.

## 5 NEW EXPERIMENTAL RESULTS

1. I could effectively develop a párizsi basic recipe that became suitable for performing my experiments aiming at the replacement of pork backfat. I successfully applied the electronic nose measuring instrument for the separation of the párizsis available on the market.
2. I have been the first to apply liquid lecithin for the replacement of pork backfat in párizsi but its application is only recommended in low concentration (1,5 %) because in higher concentration (6 %) it results a significant differences in the properties (taste, odour, texture, colour). In the fatty acid composition, lecithin increased the quantity of the  $\omega$ -6 fatty acids the most.
3. I have been the first to apply lecithin powder and ground flaxseed for the supplementation of fat content in case of párizsi, and I have experienced that with 6% of flaxseed powder supplementation both the quantity of  $\omega$ -3 fatty acids, and the  $\omega$ -6/ $\omega$ -3 ratio approached the dietetic optimum value.
4. The replacement of pork backfat with 9% of linseed oil results in a reduction, regarding the  $\omega$ -6/ $\omega$ -3 fatty acid ratio, to an extent which has even reached the value (~4) considered to be ideal, healthy.

## **6 SCIENTIFIC PAPERS AND LECTURES ON THE SUBJECT OF THE DISSERTATION**

### **Articles in foreign languages**

Belovai, J., Romvári, R., Fébel, H., Szabó, A., Bánáti, D. (2013): Effects of  $\Omega$ -3 fatty acid enrichment on the quality characteristics of special Hungarian cold cut (Párizsi). *Acta Alimentaria*, 43, (4) 2014, 604-613.

Belovai J., Romvári R., Fébel H., Mézes M., Bánáti D., Szabó A. (2015): Influence of partial fat replacement with lecithin on the product characteristics of a special Hungarian cold cut. *Acta Alimentaria: an international journal of food science* (Budapest: Akad. Kiadó), *Acta Alimentaria*, 45 (2) 2016, 277–285.

### **Articles in Hungarian**

Belovai, J., Romvári, R., Fébel, H., Szabó, A., Vámosi-Falusi, Zs., Bánáti, D. (2011): Az  $\omega$ -3 zsírsav kiegészítés hatása a párizsi minőségi tulajdonságaira. *Élelmiszer Tudomány Technológia*, LXV. Évfolyam 4. szám 12-16.

### **Abstract conference papers in proceedings**

Belovai, J., Bánáti, D., Szabó, A., Romvári R. (2011): Párizsi omega-3 zsírsavakkal történő dúsítási eljárásának kidolgozása, XVII. Ifjúsági Tudományos Fórum, Keszthely, 2011. április 21.

Belovai, J., Bánáti, D., Romvári R. Szabó, A. (2011): Sertés párizsi Omega-3 zsírsav kiegészítése, Doktoranduszok Kaposvári Workshopja, Kaposvár, 2011. június 8.

Belovai, J., Bánáti, D., Romvári R. Szabó, A. (2011): The effect of omega-3 fatty acid enrichment on the quality characteristics of special Hungarian cold-cut (Párizsi), 19. Animal Science Days, Primosten, Horvátország, 2011. szeptember 21-23.

Belovai, J., Romvári, R. Bázár, Gy., Szabó, A.(2012): Comparative study of commercial cold-cuts used NIRs and sensory analysis. 20. Animal Science Days, Kranjska Gora, Szlovénia, 2012.09.19-21. Acta Agriculturae Slovenica. Suppl. 221-225.

Belovai Judit, Bánáti Diána, Fébel Hedvig, Romvári Róbert, Szabó András (2013): Párizsi, mint funkcionális élelmiszer. „Fiatal kutatók az egészséges élelmiszerért” tudományos ülés, Debrecen, 2013. február 19.