Summary of a Doctoral (Ph.D.) Thesis

POSSIBILITY OF FUNCTIONAL BROILER NUTRITION

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I. INTRODUCTION

One of the groups of functional foods that has attracted considerable attention recently is constituted by products with modified fatty acid compositions. With respect to human nutrition, foodstuffs containing fatty acids are of high importance. Within this group, a key consideration is the absolute quantity of n-3 fatty acids, as well as their relative quantity to n-6. These essential fatty acids have an essential role in the healthy development of infants, and are indispensable for normal mental development and functioning, as well as for the prevention of cardio-vascular diseases and tumors. Furthermore, they are in fact the building blocks, base materials of several constituents of the body (cell membranes, hormones). The option to manufacture meat products with modified fatty acid compositions involves the proper modification of the composition of diets for livestock. Towards this end, such diets have been fed that resulted in the manufacturing of products with larger added values (more favourable fatty acid, mineral and vitamin contents). This feeding method is regarded as functional nutrition. The purpose of functional feeding can be the reduction of the quantities of unutilized nutritive agents that pass the animal body. In the course of our work, we have intended to produce chicken meat with a more favourable fatty acid content so that the animal production and other quality parameters of the meat should not be deteriorated.

Towards this end, the following two experiments have been conducted:

- In the first experiment, we have examined the effects of the addition of oils and fats mixed to the diet on the production of broiler roosters. The quality parameters of the meet that have been grown on these diets have been studied (fatty acid, total pigment content, chemical composition, pH, colour, TBARS values).
- As relying also on the results of the first experiment, we have used only an experimental oil mixture in the second experiment, and examined the related effects in the light of the respective feeding times. Apart from the production of the birds, similarly to the first experiment the nutritional physiological, technological and organoleptic qualities of the produced meat have been measured is.

II. MATERIALS AND METHODS

In both experiments, 1200 Ross-308 broiler chicks were settled in a 4×5×60 experimental designe. The rearing technology of the birds was designed in view to the related recommendation of the hybrid breeder. Feeding was carried out ad libitum, with a three-phase diet. The difference between the individual treatments was the fat source of the diet.

In the four treatment of the first study 3% added lard (Treatment 1), sunflower seed oil (Treatment 2), soybean oil (Treatment 3) and flax oil (Treatment 4) ensured the different fatty acid contents of the diets. In the second experiment, the differences between the individual treatments originated from the feeding time with the "experimental diet" containing 1.5% flax oil and 1.5% rape oil. While Treatment 5 involved the feeding of the control diet containing 3% sunflower seed oil all through the fattening process, in Treatment 6 the same was fed until the 35th day, and in Treatment 7 until the 21st day, followed by the "experimental" diet in both cases. The birds in Treatment 8 were fed with the "experimental" diet from Day 0 to the slaughter day (Day 42)

The growth of the weight of the birds, as well as diet consumption were measured on a weekly basis. In the first experiment, meat investigations were performed from the breast samples taken after slaughtering. These samples taken from fresh meat were subjected to the determination of the fatty acid content and chemical composition, pH and total pigment content. The rate of rancidifation processes during storage was quantified by establishing TBARS, whereas colour changes were measured in the CIE L*a*b* colour system. In the second experiment, apart from the breast the quality parameters of the thigh meat were also examined, and fatty acid analyses were carried out from the abdominal fat and skin as well, in addition to the meat.

The obtained results were evaluated with the SPSS for Windows 13.0 suite.

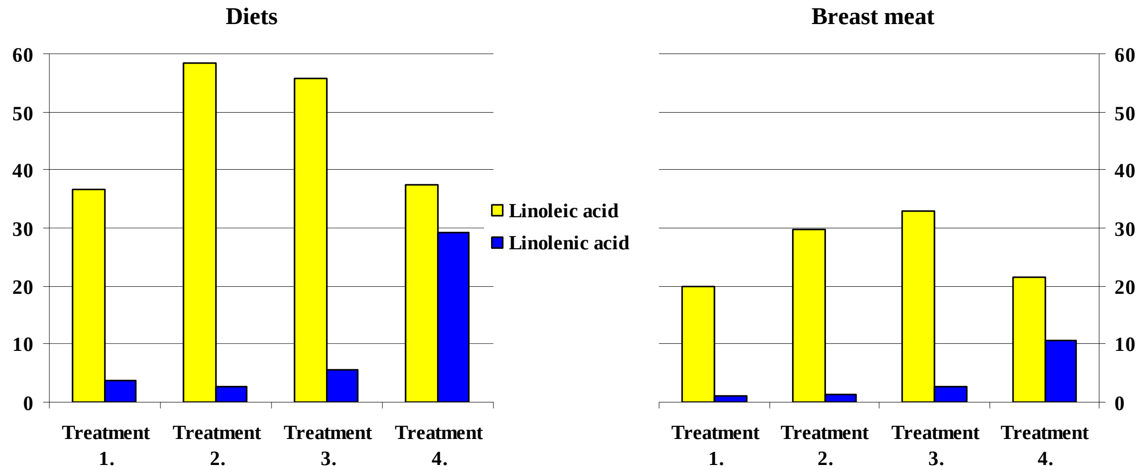
III. RESULTS

Experiment 1

As concerning all the four treatments, no differences were observed in terms of the entire, nor in weight gain and feed conversion ratio. From among the slaughtering output, the treatments did not affect the grill weight, the breast weight and the thigh weight. Measurements on the viscera showed that the liver weight of the individuals subjected to Treatment 4 was smaller than those in the other three treatments, and marked differences were detected between Treatment 1 and Treatment 4. In the birds of 1 and Treatment 2, the abdominal fat contents exceeded those of the other two treatments.

The fatty acid compositions of the diets reflected in the breast meat (Figure: 1.) According to the fatty acid analysis measured from the breast samples, Treatment 1 contained the largest quantities of saturated fatty acids (SFA), and similar tendencies could be observed for the quantities of mono-unsaturated fatty acids. The above-mentioned two fatty acid groups could be found in the smallest

Figure 1: Essential fatty acids composition of the diets and breast meat (g/100g fatty acid)



quantities in the case of Treatment 3. As a result, the PUFA contents were the highest for these treatments. In view to the linoleic acid contents, Treatment 3 (32.97%) reflected the most outstanding results, and slightly less linolenic acid could be measured in Treatment 2. In Treatment 4, the average 10.63% α-linolenic acid content was almost four time as much as that of the three other groups. Also the samples of Treatment 4 contained the highest levels of eicosapentaenoic acid and docosahexaenoic acid. The n-6/n-3 fatty acid ratio was reduced by the soybean oil addition from the very broad 20:1 (Treatment 1) ratio to a 12:1 value. The most significant change was, however, caused by the flax oil containing large quantities of linolenic acid: the above ratio was brought down to a 2:1 value.

In the 24 hours after slaughtering, the pH of Treatment 4 exceeded that of the other groups. No significant differences were found in the chemical composition of breast meats. Pigment content examinations revealed that the pigment content of Treatment 2 remained under the corresponding values of Treatment 1 and Treatment 4. Rancidification processes took place at a similar rate during the storage in all the treatments. In organoleptic examinations, the treatment consuming pig fat addition was found to be the best.

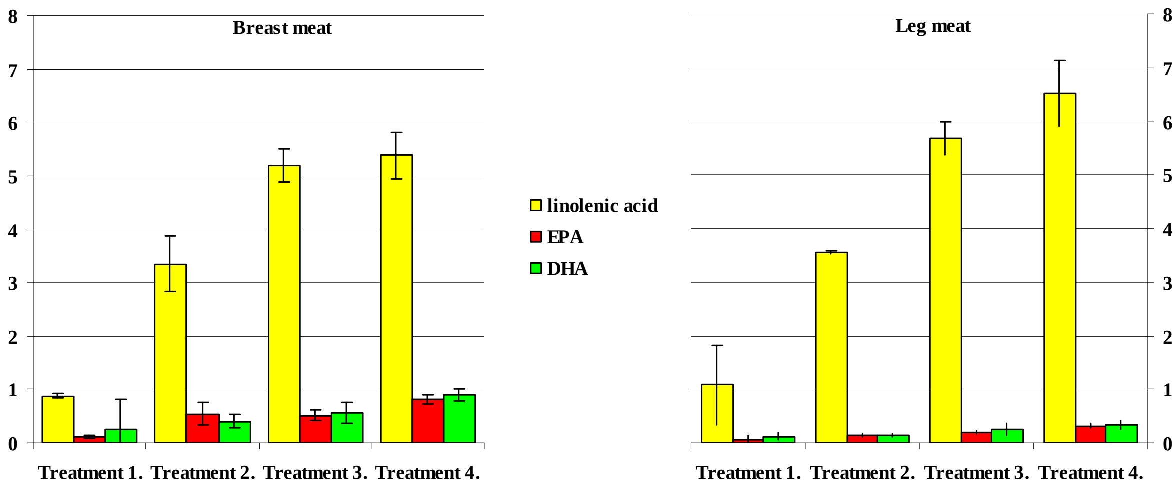
Experiment 2

In the first 4 weeks of fattening, the weight growth in Treatment 8 slightly remained under the results of the other treatments, but by the 42nd day this differences in comparison to Treatment 5 and 7 disappeared. For the entire breeding, Treatment 6 performed better than the other groups. The treatment had no effects on feed conversion ratio. From among the cut parts, differences were detected only in the weight of the bony breast meat, which in the case of Treatment 5 and 6 exceeded the corresponding value of Treatment 8.

The results of the fatty acid analysis performed from the tissues showed that the n-6/n-3 fatty acid ratio in the experimental involving the consumption of experimental diet decreasad from the initial 13:1 value to 5:1, whereas the α-linolenic acid content increased to a four-fold quantity. With the increase of the feeding time of the experimental diet, the n-6/n-3 ratio further decreased, and the α-linolenic acid content increased in all the examined tissues. In the breast and thigh meats of Treatment 7 and 8, considerable quantities of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) accumulated (Figure 2.), whereas in the abdominal fat and skin the quantities of α-linolenic acid increased.

Roasting had just minor effects on the fatty acid composition of the meat. The quantities of mono-unsaturated fatty acids (MUFA) increased slightly, whereas the quantities of polyunsaturated fatty acids (PUFA) reflected proportionate decreases. In Treatment 5 and 8, the quantities of oil acid and eicosenoic acid increased significantly. The levels of α-linolenic acid changed in none of the treatments. In Treatment 5, the quantity of linoleic acid considerably decreased as a result of roasting.

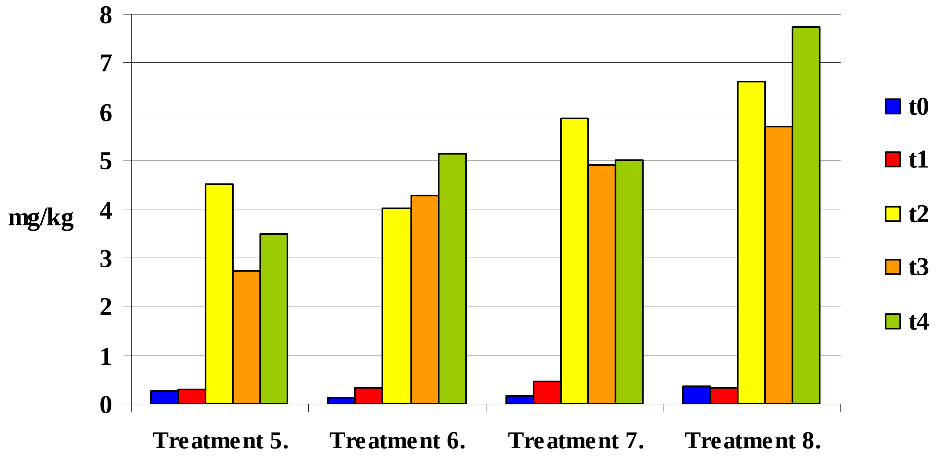
Figure 2: N-3 fatty acid content of breast and thigh meat



The chemical compositions of the samples were different just to a minor extent. From among the breast samples, Treatment 7 had the largest (26.24%) dry matter content. Here, the crude fat content exceeded the corresponding values of the other three treatment by approximately 30%. In the case of the thigh samples, the dry matter content showed no significant differences, whereas the crude fat content reflected considerable dispersions among the individual treatments: it was the smallest in Treatment 8, and the largest in Treatment 5.

Figure 2.

The lipid oxidation in fresh broiler breast meat (MDA=mg/kg)

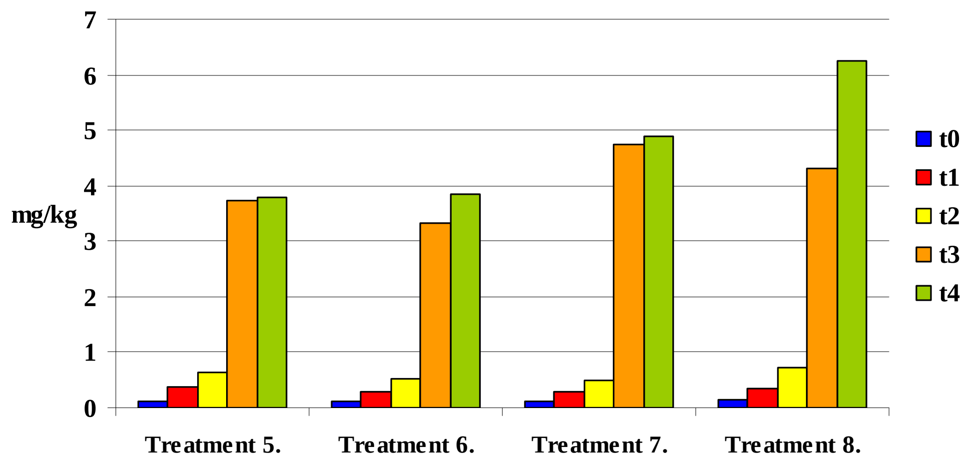


t_0=fresh meat, t_1=after roasting, t_2=roasted meat + 4 day storage, t_3=roasted meat + 6 months frozen storage, t_4= t_3 after warming

TBARS examinations suggested that roasting materially catalyzed the oxidation processes. The examinations on breast meat are presented in Figure 2. The tendencies observed in the examinations on thigh meat corresponded to those of the breast meat.

Figure 3

The lipid oxidation in frozen broiler breast meat (MDA=mg/kg)



t_0=fresh meat, t_1=after 6 month frozen storage, t_2=frozen meat after roasting, t_3=roasted meat + 3 days chilled storage, t_4= t_3 after warming

The organoleptic examinations supported the assumption on the accelerated rancidification due to roasting. For fresh-grilled meat, none of the treatments generated unpleasant organoleptic properties, but after a storage period of 3 days all the treatments gave unpleasant rancid tastes and odours.

IV. RESULTS

First experiment

The slaughtering weight of the broilers was not impacted by the oil additions used in the studies, the better performance of the soybean oil treatment could rather be viewed as a tendency. In the light of the results, when using isocaloric and isonitrogen diets the fatty acid composition of the diet did not influence feed conversion ratio.

From among the slaughtering parameters of the birds, significant effects of the treatments could be observed in the case of abdominal fat. In the treatment that consumed diet containing pig lard, abdominal fat content significantly ($P<0.05$) exceeded the corresponding values of the treatments carried out with soybean oil and flax oil containing more PUFA. The underlying reason could be the changes in the lipid oxidation and the intensity of lipogenesis. At the same time, as a consequence of the use of sunflower seed oil with high PUFA contents the abdominal fat content did not decrease considerably, which can be assumed to be associated with the high linolenic acid content and low α-linolenic acid content of the sunflower seed oil, meaning that the accumulation of abdominal fat is not inducated by the total PUFA content of the diet, but the n-6/n-3 fatty acid ratio.

According to our results, the fatty acid composition of the diet strongly influenced the fatty acid composition of the meat. Close correlations could be found between the diet and the linolenic and linolenic acid contents of the tissues. It was the flax oil treatment that approached the 6:1-4:1 n-6/n-3 fatty acid deemed to be optimal for humans. Here, however, a 2:1 ratio under the optimum developed. In the case of diets with nearly identical PUFA contents, with the narrowing of the n-6/n-3 ratio the EPA and DHA contents of breast tissues tended to increase. Concurrently, the arachidon acid content of the tissues decreased. It was suggested to be the result of the competition in connection with the utilization of enzymes involved in the biosynthesis of the n-6 and n-3 fatty acid group.

The pH of meats was appropriate, none of the treatments caused extreme changes. The final pH value of the flax oil treatment was higher than that of the other three treatments, and the former treatment also featured the highest total pigment content, as well. Presumably, due to this result and the higher pH the lowest first-day L* value could be measured also in this treatment. In order words, the instrumental measurement supported the darker colour.

No clear correlations could be drawn between the changes in the fatty acid composition of the meat and the oxidative changes during storage. In the light of the data obtained from the associated scientific literature, it was expectable that in comparison to the pig lard treatment the oxidative stability in the other three treatments with larger PUFA contents would decrease. Yet, during the 8 days of the storage it did not take place. The underlying reason can be that in view to oxidative sensitivity PUFA had no such a key role as it had been actually expected. It is rather likely, that the total unsaturated fatty acid content, i.e. the MUFA+PUFA quantity, as well as their ratio in relation to saturated fatty acids have a more significant role in the stability of the meat. Furthermore, owing to the low fat content of the breast meat (<2%) the occurring changes can be of much smaller scale than in tissues containing more fat.

In the light of the results of organoleptic examinations, it can be stated that the addition of oil impacted the quality of the cut meat. In terms of the taste and odour, the pig fat treatment performed the best, whereas in the treatment with sunflower seed oil the evaluators regarded the slightly darker colour to be good. The flax oil treatment remained under the quality of the other treatments in taste and odour, and due this very fact it was ultimately ranked lower, yet the unpleasant taste and odour experienced in the feeding with flax oil were not characteristic of the other treatments.

Second experiment

The treatments in this experiment did not influence the weight growth of the birds either, with respect to the slaughtering weight the differences between the treatments did not exceed 3%. Similarly, no differences were found in the feed conversion ratio.

On the basis of fatty acid compositions of the studied tissues, it can be ascertained that the quantity of linolenic acid decreased in all the tissues, whereas the linolenic acid level increased as a result of the use of the experimental diet, and concurrently the n-6/n-3 fatty acid ratio narrowed in those experiments where the experimental oil mixture was consumed. Changes in the diet fatty acid composition spread very quickly in the tissues. The narrowed n-6/n-3 ratio did evolve just in a week of feeding.

Feeding with experimental diets containing large quantities of linolenic acid decreased the arachidon acid contents of the tissues, as well. As concerning nutritional physiological effects, it was of high significance that the quantities of long, carbon-chain polyunsaturated fatty acids (EPA, DHA) continuously increased with the expansion of the feeding time of diets containing large quantities of linolenic acid in all the examined tissues. Yet, there were considerable differences among the various tissues and organs in terms of the incorporation rate of these fatty acids. Primarily, it was the non-feed originated long chain polyunsaturated fatty acids (EPA, DPA, DHA) that quickly accumulated in the breast and thigh tissues. On the other hand, they appeared in the abdominal far, in particular in/under the skin in smaller quantities and later. The underlying reason can be the different affinity of the individual tissues to long carbon-chain n-3 fatty acids. The EPA, DPA, DHA contents of the breast brought about outstanding results in comparison to the other body parts.

The various heat-treatment procedures (grilling, roasting in microwave ovens) did not influence the SFA content of the meat, yet increased the MUFA (3%) content to a small extent, and concurrently the quantity of PUFA (3%) decreased; however, these changes were of very small extent. No correlation could be detected between the pH and fatty acid content of cut products. On the basis of the first experiment, however, differences in pH could influence the colour of the meat: higher pH values are accompanied by lower L* and higher a* values. The total pigment content of meats and the results of the objective colour measurements were not correlated. Consequently, from the measured colour of the meat no conclusions can be drawn for the total pigment content.

The MDA content of the fresh breast meat was impacted by neither the fatty acid content, nor the ratio of n-6/n-3 fatty acids. The TBARS values of the thigh, as irrespective of the treatment, increased more intensively under storage than those of breast meat. The underlying reason can be the larger fat content of the thigh and its more developed vascular system. With the storage of thigh meat, it was found that with the narrowing of the n-6/n-3 ratio oxidative stability tended to decrease. This assumption was supported by the roasting studies for both the breast and thigh meat.

After the heat treatment, oxidative changes in the meat could be more readily detected, because as a result of cooking oxidation processes tended to accelerate significantly, which was due to the combined effect of several factors. This effect was also evidenced by a number of other practical results that congruently showed that heat treatment accelerated the lipid oxidation, which then continued as depending on the storage conditions. In the course of refrigeration, TBARS increased just to a minor extent, and unlike heat treatment it had no catalyzing effects.

The high TBARS values observed in the stored grilled meat were also supported by the organoleptic properties of the meat; strongly stale, rancid tastes could be experienced for all the treatments. The smaller differences in oxidative changes could not be evidenced by the organoleptic studies.

V. NEW SCIENTIFIC RESULTS

- The feed conversion ratio of the broilers and the chemical composition of the breast and thigh meat are not influenced by the fatty acid composition of our diet.

- For isonitrogen and isocaloric diets, the quantities of abdominal fat are not influenced by the total polyunsaturated fatty acid content, but the n-6 and n-3 fatty acid ratio. There is a positive correlation between the linolenic acid content of the diet and abdominal fat content, whereas the correlation between the α-linolenic acid content and abdominal fat content tend to be negative.

- Changes in the fatty acid content of the diet modifies the fatty acid content of the broilers even with short (one week) feeding time.

- Long chain polyunsaturated n-3 fatty acids (EPA, DHA) appear in the breast and thigh meat.

- The TBARS values of the fresh meat are not influenced by the n-6/n-3 fatty acid ratio. However oxidative stability under storage decreases with the narrowing n-6/n-3 fatty acid ratio of the meat.

- In the chicken meat, there is no correlations between the CIE L*a*b*-type colour measurements and the pigment content, as the colour is primarily determined by the ultimate pH of the meat.

- With the supply of an appropriately prepared oil mixture, such broiler meats may be produced that can be deemed as functional foodstuffs.

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