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COMPARISON OF MEAT PRODUCTION AND SLAUGHTER PERFORMANCE OF PURE LINES AND CROSSED OFFSPRING OF CHICKEN WITH DIFFERENT GENETIC ORIGIN FOR THE PURPOSE OF IMPROVING A DOMESTIC CHICKEN HYBRID, TETRA-H

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1. INTRODUCTION AND OBJECTIVES OF THE RESEARCH

Looking back to the last decades of the XX. century, lifestyle, habits and expectations of buyers of poultry products has gone through some notable changes. Healthy way of living came into fashion and as a result of this, demand for quality food products have increased. In countries with developed poultry production, special, labelled products have appeared in order to meet the changing consumer requirements, for which white broilers with fast growth, widely used in the industry, are not suitable. New genotypes had to be produced, so colour feathered, slower growing genotypes made an appearance on the market, which compared to traditional dual purpose breeds, provide a poultry meat with premium quality. This kind of product is the most popular in developed countries in Europe and in Asia, where standard of living is generally high, while looking from a different aspect, in Eastern- and Middle-Europe (Romania, Ukraine, Greece, etc.), just as in some countries in the Far-East (South-Korea, India) have a long tradition of chicken sold in markets, alive and houshold poultry keeping and fattening (SARICA et al., 2010).

Poultry consumption trends observed in the European Union in recent years, are qualitative rather than quantitative (JEZ et al., 2011). In countries surviving economical crisis, priorities of poultry consumers are changing towards sustainability, animal welfare and preference of local products, which generates new market segments (MAGDELINE et al., 2008). As a result of this, experts predict new future scenarios in poultry production and consumption for the next ten years, due to changing market stakeholders and environmental changes (JEZ et al., 2011)

Colour feathered, imported farm hibrids have a small, but increasing marked share in Hungary. Our dual-purpose, traditional hybrid, TETRA-H, bred and distributed by Bábolna TETRA Ltd. is henceforward popular in Hungary, but they had been put under increasing pressure in the last 10 years, to broaden their choice of coloured broilers, since being the sole poultry breeding company in Hungary. In line with, international competition required a research and development program, which has aimed to resort cutting edge technologies and methods. I have had the opportunity to join this program with my doctoral theme.

The most important aim of my work was the evaluation of meat producing capacity , body composition changes and meat quality in the new TETRA HB Color color feathered broiler breeding program, where the currently used and possible new pure lines and experimental purposes progeny groups were raised and examined, with the intention to provide helpful information as feedback for the selection program.

My main objectives were formulated as follows :

- • Definition of meat producing ability of the TETRA-H hybrid compared to a standard commercial control (Shaver Redbro), aimed at the early stage of market positioning rankings for the project.
- Measurement and evaluation of meat production capacity and slaughter parameters of old male elite line (HH) and the new potential male line (EE).
- Determining the positive effect of the new male line on the meat producing ability and slaughter performance of crossed and reciprocal crossed offspring (**EE**♂ x **HH**♀; **HH**♂ x **EE**♀) under field performance test conditions.

- At the end of the experiment, meat production of the new TETRA HB Color was tested, using two market competitors (TETRA-H and Shaver Farm) as control genotypes.
- In the last phase of the experiment, comparison of meat production of the new TETRA HB Color and the two market competitors under alternative (free range) housing conditions were performed.
- Investigation of gender and age related muscle and fat tissue development, in chicken used in our R & D project with different genetic backgrounds, based on *in vivo* imaging procedure (CT scans).
- Examination and meat quality assesment of muscle samples (breast and thigh) collected on the cutting tests originated from chickens reared in the series of experiments.
- Evaluation of the effects of free-range production system on meat production, in vivo body composition and post- mortem meat quality of different chicken genotypes.

2. MATERIALS AND METHODS

2.1 The main technical and methodological data of the experiments

First experiment:

In the first (1) phase of the experiment meat production ability of my target genotype; TETRA-H (= a1) was compared to a standard control (a2 = Redbro Shaver) with the purpose of defining competences between genetic abilities under test conditions. The experiment was conducted in the Poultry Test Station of the Kaposvar University in part of the predecessor of the Faculty of Agricultural and Environmental Sciences. Day-old chickens were were randomly allocated to 18 hatches (9.2 m^2 basic area), reared in a closed building up to 12 weeks of age, and separated by sex and genotype. Chicks participating in the tests were permanently marked according to gender, by cutting the end of their nails with thermo-powered kauter. Technical details of the test experiments were as follows: v = 4 (= 2 x 2), r = 3; The number of test groups: 12 (= *v x r*). Number per genotype: 717 broiler (330 [db = 3x110 / group] male and 387 [db = 3x129 / group] female), total: 1,434 (660 cockerel and pullet 774).

Second experiment:

In section (2), current male line (**HH**) used in the breeding program of TETRA-H, and the new **EE** marked - pure line flocks and crossings (HH♂ x EE♀) were participated on a comparative test, assessing the genetic capacity of the new line and examination of the most important traits have taken place. Based on the final goal of the breeding concept, we considered genotype **HE** as the reciprocal crossbred progeny. Selection process of the new paternal line (EE), which we hope to have a strong positive genetic impact, is made by rigorus selection of TETRA-H pedigree flocks, within the *Golden Plymouth types* line. The EE line has significantly higher bodyweight, improved color uniformity and black tail feathers, which remains important selection objectives as well as to preserve the favorable body compostion and natural health resistance. Examined genotypes: a_1 = HH (old male line); a_2 = HE reciprocal cross (HH♂ x EE♀ experimental cross); 3 = EE experimental new male line; sex: b_1 = male, b_2 = females. Technical details of the experiment were as follows: *v* = 6 (= 3x2), *r* = 4 (= 3 + 1 for slaughter trial); total number of groups (*v x r*) = 24.

Number per genotype: 956 broiler (440 males [db = 4x110 / group] and 516 [db = 3x129 / group] female), a total of 2,868 (1,320 cockerel and 1548 pullet) settled chicks.

Third experiment:

In trial (3) again meat producing ability of a_1 = HH (old male line) and a_3 = EE new male line were compared with the performance of crossed progeny, but now the new cock line (EE♂) was actually presented on the paternal side of the hybrid program, while the previous line HH marked served as the maternal partner (HH♀). On the basis of our concept, is seen as the $\mathbf{a_2}$ = new TETRA-H hybrid, which has distinguished on the name: TETRA HB Color. Letter 'B' in the new name refers to the higher meat production of the hybrid (broiler) and partly to Bábolna’s ambitious career in TETRA B broiler, of which on the summit the market required 150 million chicks per year.

Technical data of the experiment were as follows: *v* = 6 (= 3x2), *r* = 3; total number of groups (*v x r*) = 18. Number per genotype: 717 broiler (330 [db = 3x110 / group] male and 387 [db = 3x129 / group] female), a total of 2,151 (990 cockerel and 1161pullet).

Fourth experiment:

In stages (4), meat producing ability of TETRA HB Color (EE♂ x HH♀), which developed under the research program was compared to the original TETRA-H (HH♂ x QR♀) and a commercially available market rival hybrid, the Shaver Farm. Technical details of the fourth experiment were as follows: *v* = 6 (= 3x2), *r* = 4; the total number of groups (v x r) a total of 24. Chickens per line were 1,195 broilers (550 [db = 5x110 / group] male and 645 [db = 5x129 / group] female).

From the methodological point of view, there was no significant difference between the four (1-4) experiment, or if we changed something we did it consciously. For example, the length of raising was reduced from 84 to 70 days in the second and third experiments, because the average bodyweight for better meat production line was too large. In the fourth experiment, part of the population (25 individuals per genotype and sex (3 x 2 x 25 = 150) placed to free range environment at 7 weeks of age. Most important traits related to meat producing ability were measured during the experiments (fattening, feed conversion, slaughter parameters, CT, meat quality, etc.) by following the methodology of the first trial. The trial cuts taken place at Rembo Ltd. (Reménypuszta) in case of the first attempt, than at Babirád Ltd. (Mágocs) processing plant in the second and the third case. In the fourth experiment, the cutting test implemented at the dissecting room of Study and Experimental Unit of Kaposvár University, where manual processing occurred. We followed the bird's dissecting instructions of JENSEN (1983).

2.2 Measurement of growth and slaughter parameters

Liveweight (g) was measured individually at 19, 49, 70 and 84 days of age on the entire experimental population, namely when feed changing was occured and also at the end of the fattening period. For determining the age of the stock, the date of housing was considered day 0. The measurements were carried out on the morning after set life day , under not more than 3-4 hours, after 6 hours of fasting, and within each block along the buliding.

The daily weight gain (g) between 20-49, 50-70 and 71-84 life days has been identified from the initial and final live weight of the given stages. Cumulative and sub-period feed conversion (kg / kg) was calculated based on the total bodyweight of the group, as well as the amount of feed have been fed (kg feed / kg bodyweight).

At 50, 71 and 85 days of age 10, 15 or 20 chicken per sex and genotype, depending on the experiment, with bodyweight - within ± 3% tolerance limits - corresponded to gender and genotype, were slaughtered.

Parameters measured and calculated during slaughter:

- bodyweight before slaughter (*g*)
- carcass weight (*g*)
- slaughter yield(%)
- breast with skin and bone (*g*)
- whole leg with skin and bone (*g*)
- breast fillet (*g*)
- ratio of breast fillets compared of bodyweight before slaughter (%)
- ratio of whole leg with skin and bone, compared to the bodyweight before slaughter (%)

- ratio of abdominal fat (g) compared to the bodyweight before slaughter

2.3 Examinations of *in vivo* body composition

Changes in body composition of the chickens were examined throughout the experimental period. Computer tomography (CT) measurements were performed at the Institute of Diagnostic Imaging and Radiation Oncology of the Kaposvár University with a *Siemens Somatom Emotion 6 multislice CT* equipment. The experiments carried out on 15-15 individually tagged chickens of each sex and genotype (experiment 1), then it was reduced to 10-10 birds (experiment 2-4) and were transported to CT scan bi-weekly, between 2 and 12 weeks of age. On the test days, chickens - after 12 hours fasting and weighing - were placed
in plastic cages and transported to the Diagnostic Institute. Here, birds were excepted from the transport cage and were fixed with the help of velcro straps, in a transparent plexiglassholders (cradle), in prone position, with their rear legs outstretched. Investigation of three birds was possible at the same time and there was no need for anesthesia during that.

The evaluation of the images was carried out by colleagues of the Diagnostic Institute and based on locally developed softwares (CTPC, Histicut 2.2), than the basic dataset were made available for me. Further assessment - following ROMVÁRI (1996) - based on the consideration of (-200) to + 200 interval of the Hounsfield scale (fat tissue, muscle tissue and water density), while the outlying values (eg. densities of bone and air) were eliminated from the ratings.

Frequencies of pixel density values out of the complete images were recorded and then muscle and fat indices were calculated by determining the ratio of number of pixels with X-ray density values of muscle or fat to the total number of pixels with density values of muscle, water and fat, i.e. the range between -200 to +200 on the Hounsfield-scale:

$$\text{Muscle index} = \Sigma(+20)\text{-}(+200) / \Sigma(-200)\text{-}(+200) \times 100$$
$$\text{Fat index} = \Sigma(-200)\text{-}(-20) / \Sigma(-200)\text{-}(+200) \times 100$$

Individually tagged chicken randomly choosen for CT examinations, reserved specificly for in vivo imaging, was slaughtered at 85 days of age (10-10 birds / sex / genotype). During the cutting trial carcass weight (g), slaughter yield (%), weight of thigh with bone and skin, whole breast fillets, as well as abdominal fat weight (g) have been identified.

2.4 Meat quality examinations

Examination of the chicken meat physical parameters took place in the Department of Agricultural Product Qualification Laboratory of the Kaposvár University. During the slaughter test, 6-6 samples of pectoral muscle (*musculus pectoralis superficial*) and 6-6 samles of thigh muscle (*musculus biceps femoris*, the drip loss measurement: *ambient musculus*) of each sex and genotype (at 10 weeks in the third trial, 10 and 12 weeks of age in the fourth trial) were examined. Number of samples used in the third experiment from the breast was: 6 x 6 = 36 and 6 x 6 = 36 in case of the thigh muscles as well. In the fourth experiment, 2 x 6 x 6 = 72 pieces of breast and thigh muscle samples were prepared for the tests.

At the laboratory, samples with a unique serial number, wrapped in a plastic, sealable bag were stored by the laboratory colleagues in the refrigerator for 24 hours and then with their help I carried out the following measurements; pH24 (post-mortem), dry matter content, instrumental color measurement (L *, a *, b * values), water holding capacity, cooking (pectoral muscle) and frying (thigh muscle) loss.

The pH of the meat samples was measured with a Testo 205 portable pH meter. The meat was cut by a sharp knife on the measuring site, the electrode was pierced in the meat, then the value obtained with the pH meter was read.

MINOLTA CHROMA METER CR-300 instrument used for the determination of meat color on fresh samples. The measurement is based on the so-called CIELAB color system (GENEVA, 1924). The light source (D65) was put onto the fresh cut surface, parallel to the muscle fibers of the sample. In the fourth experiment, breast and thigh skin color was also determined.

The drip loss was determined in accordance to HONIKEL (1987). The approximately 2.5 cm thick, weighed (100 ± 20 g), wired and suspended slices (slices pierced on the narrower edge) were closed in plastic bags and stored for 24 hours at 4-5˚C, so that the sides of the sample does not touch the bag, then the slices were drained and measured.

Cooking loss measurement was carried out with approximately 50 g of breast muscle samples, that was heat treated for 2 hours at 75^{o}C in sealable plastic bags. The heat treatment was done with a JULABO heater-mixer (TYP / model ED AC: 190-235V / 50Hz 9A (230)).

Thigh samples were heat-treated in an air-circulating oven for 40 minutes on 200 ^{o}C. Fried samples were allowed to equilibrate to room temperature, wiped and re-weighed to evaluate frying loss.

Results of fattening and slaughtering performance of differentiated growing, non-industrial broiler stocks with several distinct genotypes were evaluated by sex and genotype under the same housing, feeding and management system, in the fourth experiment by housing system, with different biometric methods.

The comparative study for all four experiments, was designed and performed as a two-factor model and a random block design.

The method of evaluation of the results for the production and slaughtering traits were two-way ANOVA.

The relationship between CT results and slaughtering properties, as well as for the demonstration of the statistical differences between muscle and fat index values of the examined genotypes; two-tailed t-test and analysis of variance were used.

The results obtained on the occasion of meat quality evaluation studies and for exploring the differences between the experimental groups, a one-way ANOVA was performed.

Mathematical transformations during the processing of natural raw data was not applied. Statistical evaluation of the results done by SPSS 10.0 and SAS 9.0 software packages.

3. RESULTS

3.1. Production and slaughter performance

In the (first) trial Redbro Shaver reached the highest bodyweight, slaughter and breast fillet yields in both sexes in all three test dates (49, 70 and 84 days of age). The percentage of whole leg with bone and skin compared to liveweight was not differed significantly from the dual-purpose chickens (23.0%, 23.9% and 23.6% of Shaver and 23.5%, 23.3% and 23.6% for a TETRA-H group at 49, 70 and 84 days of age). However, comparing the genders, lower thigh weight percentage was observed in females at 84 days of age; 23.6% vs. 21.5%, in case of Shaver Redbro males and pullets, and 23.6% vs. 21.6% between TETRA-H males and pullets.

In trial (2) and (3), the slaughter performance of two pure lines (EE and HH) showed an extreme value, while the results of experimental crossed groups of both sexes occupied an intermediate place in all ages. The ratio of breast fillet compared to liveweight of the new EE line proved to be the best at 50 days of age, 13.6% and 14.0% in the case of cocks and pullets, while only 11.3% and 11.5% ratio measured in individuals of HH male and female groups. The performance of crossed group was located between the two pure lines. Although, when slaughtered at 85 days, a similar pattern was observed in terms of rates of breast fillet, while at 71 days of age, this superiority was no longer significant. Percentage of thigh did not differ between the genotypes.

In the (4) phase, the ratio of liveweight and breast fillet yield of TETRA Color HB birds at almost all test dates and both sexes surpassed the results of TETRA-H chickens (slaughter yield: 70.9%, 71.4%, 73 % in the case of TETRA HB Color males, 67.8%, 68.2%, 69.7% of TETRA-H males. 69.9%, 71.2%, 69% of TETRA Color HB pullets and 67.6% 67.3%, 69.6% of the TETRA-H pullets).

3.2. In vivo body composition changes during growing

The results of *in vivo* diagnostic imaging procedures showed that the incorporation of muscle during growing was more intense in the first 6 weeks of raising time in every tested genotype with higher final bodyweight (Shaver Redbro, TETRA HB Color, EE line), compared to the genotypes with slower growth rate (TETRA-H and HH pure line). In the remaining rearing time (after 6 weeks), the proportion of muscle tissue in the body showed a different picture according to gender and genotype. In males with intense growth ability, muscle index decreased in the second half of the rearing, while the opposite occured in the slower growing groups. In pullets, regardless of the growth rate, a decrease in muscle indexes after the 8 weeks of age, was observed. Nature of the crossing effected the pace of muscle tissue development. HH x EE crossed chickens had lower muscle index, which resembled more the muscle tissue development of the new paternal line, which means that the measured values declined after 6-8 weeks of age, while in the group of EE x HH chickens, this phenomen only occurred at 8-9 weeks of age. Ratio of muscle tissue within the body had a lower value in females, and in many cases only increased until 5 weeks of age. The proportion of fat in the body at the end of the rearing, was 10.7% -24.2% higher in females than in males depending on the genotype. The intensive incorporation of fat (fourth week onwards in the pullets of new line male line (EE) coincided with a decrease in the proportion of muscle tissue in the opposite direction.

The change in the proportion of valuable body parts at 6, 8 and 10 weeks of age, is best illustrated by 3D histograms. The whole leg ratio was more pronounced in the HH maternal line, but in terms of the total amount of muscle, it fell behind the meat production ability of new cock line (EE). In latter, continous increase of breast and thigh muscles, lasting up to 10 weeks of age, was observed. The abdominal fat visible occurs at first in females, at six weeks of age and then it can be detected in the neck area, from about 8-10 weeks of age, onwards.

In experiment (4), based on the CT results of tested TETRA-H chickens measured muscle volume at 7, 10 and 12 weeks of age was lower, than of the TETRA HB Color and Shaver Farm values in both sexes, however, the relative increase in muscle volume in the period between 7 to 12 weeks of age, was the largest in TETRA-H males (74.6% vs. 68.1% and 52.5%, in Shaver Farm and TETRA Color HB, respectively).

3.3. Meat quality parameters of the examined chicken genotypes

During the meat quality examination of pure lines and crossbred progeny, statistically proven difference was only found between the groups in respect of drip loss.

A detailed examination of breast and thigh muscles have been carried out in the fourth (4) experimental phase. By analyzing the differences between the three tested genotypes (TETRA-H, TETRA HB Color, Shaver Farm) it was established that the meat quality attributes of TETRA Color HB and Shaver Farm genotypes are closer to each other. The differences were most pronounced in thigh muscle at 10 weeks. The TETRA HB Color and Shaver Farm genotypes had lower frying loss as TETRA-H genotype, but the differences are leveled by 12 weeks of age. The gender effect on meat quality has been more pronounced in case of thigh muscles, which was manifested in relevant differences in frying loss between the two sexes. In general, both at

10 as well as 12 weeks of age, frying loss in female groups was larger than the male groups.

3.4. Effect of free range system on some traits in connection with meat production

During the investigation of the rearing system effect on meat quality, it was established that frying loss of the thigh muscle in TETRA-H and TETRA HB Color genotypes was smaller in free-range chickens compared to the group held in a closed building at 10 weeks of age, but the differences are leveled by 12 weeks of age. These results confirm that longer rearing time beneficially influence certain characteristics of the meat, related to further processing.

Free-range, as an environmental factor, had a verifiable impact on liveweight, thigh muscle and abdominal fat quantity, for all genotypes used in the (4) experiment.

These data clearly confirmed by the results of computer tomography examinations.

4. DISCUSSION AND RECOMMENDATIONS

Based on the results the following conclusions can be drawn:

1. First experiment

1.1 Assessment of meat producing ability - TETRA-H hybrid

- During the assessments of the original TETRA-H hybrids meat production ability, the aim was to position the market ranking by comparing it to a commercially available standard control (Shaver Redbro). It was concluded, that difference between the liveweight of the examined two slow- and moderate growth genotypes was statistically confirmed and highly significant in respect of any age ($P < 0.05$). The relative size at 10 weeks of age was 28-29%, depending on the gender. The data clearly confirmed the need of breeding work aimed to improving the meat production of TETRA-H.
- Shaver Redbro used as a control, had more favorable parameters in all slaughter traits, compared to TETRA-H. Due to the close correlation between weight gain and fat deposition, raising chickens with more intensive growth, accumulation of abdominal fat, up to 2-3% by the end of the raising period, can be expected.

1.2 Relation between muscle and fat deposition with growth rate

- Examination of the two hybrid *in vivo* body composition has revealed some important differences between tissue distribution of chickens with different growth rate. Muscle growth of TETRA-H chickens with essentially longer rearing period, showed continuous upward trend between 4 and 12 weeks of age, while the proportion of muscle tissue within the body decreased after 8 weeks of age in Shaver Redbro with intense growth rate, despite the higher slaughter weight. The phenomenon is probably due to the further development of bones which need to be carrying greater weight and increased fat deposition. Sexual dimorphism at this age group have not yet expressed, however, lower muscle index and higher fat index (10-11%) of females compared to male groups observed during the whole education.

- The proportion of fat tissue within the body in the first 8 weeks of age was higher at the slow-growing TETRA-H, than showed a slight decrease, probably because of increase of muscle tissue, but not differed significantly from broilers with faster growth thereafter. This phenomenon provide evidence, typically in slow-growing genotypes - occuring at the beginning of the growing period - for a higher ratio of subcutaneous and intramuscular fat.

2. Second and third experiment

2.1 Production parameters of pure lines and crossed groups used in the breeding program of TETRA HB Color

- Based on production and slaughtering results of the new male line (EE) with improved meat production and in accordance with the new selection criterias, it was concluded that the EE linewith intense growth, increased liveweight, slaughter and breast fillet ratio compared to the previously used parental line (HH), so it is appropriate to replace it the new TETRA Color HB selection program.

- Daily weight gain and periodic feed conversion calculated for certain parts of growing period was also favorable in the new paternal line, which resulted in a positive change in the crossbred chickens as well. The improvement in feed conversion indicators also significantly increased the competitiveness of the hybrid.
- The presence of considerable amount of abdominal fat experienced on slaughter tests, require serious attention, especially in the case of pure line parent stocks because of its negative effect on egg production and fertility. Further examination of breeding flocks in this field is definitely appropriate in the future.
- Production results of the crossed groups (H x E and E x H) lied between the performance of two pure lines, which was expected in traits related to meat production with good and medium heritability. However, the crossing method - H x E or E x H - did not affect the positive impact of the new male line on meat producing ability, since no significant difference in performance the crossed progeny and reciprocal crossover was occured.

- In the case of poorly heritable properties such as the viability, implementation of both crossing methods resulted in significant (31-33%) a positive heterosis in the offspring. In slaughter yield, hyperplasia (heterosis) was observed at 10 weeks of age, but then there was no evidence of a significant positive change in the cutting properties of the crossed birds.

- The results obtained definitely shows, that development of the chicken genotypes in the direction of higher meat yield can not give up neither the classic mass selection nor heterosis breeding method.

2.2 Body composition changes in pure lines and crossed groups during rearing in broiler chickens

- Muscle tissue incorporation showed an increase in pure lines and crossed chickens until 6 weeks of age, regardless of sex and genotype. No differences were found between muscle indexes of males from crossed groups and new paternal line at 12th weeks of the experiment, despite the superiority of the latter by more than 1 kilogram bodyweight.
- Gender influenced the ratio of muscle and fat tissue and its incorporation in the body. The pullets had typically lower muscle volumes and higher fat index, in overall had less favorable growth curve than males.
- The crossing had a positive impact on the nature of tissue infiltration tendency, notably in favor of the E x H combination, which is typically showed growth until 8-9 weeks of age. In this age, 2.0-2.5 kilograms of liveweight in mixed gender certainly meets the expectations of slaughterhouses and the market.
- Relatively high fat index within the body of the crossed chickens and broilers belonging to the new male line, confirms the results of slaughter tests in respect of abdominal fat, of which requires attention by the breeding company because of its high h^2 value. Increased fattening was observed in females at 12 weeks of age, fat content of pullets was higher than in males belonging to their own genotype by 24.2% in HH line, by 21.8% in EE and by 17.8% in crossed group, respectively.

- Three-dimensional histograms prepared from tissue pixel frequencies, provided detailed information of proportions of valuable body parts in chickens involved in CT examinations. Measurements carried out in potential slaughter ages, at 6, 8 and 10 weeks of age, were sufficient for determination of the optimum breast muscles development and for selecting individuals with greater potential of fat deposition in the abdomen and in the neck area.

2.3 Effect of crossing method on physical parameters of the meat

- Pure and crossbred progeny groups showed homogeneous meat quality, however high standard deviation of certain meat quality parameters indicate low uniformity of the experimental lines, namely high degree of variability.

3 Fourth experiment

3.3 Final results of TETRA-H development program concerning production parameters

- Liveweight measured in TETRA Color HB chickens at 84 days of age, showed higher values by 56.7% in males and by 60.7% in females, when compared to values of the TETRA-H birds. Objectives formulated and efforts made to develop meat production capability, is therefore a success.
- The cutting results also demonstrated the positive effect of the new cock line; which mainly prevailed in breast muscle yield. Increased abdominal fat has occurred in the new hybrid construct, however, the maximum value, 4% in percentage of liveweight, has never been reached during the slaughter tests.

3.4 In vivo body composition changes in different chicken genotypes

- Based on *in vivo* examinations of muscle and fat development in chickens with different growth, it was concluded that the relative growth of muscle volume in TETRA HB and Shaver Farm with similar meat production ability differs significantly from the slow-growing TETRA-H hybrid, between 7 and 12 weeks of age (Shaver Farm - 68.1%; TETRA Color HB - 52.5%; TETRA-H - 74.6%). Tomographic studies in common slaughtering dates (7, 10 and 12 weeks of age), were sufficient for monitoring these changes.
- Fat volume ratio was highest in genotypes with bigger liveweight at 12 weeks of age compared to the value measured at 7 weeks of age, especially in females (TETRA-H – 40,8%; TETRA HB Color – 63,5%; Shaver Farm – 63,4%). Fat content has changed the least in males of the new hybrid at 12 weeks of age, compared to what measured in in the first time of inspection.

3.5 Meat quality assessement of the new TETRA HB Color

- Analysing the differences between the three genotypes, it was determined that the meat quality characteristics of the TETRA Color HB and Shaver Farm genotypes are closer to each other. Frying loss of the former two genotypes are typically smaller than as the TETRA-H genotype. The differences more pronounced in thigh muscle at 10 weeks of age.
- As regards the impact of age on meat quality aspects - especially in thigh muscle - I found significant differences typically in frying loss between sample collected from the three genotypes. The degree of frying loss decreased in both rearing system as progressed in age.

4 Effect of free range system on meat production traits

4.3 Production and slaughter traits

- Liveweight, grillfertig weight, as well as breast, thigh and abdominal fat weight were significantly lower in free range TETRA-H hybrids at 10 weeks of age, than values measured in the case of TETRA Color HB. However, the slow-growing TETRA-H had higher leg percentage in the portion of carcass and possessed higher breast and thigh-bone in the ratio of whole muscle mass.
- Examining the mean values, it was established that genotype had an impact on all slaughtering properties, except for the breast skin, in both rearing systems.
- However, free range environment only caused significant differences in liveweight, thigh muscle, thigh skin and abdominal fat weight between the groups. Greater mobility required more thigh muscle volume, and expressed its beneficial effects in the amount of abdominal fat as well.

4.2. In vivo body composition changes

- Whatever the rearing system and age (7 to 10 weeks), TETRA-H chickens had lower muscle index than TETRA HB Color and Shaver Farm under the same conditions
- In case of the two TETRA hybrids, it was established that muscle index showed higher values in free range chickens at 10 weeks of age, after 3 weeks outdoor stay, compared to same genotype birds kept under intensive conditions ($P \leq 0{,}05$; TETRA-H - 54.3 vs. 53.4; TETRA Color HB - 56.6 vs. 55.5)

- Free range environment decreased fat indexes in all three experimental groups by week 10, compared to values measured three weeks earlier, while CT images showed no difference between the measurement data of indoor system (7 and 10 weeks of age).

4.3. Meat quality parameters

- A genotype had an effect on skin color (L * and b * values) chickens are kept outdoor. The free range system resulted in higher pH and more yellowish and reddish breast muscles compared to the values of the indoor chickens. These features serve the needs of the market, which expected by consumers opposed to farm chicken.
- The outdoor birds thigh muscle L* (lightness) value, drip and frying loss significantly influenced by genotype. In this manner, TETRA-H - more preferable from the market point of view - ended the comparative experiment with darker thigh muscle and higher frying loss than TETRA HB Color.
- Rearing system effected skin and muscle color of chicken thigh and its frying loss, which resulted in is darker and more yellowish muscle and skin color and lower frying losses of indoor chickens, compared to free range birds.

5. NEW SCIENTIFIC RESULTS

1. During the central performance test of crossed offspring groups created from pure lines used in domestic, dual or mixed purpose chicken breeds with colorful plumage, it was established, that with regard to bodyweight and slaughter traits, the crossing method (HH♂ x EE♀ or EE♂ x HH♀) does not affect the enforcement of the better meat producing line (EE). No significant difference found between the performance of the crossed and reciprocal crossbred progeny, while muscle tissue development trend based on CT examinations manifested itself better for ExH crossed group.

2. Based on CT examination results, proportion of muscle tissue found in the body of the new male line (EE) and crossbred progeny (HxE) males do not differ from each other despite significant liveweight difference measured at the last slaughter age (12 weeks).

3. Body composition changes of color feathered chicken genotypes with different growth rate were characterized according to sex and age during the whole growing period, by means of vivo CT examinations, during which it was verified that the proportion of muscle tissue within the body increase for 12 weeks in case of slow-growing TETRA-H, while for genotypes with more intensive growth, lasts only until 8-9 weeks of age. The proportion of fat within the body is higher in the case of slow-growing lines until 8 weeks of age.

4. Meat quality of medium-growing, colour feathered chicken leg (pH, drip / frying loss) statistically differ from the slow-growing TETRA-H hybrids. Drip and frying loss decreases as age progresses.

5. Bodyweight, abdominal fat and ratio of fat tissue within the body was higher in chickens kept under closed, intensive conditions, while whole thigh muscle weight and ratio of muscle tissue within the body reached a lower value, compared to individuals are kept outdoor.

6. Free-range system results in higher frying loss, which occurs more markedly with respect to the thigh muscle, while holding down the impact of the keeping system, darker and yellowish meat and skin color, are affected rather by genotype and age.

6. SCIENTIFIC PAPERS ON THE SUBJECT OF THE DISSERTATION

6.1. Articles in foreign languages

ALMASI Anita – Zoltan SUTO – Attila ORBAN – Tamas FULOP – Poce Olga KUSTOSNE – Gabor MILISITS – Peter HORN (2011): Improving the final liveweight and growing ability of TETRA-H a dual purpose chicken type by using and experimental sire line. *Agriculturae Conspectus Scientificus*, Vol. 76, No. 3, 245-248.p. Croatia.

ALMÁSI Anita – Gabriella BAKA-ANDRÁSSY – Zoltán BUDAI – Olga PŐCZE-KUSTOS – Tamás FÜLÖP – Zoltán SÜTŐ (2012): Investigation of colour, texture and organoleptic properties of retailed conventional and organic chicken breast in Hungary, *Acta Agriculturae Slovenica*, Supplement 3, 287-290. pp. Ljubljana.

Almási, A. – Sütő, Z. – Budai, Z. – Donkó, T. – Milisits, G. – Horn, P. (2012): Effect of age, sex and strain on growth, body composition and carcass characteristics of dual purpose type chicken. XXIV World's Poultry Congress, Salvador (Brazil), August 5-9, 2012, CD-ROM: RE_GB_2012pc538_1, *World's Poultry Science Journal*, 68, Supplement 1. 285-288.p.

Almasi, A. – Andrassyne, B.G. – Milisits, G. – Kustosne, P.O. – Suto, Z. (2015): Effects of different rearing systems on muscle and meat quality traits of slow-and medium-growing male chickens. *British Poultry Science*, Vol. 56:(3) 320-324.pp.

Almasi, A. – Z. Suto – Z. Budai – T. Fulop – P. Horn (2013): Development of a new colour feathered broiler for free farming systems. In: *8th European Symposium on Poultry Genetics*, Abstracts of posters 81.p. 25-27 September, Venice, Italy.

6.2. Articles in Hungarian

Almási, A. – Sütő, Z. – Orbán, A. – Milisits, G. – Kustosné, P.O. – Fülöp, T. – Horn, P. (2013): A hústermelő képesség fokozásának lehetőségei keresztezéssel előállított kettőshasznosítású tyúk genotípusoknál, *Állattenyésztés és Takarmányozás,* Vol. 62. (3) 281-292.p. Budapest.

Sütő Z. – Orbán A. – Fülöp T. – **Almási A.** – Kustosné Pőcze O. – Milisits G. – Horn P. (2011): A TETRA-H hústermelő képességének javítását célzó kutatás-fejlesztési program első eredményei. *X. Nemzetközi Baromfitenyésztési Szimpózium* (2011. április 6.) Kaposvári Egyetem, Állattudományi Kar, Proceedings 13-20.p. Kaposvár.

6.3. Presentations

Almási A. – Sütő Z. – Orbán A. – Fülöp T. – Kustosné Pőcze O. – Milisits G. – Horn P. (2011): A Tetra-H hibrid hústermelő képességének javítása új, kísérleti kakas vonal beállításával. *Doktoranduszok Kaposvári Workshopja*, Állattenyésztési Tudományok Doktori Iskola, Tradicionális állattenyésztési Szekció, 2011. június 8. Kaposvári Egyetem, Kaposvár.

Horn P. – Budai Z. – Milisits G. – Donkó T. – Molnár M. – Romvári R. – **Almási A.** – Szentirmai E. – Kustosné P. O. – Ujváriné J. – Sütő Z. (2012): A TETRA-KAP kutatásfejlesztési program legfontosabb eredményei (Kaposvári Egyetem, 2009-2012) [The most Important Results of the TETRA-KAP Research and Development Program (Kaposvár University, 2009-2012)]. *XXIII. Nemzetközi TETRA Konferencia* (23th TETRA International Poultry Breeders Conference) 2012. május 18. Bábolna.

7. SCIENTIFIC PAPERS OUTSIDE THE SUBJECT OF THE DISSERTATION

7.1. Articles in foreign languages

Almási, A. – Varga, Á. – Barna, J. – Bogenfürst, F. – Molnár, M. (2002): Preliminary Study on spermatological characteristics of frizzled Hungarian ganders, *Acta Agraria Kaposváriensis*, Vol. 6. No. 2, 289-292.p.

7.1.1. Abstracts

Forgacs, B. – **Almasi, A.** (2013): New shell color evaluation method for more accurate selection in brown layer lines. *8th European Symposium on Poultry Genetics,* Abstracts of posters 82.p. 25-27 September, Venice, Italy.

Barna, J. – Liptói, K. – Patakiné-Várkonyi, E. – Hidas, A. – Váradi, É. – Bodzsár, N. – Sztán, N. – Horváth, G. Gál, J. – Forgács, B. – **Almási, A.** (2013): Development of avian reproductive biotechnologies for the management of genetic diversity, *8th European Symposium on Poultry Genetics,* Abstracts of posters 72.p. 25-27 September, Venice, Italy.

7.2. Articles in Hungarian

Almási, A. – Bogenfürst, F. (2003): A mesterséges termékenyítés jelentősége és módszere a lúdfajban. *Állattenyésztés és Takarmányozás*, Vol. 52. (2) 173-179.p.

Varga, Á. – Barna, J. – **Almási, A.** (2003): Fodrostollú magyar gunarak spermatológiai vizsgálata és ivari jellegzetességei. *Állattenyésztés és Takarmányozás*, Vol. 52. (2) 167-172.p.

Bogenfürst, F. – **Almási, A.** (2003): A természetes és mesterséges termékenyítés sajátossága a lúdfajban (Characteristic of natural fertilizing and artificial insemination of geese). *Hungarian Journal of Poultry Industry,* Vol. 32. 17-21.p.

7.2.2. Full conference papers in proceedings

Almási, A. – Milisits, G. – Sütő, Z. (2011): Beszámoló a XIII. Európai Baromfitenyésztési Konferenciáról. *X. Nemzetközi Baromfitenyésztési Szimpózium,* (2011. április 6.) Kaposvári Egyetem, Állattudományi Kar, Proceedings 67-72.p. Kaposvár.

Sütő Z. – Budai Z. – **Almási A.** – Milisits G. – Ujváriné J. – Horn P. (2014): A tartásmód hatása a tojóhibridek főbb értékmérő tulajdonságaira a tojó típusától és genotípusától függően zárt tartástechnológiai rendszerekben. (In: Schmidt R, Bali Papp Á (szerk.)): *XXXV. Óvári Tudományos Nap*, A magyar és nemzetközi agrár- és élelmiszergazdaság lehetőségei Nyugat-Magyarországi Egyetem, Mezőgazdaság- és Élelmiszertudományi Kar, Mosonmagyaróvár, 2014. november 13. [előadások és poszterek teljes anyaga CD]. pp. 184-190. Mosonmagyaróvár.