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DOCTORAL THESIS

RESEARCH ON THE KNOWLEDGE OF QUALITY PARAMETERS THAT CHARACTERIZE THE MEAT OF CERTAIN GAME SPECIES USED IN HUMAN CONSUMPTION

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SUMMARY

Nourishment has an essential role in determining the health state of the people of a country; healthy nourishment requires adequate and continuous involvement of scientific research, with the aim of galvanizing regulation and adaptation systems of the organism.

The main criterion to represent the basis on which the choice of the doctorate topic was made was the fact that at the moment there is little information regarding cynegetic fauna specific to Romania, provided by scientific research quoted in specific literature and by consulting the latest scientific data from online sources, international researches focusing on nutritional value of semi-domestic game and game exploited in semi-intensive conditions, with emphasis on the influence of the feeding diet and of manipulation techniques of animals before slaughter on meat quality.

Compared to the aforementioned, the researches within the doctorate thesis sought to assess the quality of the meat of a few cynegetic mammals (*Sus scrofa ferus*, *Cervus elaphus L.*) with the purpose of constituting a solid scientific basis at national level, in order to increase the efficiency of correct information and realize a global image as faithful as possible of the nutritional-dietary, sensorial and technological quality of this type of meat. The purpose of the research was grounded on the following aspects: insufficient information regarding describing the quality of game meat minutely and objectively, as specific to the cynegetic fauna of Romania; extending the area of knowledge with analytic data on the nutritional quality of game meat, especially through information regarding the intrinsic quality of intramuscular lipids of cynegetic mammal meat, useful in managing a healthy diet; obtaining information regarding the content in several minerals of game meat, important from the standpoint of completing the concept of meat quality (nutritional-biological); lack of information on the contamination of game meat with heavy metals, considering the limited possibilities of controlling game feed when exploited in its natural environment, as well as environmental pollution factors; the need for information on technological quality of game meat is relevant and strictly necessary to the processor, for subsequent processing, adequate to increased economic efficiency; correlating physical, chemical and technological parameters with sensorial attributes of game meat for efficient culinary preparation.

The organization of personal research was realized according to a clearly structured plan, which aimed towards organizing the experiments in order to complete the aforementioned information gaps, characterizing the quality of game meat from carcasses of ruminants – cervids (*Cervus elaphus L.*) – and omnivorous mammals (*Sus scrofa ferus*) exploited under conditions of a climate specific to the North-Eastern area of Romania, qualitative parameters tracked for achieving the goals being physical, chemical, technological and sensorial.

At the same time, qualitative analyses of game meat were correlated with the brief description of the physiological status of animals used as biological material, with the aid of hematological indexes and metabolic parameters, acknowledging the influence of certain physiological states in meat processing upon the carcass conformation, therefore upon the quality of meat. Biochemical profile tests are an efficient method of updating the adaptation capability of animals' organism to the natural habitat and the hematological ones are important from the standpoint of assessing the health state of the animals at the moment when samples are taken (in current research), the necessity of assessing animal effectives nutritionally and metabolically imposed due to the fact that many nutritional deficiencies can trigger pathogenic states or nutritional losses of balance.

In order to achieve the established aim, investigations were performed on a total number of 37 adult wild boars (17 males and 20 females), and 21 red deers (10 males and 10 females), taken hold of during the course of several hunts organized in the North-Eastern side of Romania (Suceava Forest District, Frasin hunting stock) in the 2008-2009, 2009-2010 and 2010-2011 hunting seasons, in conformity with the regulations of Law no.47/2006 as modified and completed through the O.U.G. no. 102/2010. These implied establishing several natural parameters as following:

- **physical parameters** (dynamic of meat acidity during maturation, colour (L*, a*, b*, C*, h);
- **chemical parameters**: crude chemical composition (dry matter, water, total lipids, organic substances, non-nitric extractive substances, total of mineral substances), energetic value, profile of intramuscular lipids in fatty acids, trace elements (Mn, Cu, Zn, Fe, Mg), xenobiotic heavy metals (Pb, Cd);
- **technological parameters**: water holding capacity (losses encountered by refrigeration-pouring, losses by cooking);
- **sensorial parameters**: global image, flavor, colour, taste, succulence, tenderness;
- **sanguine parameters**: **hematological** – erythrocytary parameters (red blood cells – RBC; hemoglobin – HGB; mean corpuscular volume – MCV; mean corpuscular hemoglobin

concentration – MCHC); leukocytary (White blood cells – WBC) and thrombocytary (Platelets – PLT) and **biochemical** (glucose, total protein, triglycerids, cholesterol, Ca^{2+} and P^{3+}).

Since the experimental protocol of the current research aims for qualitative characterization of game meat from a physico-chemical, toxicological, sensorial, technological and physiological status standpoint, harvesting and sampling required using two types of tissue: muscular tissue (*Longissimus dorsi*, *Semitendinosus*, *Triceps brachii* and *Trapezius cervicalis* muscles) and blood.

The analysis methods used in personal researches are included within a legislative frame provided by Romanian standards, harmonized with the European Union legislation and international standards or in conformity with used methods in reference works.

Assessment of wild boar meat quality (*Sus scrofa ferus*) and physiological status of animals before slaughter highlighted the following aspects:

Hematological and metabolic profile indicators determined on sampled blood from studied boars highlighted insignificant existing differences between males and females for each index, females presenting superior value compared to males. Correlations between analyzed metabolic indexes suggest adequate functioning of anabolic metabolism, being directly related to the nutritional status of animals and the nutritional composition of the last ration before slaughter.

During wild boar meat refrigeration/maturation, pH dynamic presented a descending tendency in the first 48 h postmortem, average values registered in this interval reaching the upper limit of 5,38 (*Triceps brachii* muscle) – 5,44 (*Trapezius cervicalis* muscle), both extremes characterizing sampled muscles from female carcasses. The following ascending evolution of the parameter reached towards the end of the 10 maturation days an average acidity value placed within the 5,79 – 6,02 range; at all muscular samples, the postslaughter dynamic of pH registered at all studied groups of muscles fitted within the safety range for avoiding undesired manifestations, such as PSE (pale, soft, exudative) or DFD (dark, firm, dry). From a statistical viewpoint, the animals' sex influenced meat acidity spontaneously, a possible cause of spontaneous and intermittent influence being represented by the varying microbial load of slaughter parts.

The colour of wild boar meat (maturated and vacuum packed) was described by a luminosity (L*) of average values that stood within the range of 45,76 – 49,44 units, *Longissimus dorsi*, *Semitendinosus* and *Triceps brachii* muscles from male carcasses presented superior luminosity compared to homologous muscles sampled from female wild boar carcasses. Results of actual researches describe an attractive colour of wild boar meat, from a commercial

standpoint, with a darkly red pigmentation (specific to game), much more intense than swine meat, a fact correlated with the reduced speed of descending rate for meat acidity corroborated with the fast decrease of preserving temperature (*Marchiori et. all, 2003*), as well as the richer myoglobin content of game as a result of intense muscular effort *(Hedrick et. all, 1994 cited by Marchiori et. all, 2003).*

Wild boar meat tenderness described through the Warner – Bratzler shear forces (which express the resistance opposed by thermally treated meat when ripped) was characterized by averages that varied within the range of 35,00 – 51,44 N/cm^2, male muscles expressing lower tenderness compared to that determined at samples from female carcasses; comparing muscles, the *Longissimus dorsi* was defined as having lowest hardness. Through statistical analysis, *Triceps brachii* muscle presented distinctly significant differences between males and females for the Warner – Bratzler shear forces values, 75% of the tests performed for the entire musculature being insignificant.

Analytical data referring to wild boar meat composition highlighted the following aspects:

a) at the level of all analyzed muscle groups, determined value for dry substance of male musculature is superior to that determined at samples from female carcasses, average content varying between 26,23±0,46% (*Semitendinosus* muscle at females) and 27,84±0,60% (*Trapezius cervicalis* muscle at males);

b) according to obtained data, average protein content denotes compositional uniformity for the four analyzed groups of muscles, ranging between 20,9% – 22,77%, with minimal protein registered predominantly in samples from female carcasses;

c) determined value for total number of lipids of wild boar meat constituted the component that set the largest variation between studied muscles, calculated environments being placed between 2,65% (*Longissimus dorsi* muscle at male) and 5,22% (*Trapezius cervicalis* muscle at female), the total lipid content of female musculature being superior to that belonging to male meat for *Longissimus dorsi*, *Triceps brachii* and *Trapezius cervicalis* muscles;

d) quantitative and qualitative description of fatty acid profile of wild boar meat lipids denotes a large variation range of values, averages of main lipidic fractions being reproduced in the following intervals: 33,60 ÷ 37,03% SFA, 43,70 ÷ 47,15% MUFA (monounsaturated fraction of lipids in wild boar meat is dominated by ω-9 fatty acids (C18:1ω-9; C16:1ω-9)) and 17,53 ÷ 21,01% PUFA (major lipidic polyunsaturated fractions are represented by C18:2ω-6, C20:4ω-6 and C18:3ω-3), percentage expression being reported to the determined total quantity of fatty acids. PUFA content correlated with the values of the PUFA ratio (ω-6/ω-3) represents the

scientific basis for the quality assessment of lipids in wild boar meat; obtained analytical data indicate the superior nutritional value of lipids in analyzed muscles in the following order: *Longissimus dorsi*, *Triceps brachii*, *Trapezius cervicalis* and *Semitendinosus* muscles;

e) the calculated energetic value highlighted the caloric specificity of wild boar meat, boar placed between 154,41 *(Semitendinosus* muscle*)* and 171,03 Kcal/100 g meat *(Trapezius cervicalis* muscle*)*, both muscle groups belonging to female carcasses;

f) through analytical data obtained from the analysis of several minerals of wild boar meat, the presence of important quantities of Cu, Zn, Mn, Fe and Mg, essential metals in a balanced daily diet, is confirmed, the quantitative variation of each trace element being specific to muscular group and wild boar sex as following:

- average Cu content of sampled meat from female carcasses was superior to homologous muscle samples from male carcasses for analyzed muscles from the dorsal region, shoulder and thigh region, as a whole values were placed within the range of 1,80 ÷ 1,93 mg/kg dry substance;
- comparatively between sexes, female muscles from the shoulder and dorsal region presents an average Zn and Mn content that is superior to corresponding muscles from male carcasses, the situation being inversed in the case of the cervical region, variation ranges for average values being 34,35 ÷ 40,09 mg/kg dry substance for Zn and 0,28 ÷ 0,37 mg/kg dry substance for Mn;
- average Fe content of dorsal and cervical muscles from male carcasses encountered superior values compared to those obtained for corresponding muscles from female carcasses, average values ranging between 57,72 ÷ 65,00 mg/kg of dry substance;
- average Mg content of wild boar meat emphasizes the resulted unanimous superiority of samples from female carcasses, average values placed between the range of 218,16 ÷ 280,02 mg/kg dry substance; these values leaded towards strictly significant differences between males and females in the case of *Longissimus dorsi* and *Semitendinosus* muscles.
- research results confirm the presence of xenobiotic heavy metals in wild boar meat (Cd and Pb), quantitatively these being below the admitted higher limit (LMA) of 0,05 ppm for Cd and 0,1 ppm for Pb (*EC, no. 1881/2006*), encountered environments varying between 0,0088 ÷ 0,0154 mg/kg dry substance for Cd and 0,0023 ÷ 0,0082 mg/kg dry substance for Pb. Accumulation of these two heavy metals in muscle tissue of wild boars are the result of contaminated sources from the inhabited environment (air, water, soil).

From a technological standpoint, losses through dripping during refrigeration of wild boar meat were higher at male samples than at female samples, the variation interval of the average values ranging between 4,27% (*Triceps brachii* muscle at females) ÷ 5,40% (*Trapezius cervicalis* muscle at males). This superiority is also preponderantly reiterated by cooking muscle

samples, with significant differences between males and females for the values from *Longissimus dorsi*, *Semitendinosus* and *Triceps brachii* muscles.

From a sensorial standpoint, boar meat was characterized by a dark color, juicier and more tender in the case of females, specific gamey taste (noticing a slightly nutty taste) and pronounced intensity (especially in male samples) correlated with pleasant taste and an average score of global appreciation reflecting a positive image (4,04 and 4,33 points).

Assessment of Carpathian red deer (*Cervus elaphus L.*) meat quality and physiological status of animals before slaughter highlighted the following aspects:

High sex based variations of hematological and metabolic parameters may be justified by the existence of differences between analyzed specimens (sex, age, body weight) correlated with stress factors before slaughter, calculated average values for each blood index being similar to those mentioned in literature, which describe the physiological status of cervids contented through physical methods.

Evolutionally, the pH of cervids meat presented a descending curve during the first 48 hours *postmortem*, an exception constituted by muscles sampled from the dorsal and cervical regions of male carcasses as well as the thigh muscles of females, average values of cervids meat acidity at this moment ranging between 5,48 and 5,57. After 120 hours of maturation, cervids meat acidity was homogenized within the 5,64 ÷ 5,66 range, and at the end of the maturation process (240 hours) meat acidity was placed within the range of 5,70 ÷ 5,76, no statistically significant differences between males and females for the parameter's values being registrated, over the maturation time span.

From a colorimetric standpoint, red deer meat was characterized by a luminosity (L*) ranging between 25,76 (*Trapezius cervicalis* muscle at females) and 28,99 units (*Triceps brahii* muscle at males); by a sex-based comparison, the *Longissimus dorsi* and *Semitendinosus* muscle sampled from female carcasses possess a luminosity superior to those sampled from males, the situation reversing for the other two analyzed groups of muscles. Values of colorimetric parameters specific to venison meat from current papers confirm the dark color of game, specific to the species, obtained data being close to characteristic colorimetric indexes of meat from cervids aged between 5 and 6 years exploited in farms, the literature specifying values of meat luminosity between 32 and 34 units for youth.

The tenderness of cervids musculature, objectively described through the expression of firmness towards ripping from a physical standpoint, was placed within the range of 19,65 (*Longissimus dorsi* muscle at females) ÷ 45,26 N/cm^2 (for the *Triceps brahii* muscle at males), muscle samples from female carcasses being more tender in comparison to muscles from male carcasses.

The compositional characteristics of cervids meat sketched the following aspects:

a) dry matter content of analyzed musculature shows the values of muscles sampled from females to be superior, values ranging between 24,53% (*Triceps brahii* muscle at males) and 25,63% (*Trapezius cervicalis* muscle at females);

b) referring to the total protein content of analyzed muscles, greater expansiveness of values from muscles samples from female carcasses was highlighted (from 21,71% at shoulder musculature to 22,72% at *Longissimus dorsi* muscle), whereas males' average values ranged between 21,35% and 22,58%;

c) total lipid average is concordant to and depending on the total protein and water content from analyzed samples, the parameter of female carcasses samples being superior to that of male carcasses samples; the maximum value of 1,77% at cervical musculature of does was counterbalanced, within the same sex category, by the minimum of 1,13% characteristic to *Longissimus dorsi* muscle, a situation reoccurring at male samples' average, though at different amplitude (1,32% maximum, 0,83% minimum);

d) the quantitative and qualitative description of fatty acid profile of venison meat lipids showed average values for the main lipidic fractions placed between 30,34 ÷ 45,84% for SFA, 24,68% ÷ 45,15% for MUFA (the monounsaturated fraction of venison meat lipids is dominated by ω-9 fatty acids (C18:1ω-9; C16:1ω-9)) and 21,69 ÷ 41,91% for PUFA (major polyunsaturated lipidic fractions, represented by C18:2ω-6, C20:4ω-6, C18:3ω-6, C20:5ω-3 and C22:5ω-3), percentage expression reported to the determined total quantity of fatty acids. The SFA, MUFA and PUFA content correlated with the values of PUFA/SFA and PUFA (ω-6/ω-3) ratios of venison meat and obtained analytic data attesting red deer meat as a high potential protein source in ensuring a favorable lipidic balance for all analyzed muscular groups;

e) calculated energetic value for cervids meat highlighted its dietetic properties by placing caloricity within a variation range between 153,37 Kcal/100 g meat (*Longissimus dorsi* muscle at males) and 166,66 Kcal/100 g meat (*Trapezius cervicalis* muscle at females) as well as the poor fat content and the water:protein ratio;

f) nutritionally, analytical data obtained through mineral analysis shows the presence of important quantities of Cu, Zn, Mg, Fe and Mn, average values and variations limits of the content being presented depending on the muscle group and sex of the cervids:

- average Cu content of sampled meat from female carcasses was superior to corresponding muscle samples from male carcasses for analyzed muscles from the thigh, shoulder and cervical region, average values being placed within the range of 7,75 ÷ 10,174 mg/kg dry substance;

- through a sex-based comparison, male muscles sampled from the dorsal, thigh and shoulder region presents a Zn content superior to corresponding muscles from female carcasses, the situation being the opposite for the cervical region, average values ranging between 82,88 and 116,06 mg/kg dry substance;
- average Mn content of cervids meat describes quantitatively the superior character of the values resulted from analyses of samples from male carcasses for the *Longissimus dorsi*, *Triceps brachii* and *Trapezius cervicalis* muscle, calculated average values being defined by the range of 2,04 ÷ 3,48 mg/kg dry substance;
- average Fe content of dorsal, thigh and cervical musculature from male carcasses was reflected by values superior to those from muscles sampled from female carcasses, average values for the entire set of samples ranging between 79,80 ÷ 92,23 mg/kg dry substance, significant differences between males and females appearing at the level of the *Semitendinosus* muscle;
- average Mg content of cervids meat was placed between 214,00 ÷ 285,03 mg/kg dry substance, sampled muscles from the dorsal and shoulder regions of male carcasses presenting a higher content of this macroelement than their correspondents from female carcasses. Sex-wise, statistical analysis highlighted significant differences for obtained values at the *Longissimus dorsi* and *Triceps brachii* muscles, along with distinctly significant differences at the *Semitendinosus* muscle;
- from a toxicological standpoint, performed analyses confirm the presence of xenobiotic heavy metals in red deer meat (Cd and Pb), assesses average concentrations placed below the high limit, varying between 0,021 ÷ 0,039 mg/kg dry substance for Cd and 0,026 ÷ 0,06 mg/kg dry substance for Pb; though obtained data is the result of the bioaccumulation of heavy metals, the low level of these does endanger neither the animals' health, consequently, nor the consumer's;

Losses encountered through applying the thermal treatment of cooking the cervid meat have values ranging between 31,62% (*Longissimus dorsi* muscle) and 39,48% (*Trapezius cervicalis* muscle), whereas losses encountered through sample refrigeration had values ranging from 2,93% (*Longissimus dorsi* muscle at females) and 3,86% (*Trapezius cervicalis* muscle at males).

Sensorial analysis of muscle samples from cervids carcasses emphasized a very pleasant and strongly grassy aroma, completed by high intensity and particular taste; the meat was assessed as satisfyingly juicy, with a good tenderness and very pleasant looking, assessed through 4,58 and 4,71 points.

Research results represent comparison data regarding quality parameters of game meat (wild boar and red deer), specific to a certain zone, along with those mentioned in the literature.

Considering the presented data, game meat consumption is a viable gastronomic alternative to meat originating in other species of industrially exploited domestic animals.