ON THE PURE MUSCULAR AND CONNECTIVE COMPONENTS PROPORTIONS IN PORK PRODUCED BY FOUR SWINE GENOTYPES

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Abstract

Meat texture is a major determinant of consumer satisfaction, influenced by factors such as muscle structure, connective tissue, and intramuscular fat. It shapes perceptions of tenderness, juiciness, and overall quality. Histological analysis-microscopic evaluation of muscle fibers, fascicles, and connective tissue-is used to assess meat quality and verify authenticity. Texture is affected by genetics, age, feeding, pre-slaughter handling, anatomical location, and post-slaughter processes such as aging and cooking. The study aimed to determine how genetic origin affects the histological structure and, subsequently, the texture of pork in three economically valuable cuts: Loin (Longissimus dorsi), Sirloin (Psoas major), Ham (Semimembranosus). Four pig genetic groups were tested: L – Landrace (control); LD – Landrace × Duroc; LY – Landrace × Yorkshire; LDY – Landrace × Duroc × Yorkshire. Muscle samples were collected from 10 carcasses per group (after 48 h chilling) and processed using a standard paraffin embedding histological protocol. Microscopy measurements included: myocyte (muscle fiber) diameter, circumference, area, 1st-order muscle fascicle area, proportion of muscle tissue vs. connective stroma. Genetic origin significantly ($p<0.001$) influences muscle histology and thus meat quality. Across all three cuts, the LDY and LY (Landrace × Yorkshire) groups consistently showed higher muscle fiber density, lower connective tissue content, more favorable muscle: connective tissue ratios. LD produced thick muscle fibers and larger fascicles but not necessarily optimal tenderness due to higher connective tissue. Pure Landrace (L) showed the least favorable tissue profile: highest connective stroma and lowest muscle proportion. Therefore, among the tested variants, the best overall genetic options for high-quality pork are the LDY and LY hybrids, based on their optimized histological structure for consumer-preferred tenderness, juiciness, and processing efficiency.

Key words: *meat structure, pure muscular tissue, connective stroma, Landrace, Duroc, Yorkshire*

INTRODUCTION

Consumer happiness, flavor perception, and purchase decisions are all impacted by meat texture, which is a crucial quality indicator [8].

Consumers have formed expectations for texture, with features like softness, juiciness, and chewiness greatly impacting whether they accept or reject a product [5].

A good texture can enhance the overall eating experience, while a poor texture can lead to disappointment, even if other features are good [1].

Meat texture can be analyzed using histological methods, which involves the microscopic examination of tissue structure to determine how muscle fibers, connective tissues, and fat are structured [4]. This microscopic assessment is utilized for quality control, authenticity verification and processing procedure optimization. It correlates with objective texture measurements, such as shear force and Textural Profile Analysis [10]

The animals' genetics, age, sex, feeding, and handling prior to slaughter all have an impact on the texture of the meat [11, 12].

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The manuscript was received: 24.07.2025
Accepted for publication: 30.08.2025

The final texture is also greatly changed by post-slaughter variables such as the meat cut, age time, cooking style, and processing methods [3]. The muscle's inner structure, including the amount of connective tissue and muscle fibers, plays a key role in deciding whether meat is soft or tough [7].

The anatomical location of a carcass substantially impacts meat texture since different muscles have varying quantities of connective tissue and are used for distinct functions, which influences their tenderness [14]. Muscles used for movement, such as those in the round, are tougher due to higher collagen content, while muscles that are not used as much, like the tenderloin, are more tender [7].

Other characteristics like the quantity of intramuscular fat, or marbling, are also controlled by the anatomical location and affect texture by increasing juiciness and softness [13].

Muscle fiber type: distinct muscles have distinct fiber types and compositions, which also affect texture. For example, the *Longissimus dorsi* (loin) and *Gluteus medius* (hindquarter) muscles exhibit differing textural qualities [13].

Within this context, the research aimed to investigate to what extent the genetic origin affects the histological structure of pork, particularly of three carcass cut of high economic value: loin, sirloin and ham.

MATERIAL AND METHOD

The biological material consisted in muscle samples taken from four groups of pigs that reached 105 kg and have been sent to slaughterhouse. They issued from a farm experimenting four types of genetic origin, to find out what group exhibit the best performance relate to quantitative and qualitative pork production: L group – pure Landrace breed (considered as control), LD group – Landrace x Duroc cross, LY group – Landrace x Yorkshire cross, LDY – Landrace x Duroc x Yorkshire cross. Each group comprised 75 sows of the same age. Ten carcasses from each group were randomly selected for meat sampling. The election anatomical sites were the middle section of each of the following muscles (region): *Longissimus dorsi* (loin)*; Psoas major* (sirloin)*; Semimembranosus* (ham). The samples, taken from maturated carcasses after they were kept 48 h at chilling storage (4°C), were submitted to paraffin inclusion technique, by a) fixing into cassettes and immersing them in 10% buffered neutral formalin to preserve cellular structure and prevent autolysis; b) dehydration through a series of graded alcohols (e.g., 70%, 80%, 90%, 100%) to remove all water from the tissue; c) clearing in xylene, miscible with both alcohol and paraffin, to prepare it for wax infiltration; d) infiltration at 56-58°C with molten paraffin; e) embedding (molding) into stainless steel mold then cooling for solidifying the wax around the muscle, forming a firm block; f) sectioning (microtomy) at 3-5 micrometers thickness slices; g) mounting by floating the thin sections on a warm water bath to unfold them and then pick them up onto a glass microscope slide, drying the slides; h) staining using the Hematoxylin, Eosin, Methilene Blue pigments. Stages b) to d) were performed on a THERMOSCIENTIFIC STP-120-2 authomated device, stage f) on a THERMOSCIENTIFIC HM355S microtome and stage h) on a Varistain Gemini AS – THERMOSCIENTIFIC stainer. All steps, briefly enumerated above are part of a histopathological protocol published by [1]. Ten slides were prepared from each group, then submitted to microscopic analysis using an Optika 383B microscope and an Optika LiteView software analysis, to measure myocytes diameter, circumference and area, 1st order muscle fascicle circumference and area. The total area occupied by the myocites was reported to the area of the 1st order and represented the relative value of pure muscle tissue in meat structure, while the difference

till 100% represented the connective matrix stroma, according to previous similar type investigations [9]. Achieved data from 75 repeated microphotograph readings per each group were statistically processed in XLStat plugin form Microsoft Excel, to obtain main statistical descriptors (mean, standard deviation, standard mean error, coefficient of variation), then the Fisher test was performed to analyse the variance between the means of L group (considered control) with LD, LY and LDY groups values [6].

RESULTS

The tissue composition of the anatomical region of the **Loin** showed that the highest mean diameter of muscle fibers (μ) was recorded in the LD group (70.15 μ), followed by the L group (68.24 μ). The lowest values were obtained in the LDY group (65.48 μ). The LD group developed thicker and relatively homogeneous muscle fibers (CV = 7.64%), which may indicate a higher level of muscle maturity, and the LDY group had histologically finer fibers, but the differences between the groups are statistically insignificant. The total area of muscle fascicles (μ²) was qualitatively most evident in the LY (20866 μ²) and LDY (20626 μ²) groups, with the L and LD groups presenting slightly lower values. The LY and LDY groups show a more robust development of muscle fascicles at the histological level, which may mean an increased intake of muscle mass in the chop area (Table 1). The area occupied by muscle fibers (μ²) recorded the highest value in the LY group (18368 μ²), followed by the LDY group (18243 μ²). The LD and L groups have values below 17800 μ². In conclusion, the LY and LDY groups have a higher density of muscle fibers in bundles, which supports the muscle quality of the chop. The lowest values of the area occupied by the connective stroma (μ²) were in the LDY groups (2382 μ²) and LE2, and the highest in the L group (2735 μ²), which indicates a higher content of connective tissue.

The LDY and LY groups are advantageous in terms of meat fragility and juiciness, due to the reduced amount of connective stroma. Among the tissue components expressed as a percentage, the myocyte (muscle) component had the best results in the LDY (88.45%) and LY (88.03%) groups, and the lowest in the L group (86.64%).

Table 1. Histological structure of Loin samples (n=75/group)

Histological trait	L group		LD group		LY group		LDY group	
	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM
Myocytes diameter (μ)	68.24	0.08	70.15	0.07	67.31	0.07	65.48	0.07
ANOVA	L x LD: $\hat{F}$=8312966.6 < Fα0.001(11.27) ; P=4.5 X 10^{-103} ***; L x LY: $\hat{F}$=3232781.3 > Fα0.001(11.27) ; P=2.8 X 10^{-95} *** L x LDY: $\hat{F}$=1907431.4 > Fα0.001 (11.27) ; P=1.1 X 10^{-109} ***							
Total surface of muscle fascicles (μ²)	20472.00	25.60	20343.50	23.46	20866.1	24.46	20626.20	22.33
Surface of myocytes (μ²)	17736.94	19.78	17776.15	20.57	18368.43	17.76	18243.87	17.98
Surface of connective matrix (μ²)	2735.06	3.19	2567.35	3.13	2497.67	2.61	2382.33	2.52
Myocytes %	86.64	0.09	87.38	0.10	88.03	0.09	88.45	0.09
ANOVA	L x LD: $\hat{F}$=1203790.2 < Fα0.001(11.27) ; P=3.9 X 10^{-87} ***; L x LY: $\hat{F}$=3170473.8 > Fα0.001(11.27) ; P=4.1 X 10^{-95} *** L x LDY: $\hat{F}$=7392759.6 > Fα0.001 (11.27) ; P=4.0 X 10^{-102} ***							
Connective matrix %	13.36	0.02	12.62	0.02	11.97	0.01	11.55	0.01
ANOVA	L x LD: $\hat{F}$=1605779.4 < Fα0.001(11.27) ; P=1.6 X 10^{-89} ***; L x LY: $\hat{F}$=4883743.8 > Fα0.001(11.27) ; P=1.1 X 10^{-98} *** L x LDY: $\hat{F}$=11032489.2 > Fα0.001 (11.27) ; P=2.5 X 10^{-105} ***							
Myocytes/connective stroma ratio	6.49	0.01	6.92	0.01	7.35	0.01	7.66	0.01

The connective component follows the opposite trend, with the lowest value being recorded in the LDY group (11.55%) and the highest in the L group (13.36%). The LDY and LY groups have a superior tissue profile, with a composition rich in muscle fibers and low in connective tissue, being a direct indicator of the superior quality of the Loin meat.

The average diameter of muscle fibers (μm) for the **Sirloin** was noted in the LD group (50.08 μm), which suggests a more intense muscle development. The lowest values were recorded in the LDY (43.19 μm) and LY (44.32 μm) groups (Table 2). Individuals in the LD group presented more developed fibers, but those in the LDY group, although with finer fibers, offer other histological advantages, a possible indicator of superior fineness and tenderness. The total area of muscle fascicles (μ^2) recorded relatively close values, the highest in the LD group (14523 μ^2), and the lowest in the LDY group (13604 μ^2). The LD group presented fascicles that were more extensive in section, which may reflect a greater structural development of the muscle, but not necessarily a higher quality of it. The area occupied by muscle fibers (μ^2) recorded the highest values in the LD (13133 μ^2) and LY (12480 μ^2) groups. The LDY lot remained competitive (12387 μ^2), with a very low CV (7.57%), indicating uniformity of character. All hybrid groups presented a compact and consistent muscle content, in the Sirloin.

The area occupied by the connective stroma (μ^2) for the LDY lot was the lowest in quantity (1217 μ^2).

The L and LD groups presented the highest values (over 1350 μ^2), and the LDY lot offered more tender and less fibrous meat, an essential fact for the Sirloin, which is considered a Premium cut. The myocyte component was noted with the highest value in the LDY group (91.05%), followed by the LY group (90.84%), and the lowest in the L group (90.21%). The most favorable muscle tissue: connective tissue ratio was recorded in the LDY group (10.17), followed by the LY group (9.92), in relation to the values recorded in the LC group, which presented the weakest ratio (9.21), from this point of view.

Table 2. Histological structure of Sirloin samples (n=75/group)

Histological trait	L group		LD group		LY group		LDY group	
	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM
Myocytes diameter (μ)	46.19	0.039	50.08	0.040	44.32	0.038	43.19	0.041
ANOVA	LC x LE1: $\hat{F}$=381684.4 > Fα0.001(11.27) ; P=1.1 X 10^{-115} *** LC x LE2: $\hat{F}$=869515.8 > Fα0.001(11.27) ; P=2.1 X 10^{-103} *** LC x LE3: $\hat{F}$=224085.9 > Fα0.001 (11.27) ; P=4.2 X 10^{-111} ***							
Total surface of muscle fascicles (μ^2)	13857.00	15.132	14523.20	15.201	13739.2	15.095	13604.85	15.147
Surface of myocytes (μ^2)	12500.40	12.717	13133.33	12.993	12480.69	12.997	12387.22	12.503
Surface of connective matrix (μ^2)	1356.60	1.418	1389.87	1.331	1258.51	1.232	1217.63	1.059
Myocytes %	90.21	0.092	90.43	0.089	90.84	0.095	91.05	0.092
ANOVA	LC x LE1: $\hat{F}$=106357.4 < Fα0.001(11.27) ; P=4.1 X 10^{-67} *** LC x LE2: $\hat{F}$=914338.12 > Fα0.001(11.27) ; P=7.3 X 10^{-85} *** LC x LE3: $\hat{F}$=1359.67 > Fα0.001 (11.27) ; P=3.9 X 10^{-88} ***							
Connective matrix %	9.79	0.010	9.57	0.009	9.16	0.009	8.95	0.008
ANOVA	LC x LE1: $\hat{F}$=120739.2 > Fα0.001(11.27) ; P=3.7 X 10^{-68} ***; LC x LE2: $\hat{F}$=1420090.1 > Fα0.001(11.27) ; P=1.7 X 10^{-88} *** LC x LE3: $\hat{F}$=2372099.4 > Fα0.001 (11.27) ; P=9.9 X 10^{-93} ***							
Myocytes/connective stroma ratio	9.21	0.010	9.45	0.009	9.92	0.010	10.17	0.010

The LDY and LY groups offer an obvious tissue superiority, which reflects an increased economic and sensory value.

The average diameter of muscle fibers (μm) for the **Ham** area (Table 3) was noted in the LD group (69.38 μm), which indicates a strong muscle development. The weakest results were in the LDY (61.48 μm) and LY (63.50 μm) groups. LD group was noted with thicker fibers, compared to the LY and LDY groups, which presented thinner fibers, which induces a favoring of a finer texture and a superior tenderness.

The average total area of muscle fascicles (μ²) recorded a maximum value, in the LD group (20121 μ²) and a minimum, in the LDY group (19367 μ²), the differences being statistically insignificant. The LD group presented slightly more extensive fascicles, but the individuals in all groups have a good structural muscle development.

The area occupied by muscle fibers (μ²) recorded the best average values in the LD (15964 μ²) and LY (15780 μ²) groups, followed by the LC lot, with the lowest value (15446 μ²), and the LD and LY groups ensured a dense muscle content, which is favorable for yield and quality.

The largest area occupied by connective stroma (μ²) was found in the L lot (4323 μ²), and the smallest in the LDY lot (3772 μ²), a lot that presented the lowest connective tissue load, associated with a more tender and qualitatively more valuable meat.

The myocyte component in the Ham was superior in the LDY (80.52%) and LY (80.17%) groups, and the lowest average value was recorded in the L lot (78.13%).

Table 3. Histological structure of Ham (thigh) samples (n=75/group)

Histological trait	L group		LD group		LY group		LDY group	
	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM
Myocytes diameter (μ)	65.90	0.085	69.38	0.085	6.34	0.079	61.48	0.078
ANOVA	LC x LE1: $\hat{F}$=16826.10 > Fα0.001(11.27) ; P=6.5 X 10^{-52} ***; LC x LE2: $\hat{F}$=8707.89 > Fα0.001(11.27) ; P=1.7 X 10^{-46} *** LC x LE3: $\hat{F}$=22094.90 > Fα0.001 (11.27) ; P=3.7 X 10^{-54} ***							
Total surface of muscle fascicles (μ²)	19769.82	26.940	20121.24	25.406	1905.48	21.494	19367.38	22.415
Surface of myocytes (μ²)	15446.16	17.856	15964.19	16.794	1259.57	16.895	15594.62	16.967
Surface of connective matrix (μ²)	4323.66	5.292	4157.05	4.573	342.95	4.601	3772.77	4.296
Myocytes %	78.13	0.090	79.34	0.083	6.26	0.086	80.52	0.088
ANOVA	LC x LE1: $\hat{F}$=2425.74 > Fα0.001(11.27) ; P=4.9 X 10^{-36} ***; LC x LE2: $\hat{F}$=7932.03 > Fα0.001(11.27) ; P=1.0 X 10^{-45} *** LC x LE3: $\hat{F}$=12462.10 > Fα0.001 (11.27) ; P=1.9 X 10^{-49} ***							
Connective matrix %	21.87	0.027	20.66	0.023	1.70	0.023	19.48	0.022
ANOVA	LC x LE1: $\hat{F}$=1896.25 > Fα0.001(11.27) ; P=4.8 X 10^{-34} ***; LC x LE2: $\hat{F}$=6786.98 > Fα0.001(11.27) ; P=1.3 X 10^{-42} *** LC x LE3: $\hat{F}$=6825.83 > Fα0.001 (11.27) ; P=1.7 X 10^{-44} ***							
Myocytes/connective stroma ratio	3.57	0.004	3.84	0.004	0.31	0.005	4.13	0.005

CONCLUSIONS

The average diameter of muscle fibers was the largest in the Loin, and the lowest in the Sirloin. The Loin and the Ham express the largest average fiber dimensions, suggesting increased potential for juiciness and firmness, especially in the LD group. The Sirloin has fine fibers, specific to a tender and valuable meat in terms of quality.

The surface area occupied by muscle fibers was noted by the highest percentage in the Loin. This cut is noted by high muscle density, with advantages in terms of yield in slicing and industrialization.

The connective component recorded the lowest value in the Sirloin. The Sirloin and Loin are therefore ideally suited for rapid thermal preparation.

The muscle tissue/connective tissue ratio was highlighted in the sirloin. The ratio highlights the superiority of the Sirloin and Loin in terms of tissue efficiency. Hybrids of lots LY and LDY offer meat with an optimized ratio for quality and industrial processing.

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