Ph.D. THESIS

Evaluation of the morpho-functional relationship between the arterial and digestive system in the goat (*Capra hircus*)

(SUMMARY OF Ph.D. THESIS)

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INTRODUCTION

Goats are a highly profitable species that has been unjustly undervalued for a long time, including in our country where they were often referred to as the "poor man's cow." When we consider the advantages of raising goats, we find that they are numerous and can be achieved with relatively little effort. It is true that goats are not the best suited for large-scale farming with permanent housing, as is the case with cows, but they can be successfully raised in numbers ranging from 1-2 animals in a household to herds of hundreds or even thousands. Goats can utilize a wide range of feed, from highly nutritious to low or very low-quality forage, and they can transition relatively easily from one type of feed to another. Goats can also adapt relatively easily to varied climatic conditions, including the high temperatures of desert areas, where, in addition to thermal discomfort, there are also issues related to the availability and modest quality of forage. Another noteworthy aspect is that the shelters required for raising goats are among the simplest and cheapest to construct.

The remarkable adaptability to very different environments and conditions has led to the widespread geographical distribution of goats, with significant populations in several continents such as Asia, Africa, and America, and to some extent in Europe as well. There are countries where goat farming is of great importance, such as India, where over 140 million goats are raised annually, representing more than 10% of the total contribution of the livestock sector, while the number of sheep is around 70 million.

The wide range of distribution and the very different conditions from one continent to another, and even from one region to another, has led to the emergence of over 300 breeds of goats, adapted to conditions in which other species might not even survive. Because goats consume a wide variety of feed, from grass to leaves and shoots, they can also be used for pasture control and restoration. As part of their adaptive process, some breeds have become suitable for milk-meat production, while others are specialized in meat production. Milk-meat breeds are the most numerous, including the goats raised in our country (Capra hircus), while meat breeds are specific to certain regions. Goat milk production is very high relative to the size of the animal, and it should also be noted that it is obtained at much lower costs than in other species raised for milk production. In addition to milk and meat, goats also provide other products of industrial utility, such as skins or hair from certain breeds, such as the Angora goat.

THESIS STRUCTURE

The Ph.D. thesis titled ***"Evaluation of the morpho-functional relationship between the arterial and digestive systems in the goat (Capra hircus)"*** contains 136 pages and includes a wealth of imagery - 76 figures (23 macroscopic and 53 microscopic). The doctoral candidate adhered to the dissertation writing methodology required by IOSUD USAMV - Cluj-Napoca. The thesis is divided into two parts, as follows:

The first part of the thesis, *The Current State of Knowledge*, spans 24 pages and is structured into three chapters.

Chapter I, titled "The Cardiovascular System - General Overview," covers anatomical aspects related to the structure and distribution of the arterial component of the cardiovascular system.

Chapter II, titled "Basic Concepts of Hemodynamics," presents the structure-function relationship of the components of the arterial system.

Chapter III, "Morphofunctional Aspects of the Stomach in Ruminants," discribes both general morphological and physiological aspects of the ruminant stomach.

The second part of the thesis, personal contribution, spans 84 pages and is organized into eight chapters. These chapters detail the working hypothesis, objectives, materials and methods, macroscopic and microscopic morphological research, results and discussions, general conclusions, and finally, aspects regarding the originality and innovative contributions of the thesis.

RESEARCH OBJECTIVES

1. Anatomical study of the arterial system and the pregastric compartments.

2. Histological study of the major arteries - the aorta and its main branches.

3. Study of the elastic components present in the walls of the aorta and its main distribution branches.

4. ***Assessment of the relationship between the adaptive structures of the arterial system and the presence and functionality of the forestomach***.

MATERIALS AND METHODS

The study was conducted on 10 fresh goat corpses (*Capra hircus*).

For anatomical investigations, dissection was performed according to the protocol used in the Department of Anatomy at the Faculty of Veterinary Medicine, Cluj-Napoca. After opening the thoracic cavity, the aorta was exposed. Using special devices mounted in the thoracic aorta, red acrylic dye was injected to highlight the arterial components of interest.

For histological investigations, portions of the aorta and its main branches were collected and then prepared histologically according to standard techniques. General histological sections were stained using the Goldner's Trichrome method, while Verhoeff staining was used for the elastic components.

RESULTS AND DISCUSSIONS

Chapter VI, titled ***"Anatomical evaluation of the arterial system and pregastric compartments"*** addresses the following objectives:

1. ***Evaluating the distribution pattern of the aorta and its major branches in domestic goats through anatomical study.***
2. ***Identifying any particularities in the distribution of the major arteries in goats.***

Based on the anatomical investigations of the arterial system in goats, the following conclusions were reached:

1. The aortic arch in goats emits a single anterior branch, the brachiocephalic trunk, which supplies blood to the forelimbs, neck, head, and the ventral portion of the thorax.
2. From the brachiocephalic trunk, the left and right subclavian arteries branch off, after which it continues as the bicarotid trunk, from which the common carotid arteries arise. These further divide into the external carotid arteries and occipital arteries.
3. The portion of the aorta between the aortic arch and the diaphragm is known as the thoracic aorta, from which collateral branches such as the dorsal intercostal arteries, the cranial phrenic artery, and the bronchoesophageal arterial trunk arise.
4. After the descending aorta passes through the aortic hiatus and enters the abdominal cavity, its first branch is the celiac trunk, which in goats branches off on the ventral side at the level between the first and second lumbar vertebrae.
5. The celiac trunk in goats gives rise to the following arteries: splenic, left ruminal, hepatic, and left gastric arteries, which supply blood to the stomach, liver, pancreas, and the upper part of the duodenum.

6. The splenic artery branches into the pancreatic, epiploic, right ruminal, and left ruminal arteries. The right ruminal artery supplies the ruminal atrium as well as the dorsal and ventral ruminal sacs, while the left ruminal artery gives rise to the reticular artery and the esophageal artery.

7. The hepatic artery branches from the right side of the celiac trunk, passes on the ventral side of the liver, and continues as the gastroduodenal artery, which gives rise to the cranial pancreaticoduodenal and right gastroepiploic arteries.

8. The hepatic artery emits the cystic artery, which supplies the gallbladder and two-thirds (distal) of the right liver lobe, as well as the right branch of the caudate lobe, the right liver lobe, small branches to the lesser omentum, and the left branch for the papillary process, quadrate lobe, and left liver lobe.

9. The left gastric artery gives rise to reticular, left gastroepiploic, omasal, and accessory reticular branches. The reticular branches supply the reticulum, omasum, and reticulo-omasal junction, while the gastroepiploic artery gives rise to reticular, omasal, omaso-abomasal, abomasal, and omental branches.

10. The intestinal tract is supplied by the cranial and caudal mesenteric arteries, which also receive additional branches from the gastroduodenal arteries, as well as from the middle and caudal rectal arteries of the urogenital and dorsal perineal arteries.

The purpose of ***chapter VII***, titled "***Histological evaluation of major arteries - The aorta and its main branches"*** was to conduct a general structural investigation of the major arteries in goats. The following objectives were set for this chapter:

1. To verify, through histological study, the structural components of the walls of the major arteries, including those within the abdominal cavity.

2. To identify any particular structures in the arteries that are more hemodynamically stressed.

The histological investigations led to the following conclusions:

1. The arterial system in goats contains the same vessels as those found in other mammals. However, the presence of the prestomachs results in a much more extensive peripheral capillary network compared to similarly sized monogastric mammals.

2. To sufficiently supply all tissues and organs with blood, the goat's arterial system requires a larger volume of blood, propelled at a higher pressure compared to monogastric animals.

3. The specific hemodynamic conditions place greater demands on the goat's arterial system than those on a monogastric animal, enforcing structural adaptations in certain components.

4. Adaptive structures primarily appeared in the arteries most stressed by increased blood pressure, with their presence and arrangement directly related to the blood pressure in each arterial segment.

5. The main adaptive structures were represented by polymorphic muscular islands present in the tunica media. These islands occupy the largest areas in the initial arterial segments that originate from the heart and gradually decrease in the subsequent segments.

6. Such muscular islands are present in the media of the ascending aorta, aortic arch, thoracic descending aorta, brachiocephalic trunk, bicarotid trunk, subclavian artery, and pulmonary arterial trunk.

7. These muscular islands enhance the vascular wall's resistance, contribute to the Windkessel effect, and assist in propelling blood to the next segments, making the elastic arteries of goats stronger than those of monogastric animals.

8. The muscular islands function as an additional pump, helping to preferentially propel a large volume of blood to the most demanded organs at any given time, both cranially and caudally.

9. The only aortic segment that does not contain muscular islands is the abdominal descending aorta. Therefore, it is considered suitable for investigations whose results can be extrapolated to human researches.

10. The branches of the abdominal descending aorta contain a well-developed tunica media with a typical muscular structure that occupies 70-75% of the wall thickness, demonstrating their considerable strength.

Chapter VIII, titled ***"Evaluation of the elastic components in the walls of the aorta and its major distribution branches"*** aimed to identify the elastic components in the walls of the major arteries. The following objectives were set for this chapter:

1. To verify the presence and distribution of elastic tissue in the large arteries, specifically the aorta and its main branches.
2. To verify the presence and distribution of elastic tissue in the large arteries within the abdominal cavity, namely the descending aorta and its main branches.

Based on the results obtained, the following conclusions were drawn:

1. The ascending aorta, aortic arch, thoracic descending aorta, abdominal descending aorta, brachiocephalic trunk, bicarotid trunk, and pulmonary arterial trunk are classified as elastic arteries.
2. The number of elastic lamellae was found to be 91.5 in the ascending aorta, 78.5 in the aortic arch, 66 in the thoracic descending aorta, 31 in the abdominal descending aorta, 62 in the brachiocephalic trunk, 49.66 in the bicarotid trunk, and 34.66 in the subclavian arteries.
3. The gradual decrease in the number of elastic lamellae is attributed to the position of each arterial segment relative to the heart, directly related to blood pressure, which is highest in the ascending aorta and gradually decreases as the distance from the heart increases.
4. The abdominal descending aorta and its branches contain a fibro-elastic adventitia composed of elastic lamellae arranged in a circular manner, closely resembling the arrangement of elastic lamellae in the media of elastic arteries.
5. Arteries with fibro-elastic adventitia similar to that found in the abdominal arteries are also present in other anatomical regions, such as the carotid arteries in the cervical region and the external and internal iliac arteries located in the pelvic region.
6. Fibro-elastic adventitia is an adaptive structure that has developed in response to external stresses to which arteries in demanding anatomical regions, such as the abdominal cavity, cervical region, and pelvic cavity, are subjected.
7. All arteries with fibro-elastic adventitia also have a tunica media characteristic of muscular arteries. Therefore, considering the muscular appearance of the media and the fibro-elastic nature of the adventitia, these arteries are classified as transitional arteries.

Chapter IX, titled "Assessment of the relationship between the adaptive structures of the arterial system and the presence and functionality of the forestomachs," provides a detailed analysis of the morphological aspects of arteries in relation to the activity of the organs they serve. The main objectives of this chapter were:

1. Highlighting adaptive structures in the walls of major arteries, particularly the aorta and its main branches;

2. Assessing the relationship between the adaptive structures of the arterial system and the presence and functionality of the forestomachs.

The conclusions drawn from this chapter are as follows:

1. The first adaptive structures that appeared due to the high stress on the walls of the aorta and its main branches, caused by internal pressure, are the muscle islands present in the tunica media of these arteries.
2. The muscle islands provide increased resistance to the arterial wall, contribute to the enhancement of the Windkessel mechanism, and facilitate preferential blood distribution.
3. The specific way goats collect and process forage causes the blood vessels in certain anatomical areas to be subjected to external stresses that may exceed certain limits.
4. The blood vessels in these areas have developed adaptive structures, represented by fibro-elastic adventitia, which provide both resistance and elasticity to arteries located in regions with high pressure and significant amplitude and frequency of mobility.
5. Most of these vessels are located in the abdominal cavity, where the large volume of the forestomachs exerts significant pressure on other organs in the abdominal cavity, including the blood vessels.
6. The large volume variations of the forestomachs cause significant mobility of the organs in the abdominal cavity, including the blood vessels, both those that are free-floating and those embedded in the walls of certain organs.
7. Due to the pressure and large volume variations of the forestomachs, the vessels that supply the organs in the abdominal cavity are adapted to coexist with the presence and activity of the forestomachs.

Chapter X, titled ***"General Conclusions"*** summarizes the conclusions drawn from the anatomical and histological investigations as follows:

1. The aortic arch gives rise anteriorly to the brachiocephalic trunk, which branches into the subclavian arteries. It then continues as the bicarotid trunk, from which the common carotid arteries originate. The terminal branches of the common carotid arteries are the external carotids and the occipital arteries.
2. The aortic arch continues posteriorly as the thoracic aorta, from which collateral branches emerge, including the dorsal intercostal arteries, the cranial phrenic artery, and the bronchial-esophageal arterial trunk.
3. The thoracic aorta transitions into the abdominal aorta, which gives rise to the following collateral branches: the celiac trunk, the cranial mesenteric artery, the renal arteries, the small mesenteric artery, and finally, in its terminal portion, the external and internal iliac arteries.
4. The presence of the rumen (prestomachs) has led to the development of adaptive structures in the media of large arteries, represented by polymorphic muscular islands, whose number and size gradually decrease as the distance from the heart increases.
5. The muscular islands increase the vascular wall's resistance, contribute to the Windkessel mechanism, and assist in the propulsion of blood to subsequent segments. Goats require a larger volume of blood compared to monogastric animals.
6. The muscular islands function as an additional pump, supplying blood preferentially to organs that are under greater demand at any given time, either caudally to the digestive organs in the abdominal cavity or cranially to support the rumination process.
7. The abdominal aorta does not contain muscular islands but has a typical elastic artery structure. Therefore, it is considered the only segment suitable for investigations whose results can be extrapolated to human research.
8. The ascending aorta, aortic arch, thoracic descending aorta, abdominal descending aorta, brachiocephalic trunk, bicarotid trunk, and pulmonary arterial trunk all contain numerous elastic lamellae in the tunica media, classifying them as elastic arteries.
9. The abdominal descending aorta and its branches have a fibro-elastic adventitia composed of circularly arranged elastic lamellae, which closely mimics the arrangement of elastic lamellae in the media of elastic arteries.
10. Arteries with a fibro-elastic adventitia exhibit a tunica media characteristic of muscular arteries. Thus, considering the muscular appearance of the media and the fibroelastic nature of the adventitia, these arteries are categorized as transitional arteries.

Chapter XI, titled "Originality and innovative contributions of the thesis," highlights the unique morphological aspects revealed by the investigations and their relationship with the functioning of the digestive organs in goats, as follows:

We have identified muscle islands in the media of arteries originating from the heart, both cranially and caudally.

These muscle islands function as a third mechanism for blood propulsion, in addition to the cardiac pump and the Windkessel mechanism.

The presence of these muscle islands in the brachiocephalic trunk and bicarotid trunk ensures the preferential propulsion of a significant volume of blood toward the masseter muscles during the rumination process.

In the subclavian artery, these muscle islands facilitate the preferential distribution of blood during periods of forage collection, as opposed to rest periods.

The muscle islands in the ascending aorta, aortic arch, and thoracic descending aorta ensures the preferential delivery of a large volume of blood to the rumen (prestomachs) during intense digestion periods.

Fibroelastic adventitia in abdominal vessels suggests that these vessels are exposed to more significant and diverse external stresses than those found in monogastric animals.

These adaptive structures have emerged as a necessity to support the very particular and demanding digestive system of goats. The arterial system has evolved to accommodate the unique functional demands posed by the goat's digestive organs.