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PRELIMINARY OBSERVATIONS ON THE ANATOMICAL LINKS WITHIN THE DONKEY DIGESTIVE SYSTEM

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Abstract

The domestic donkey (Equus asinus) is descended from the African wild ass (Equus asinus africanus). In most developing countries, donkeys are used to carry goods and water, and to guard herds as livestock guardians. Little attention has been given to the anatomical structure and morphological characteristics of donkeys, and they have not been extensively studied. This study aims to contribute to a better understanding of a part of donkey anatomy. The length of the intestine from the stomach to the rectum was measured in 9 animals. The donkeys belong to the

Balkan donkey group. Considerations for analysis could include the efficiency of nutrient absorption, the role these segments play in donkeys' overall digestive process, and the variability observed across specimens.

Keywords: Donkey; Digestive Tract; Abdominal Organs; Stomach; Intestine

INTRODUCTION

The domestic donkey (*Equus asinus*) is descended from the African wild ass (*Equus asinus africanus*). Two African wild asses played a role in the domestication of the domestic donkey: the Nubian wild ass and the Somali wild ass. Today, only a few specimens of the Somali wild ass remain in East Africa, as the last wild Nubian wild ass was recorded in 1930. Thanks to conservation efforts in zoos, the Nubian wild ass has survived to this day.

Domestication has a long history, and it is assumed that the domestic donkey has been an important helper to humans for around 6,000 years. The donkey belongs to the *Equidae* family, like the horse, and is domesticated in most parts of the world (Smith and Burden, 2013). However, no attention was paid to its selection as a domestic animal. What nature offered was accepted. Over the last 10 years, numerous studies have investigated the quality of donkey milk and meat. Donkey meat is considered tastier than horse meat and is eaten in many parts of the world (Li et al., 2020). Donkey milk is used as an alternative to human breast milk, as it has many of the same important qualities, such as being low in fat content, promoting healthy intestinal flora, having anti-inflammatory properties, and containing immune-enhancing compounds that protect the body against pathogens (Li et al., 2020). Little attention has been given to the anatomical structure and morphological characteristics of donkeys, and they have not been extensively studied. In the classical textbooks of veterinary anatomy, we have very good descriptions of the horse intestinal anatomy (Getty, 1975; Barone, 1997; König and Liebich, 2012), but there are no studies about the stomach and intestines of donkeys and the eventual differences between them and horses.

Before presenting the results of our research, we consider it necessary to give an overview of the donkey's digestive tract (Figure 1).

As in other animals, the digestive tract of the donkey begins with the oral cavity and ends at the anal opening. The aim of our study was primarily to measure the stomach and intestines. The small Intestine (*Intestinum tenue*) consists of: *duodenum*, *jejunum*, and *ileum*. The large Intestine (*Intestinum crassum*) also consists of three parts, of which the first part is the *cecum*, followed by the colon and rectum. Colon is subdivided into three parts: the ascending colon (*Colon ascendens seu Colon crassum*), the transverse colon (*Colon transversum*) and the descending colon (*Colon descendens seu Colon tenue*). The ascending colon has four parts that are connected by three flexures (*flexura pelvina*, *flexura diaphragmatica ventralis et dorsalis*): right ventral colon (*colon ventrale dextrum*), left ventral colon (*colon ventrale sinistrum*), left dorsal colon (*colon dorsale sinistrum*), right dorsal colon (*colon dorsale dextrum*). Before it reaches the cranial opening of the pelvic cavity, the small colon (*colon descendens*) merges into the straight, rectal intestine without a clear boundary.

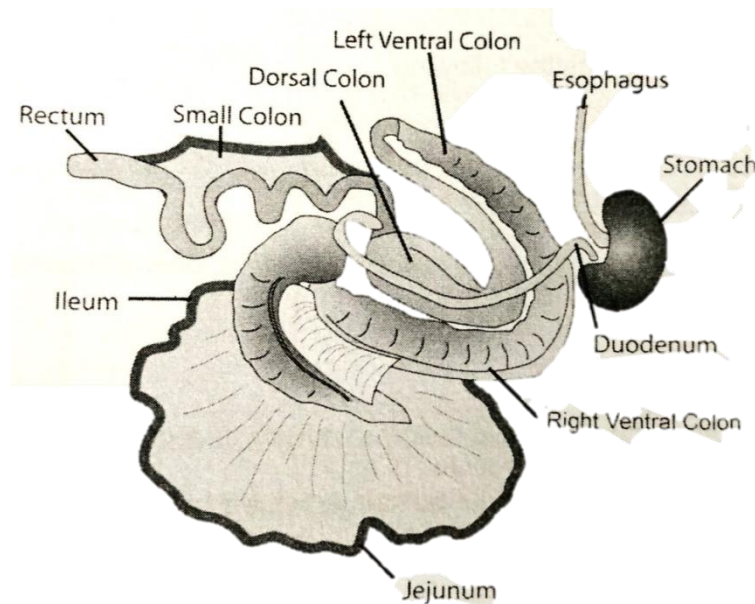


Figure 1: Topographical Position of the Digestive Tract of a Donkey (Source: Onyango et al. 2009)

MATERIALS AND METHODS

The material for the analysis was obtained from healthy male Balkan donkeys. The length of the intestine, from the stomach to the rectum, was analyzed in 9 animals. The donkeys belong to the Balkan donkey group. For each individual, the body mass was determined by measurement on an automatic scale installed before the animal was brought to the anesthesia department. After determining the body mass, the height at the withers was measured for each animal. The measurement was carried out using a flexible 3-meter measuring tape with a stopper and a system for determining the horizontal position of the measuring rod attached to the withers. The chest circumference was determined using a “Horse & Pony Weighing Tape.”

Slaughter was carried out in an officially registered meat industry facility. Due to the technological method of carcass processing, it was not possible to preserve the esophagus, which is a certain shortcoming of this study. The stomach and associated intestines remained intact after the technological opening of the carcass. The length of the intestine was measured with a tape measure and the width of the intestine with a vernier caliper. The measurements were carried out on a hard surface.

Statistical analysis was done using GraphPad Prism 7.00 (San Diego, CA, USA). P-values < 0.05 were considered statistically significant.

RESULTS

In this study, the greater and lesser curvatures of the stomach, its oblique length, and the width at its widest point were measured (Figure 2). The measurement of the greater curvature of the stomach was 57.5 cm, and the lesser curvature was 5.5 cm. The widest part of the stomach had a width of 12.16 cm, and the oblique length was 24 cm. It is important to note that these measurements were taken with the stomach full, as the body was extracted.



Figure 2: Stomach Immediately After Evisceration (Photo: Urošević)

The esophagus was 2.29 cm wide just before entering the stomach, and the duodenum was initially 3.47 cm wide. After the stomach contents were emptied, they were dissected, revealing two distinct mucosal types: cutaneous and glandular (Figure 3).



Figure 3: Stomach Mucosa (Photo: M. Urošević)

As you can clearly see in the photo, the gastric mucosa consists of two different parts. The lighter part covers the esophageal section of the stomach, which is lined with cutaneous mucosa that is an extension of the esophageal mucosa. This cardiac part is glandless and has a stratified *squamous epithelium*.

The remaining part of the stomach is covered with a glandular mucosa containing numerous glands. These glands secrete mucus, which consists of two main components: an alkaline and a mucous part. These secretions protect the gastric mucosa from hydrochloric acid.

The surface of the glandular part, including the gastric fundus, the body of the stomach and the pylorus, is enlarged by numerous folds (Figure 4).



Figure 4: Numerous Mucous Folds Increase the Surface Area of the Mucous Membrane and the Number of Mucous Glands (Photo: Urošević)

In contrast to the oesophageal part, which is characterized by a cutaneous mucosa and *squamous epithelium*, there are fundic glands in this part of the stomach, which have a cylindrical shape.

The Length of the Intestine

During the examination, the length of the small intestine, the ventral part of the large colon, the dorsal part of the large colon, the *cecum* and the continuation of the small colon, up to the anal opening, were determined (Figure 5). The measurements were carried out on nine fresh digestive tracts.



Figure 5: Digestive Tract Without the Esophagus After Evisceration (Photo: Urošević)

The average length of the small intestine was 952.00 cm, with a minimum value of 712.00 cm to a maximum value of 1,305.00 cm (Table 2,3). The difference between the maximum and minimum length of the small intestine is 593.00 cm.

The mucosal epithelium of the small intestine consists mainly of columnar cells that are involved in absorption, mucus production and endocrine function and control the secretion of the

pancreas and the muscle function of the gall bladder and intestinal walls (Figure 6). In the small intestine, the mucosal surface has a characteristic velvety appearance due to the presence of intestinal villi. The ileum is the relatively short part of the small intestine, starting from an ileocaecal fold (*plica ileocaecalis*), between the *jejunum* and the *ileum* (Figure 7).



Figure 6: The Interior of the Donkey Small Intestine (Photo: Urošević)



Figure 7: Transition of the Jejunum into the Ileum (Photo: Urošević)

As far as the large intestine is concerned, the average length of its ventral part was 102.00 cm. The range of variation is between 90.00 cm and 118.00 cm. The dorsal part of the colon had an average length of 99.00 cm with a minimum value of 86.00 cm and a maximum value of 112.00 cm (Table 2,3).

The ventral part of the large intestine has clearly defined folds, characterised by four bands (taeniae) with four rows of sacculations (haustra) between them, which considerably increases the active surface area of the mucosa (Figure 5).

It is known that donkeys consume more cellulose than horses and other monogastric animals and digest it very successfully. The caecum plays a critical role in digestion (Figure 8). The wall of the *cecum* is strongly folded, because the longitudinal muscular layer is concentrated in four bands, which are visible on the outer surface (Figure 5) as taenia and between which the caecal wall is ruffled into four rows of sacculations (haustra). This considerably increases the absorption surface of the mucosa, although the mucosa of the *cecum* has no villi.

In the nine digestive tracts examined, the average length of the caecum in male throats was 80.00 cm, with a minimum length of 65.00 cm and a maximum length of 88.00 cm (Table 2,3). The difference between the minimum and maximum values is not as pronounced as in the small intestine.



Figure 8: The Interior of a Donkey Cecum (Photo: M. Urošević)

In this research, the length of the small colon, the last straight part of the large colon, was determined up to the rectum. The average value was 128.00 cm, with a minimum of 109.00 cm and a maximum of 145.00 cm (Table 2, 3).

Despite considerable variation in specific parameters, particularly in the absolute lengths of the small intestine, such discrepancies are virtually non-existent in the sections of the large intestine.

An interesting aspect to investigate is the relationship between the shoulder height (height at withers) of donkeys and the total length of their intestines (Table 1).

Table 1: Height at Withers and Total Intestinal Length (cm)

HW	95.00	92.40	96.50	95.90	99.90	98.30	99.20	87.30	89.10
TLI	1461.00	1424.00	1457.00	1194.00	1742.00	1337.00	1206.00	1281.00	1063.0

HW- height at withers. TLI- total length of intestines.

From the data in Table 1, it can be seen that the donkeys studied were not very large, with the tallest having a height at withers of 99.90 cm and the shortest 87.30 cm. The group of 9 male individuals was relatively uniform with an average height at withers of 95.00 cm.

The average total length of the intestine was 1352.00 cm, with a minimum of 1063.00 cm and a maximum of 1742.00 cm. The minimum length accounts for only 61.02% of the maximum total length. This remarkable discrepancy is mainly due to the considerable variance in the length of the small intestine. The donkey with the lowest height at the withers (87.30 cm) had a total intestinal length of 1281.00 cm, while the tallest donkey (99.90 cm) had the longest intestine (1742.00 cm). Interestingly, the shortest total intestinal length (1063.00 cm) was found in a donkey with a height at withers of 89.10 cm. This height is 10.81% smaller than the maximum recorded height, but the difference in total gut length between the shortest and the tallest donkey is as much as 38.98%. Of particular note is that the second-tallest donkey, whose height at the withers was 0.7% less than the tallest individual, had a total intestinal length 30.77% less than the maximum recorded total intestinal length. This illustrates the disproportion between the height at the withers and the total length of the intestine.

The evaluation of the absolute length values of certain intestines in relation to the height at the withers is fascinating. The following table provides such a comparison.

Table 2: Ratio of Individual Intestine Lengths to Height at Withers (cm)

HW (cm)	Small intestine (cm)	%	Ventral colon (cm)	%	Dorsal colon (cm)	%	Cecum (cm)	%	Small colon (cm)	%
95.00	1044.00	1098.90	99.00	104.20	100.00	105.30	74.00	77.90	144.00	151.60
92.40	1042.00	1127.70	104.00	112.55	89.00	96.32	75.00	81.20	114.00	123.40
96.50	1080.0	1119.20	105.00	108.81	88.00	91.20	75.00	77.70	109.00	112.90
95.90	796.00	830.03	90.00	93.85	93.00	96.98	70.00	72.99	145.00	151.20
99.90	1305.00	1306.30	118.00	118.12	112.00	112.10	77.00	77.10	130.00	130.10
98.30	930.00	946.10	110.00	111.90	95.00	96.64	72.00	73.24	130.00	132.20
99.20	800.00	806.45	97.00	97.78	98.00	98.79	73.00	73.60	138.00	139.10
87.30	860.00	985.11	108.00	123.71	95.00	108.80	88.00	100.80	130.00	148.90
89.10	712.00	799.10	90.00	101.01	86.00	96.52	65.00	72.90	110.00	123.50

HW- height at withers.

Table 3: Descriptive Statistics of Measured Values

	$\bar{X}$	SD	SE	CV(%)	Min	Max
HW (cm)	95.00	4.40	1.50	4.70	87.00	100.00
Small intestine (cm)	952.00	184.00	61.00	19.00	712.00	1305.00
Ventral colon (cm)	102.00	9.30	3.10	9.10	90.00	118.00
Dorsal colon (cm)	95.00	7.80	2.60	8.30	86.00	112.00
Cecum (cm)	74.00	6.20	2.10	8.30	65.00	88.00
Small colon (cm)	128.00	14.00	4.60	11.00	109.00	145.00

The data in Table 3 show the greatest variability in the length of the small intestine, whereas the length of the cecum shows the least variability. We also decided to check whether there is a correlation between the height at the withers and the length of the intestines mentioned above. After statistical analysis, we can conclude that there is no significant difference, as all P-values are > 0.05 (Table 4).

Table 4: Correlation Between Withers Height (cm) and Intestinal Length

	HW vs. small intestine	HW vs. ventral colon	HW vs. dorsal colon	HW vs. cecum	HW vs. small colon	HW vs. total length of intestines
P value	0.2190	0.4384	0.1255	0.5150	0.3542	0.1972

It has already been established that donkeys require and consume more cellulose than horses and other monogastric animals. Cellulose digestion takes place in parts of the large intestine, with the cecum being the most important section for this process. The *cecum* harbors groups of specific bacteria: cellulolytic, hemicellulolytic, amylolytic and proteolytic. The groups *Ruminococcus* and *Fibrobacter* are most important for the degradation of cellulose fibers. Hemicellulolytic bacteria (*Bacteroides*) are responsible for the degradation of hemicellulose.

It is therefore interesting to investigate the relationship between the total length of the small intestine (from the stomach to the large intestine) and the combined length of the ventral and dorsal colon (Table 5).

Table 5: Ratio (%) of the Various Intestinal Segments (cm) to the Total Length of the Ventral and Dorsal Colon

No.	Length of the small Intestine in relation to the total length of the ventral and dorsal colon (%)	Length of the cecum in relation to the total length of the ventral and dorsal colon (%)	Length of the small colon to the total length of the ventral and dorsal colon (%)
1	72.36	37.18	524.62
2	59.07	38.86	539.90
3	56.48	38.90	559.60
4	79.23	38.25	434.97
5	56.52	33.48	567.40
6	63.41	37.56	453.65
7	70.76	37.43	410.30
8	64.04	43.43	423.64
9	62.50	36.93	404.54

The specimen with the longest small intestine, which measured 1305 cm, also had the longest combined ventral and dorsal colon length, totalling 230.00 cm. Conversely, the specimen with the shortest small intestine (712.00 cm) had the smallest combined ventral and dorsal colon length (176.00 cm).

It is interesting to note that the length of the small intestine is significantly greater than the combined length of the ventral and dorsal colon. However, this should be viewed from a different angle. For example, a small intestine measuring 1042.00 cm in length had a diameter of only 1.1 cm, resulting in a volume of 134.95 cm³. In contrast, the width of the large intestine (ventral and dorsal colon) is significantly greater than that of the small intestine, resulting in a much larger volume.

As already said, the *cecum* is a crucial part of the cellulose digestion process. Measurements of this part of the digestive tract showed minimal variability in the differences in length between the *cecums* of the individual male donkeys in the studied group. A noteworthy aspect is the relationship between the cecum length and the total length of the ventral and dorsal colon, as shown in Table 5.

The longest caecum at 88.00 cm was found in a specimen whose combined ventral and dorsal colon length was not the longest at 203.00 cm. The shortest caecum of 65.00 cm was found in the specimen with the shortest total ventral and dorsal colon length of 176.00 cm (Table 2).

The large intestine also includes the small colon and rectum. When considering its length, it is important to know that the length of the last section of the large Intestine - rectum could not be measured during the measurements.

Table 5 also displays data on the percentage ratio of the small colon's length to the combined length of the ventral and dorsal colon, providing insight into their proportional relationship within the large intestine. This information helps understand how the different intestinal segments relate to one another in terms of their length ratios and potential functional significance.

At the end of the results of the mutual relationships of individual parts of the digestive tract of a donkey, nine males, we consider it necessary to show the proportion of the longest single part, the small intestine, to the total length of the other parts of the intestine, namely, the ventral and dorsal colon, the appendix, and the small colon. Table 6 shows this ratio, and the lengths of the small intestine are arranged in order of absolute value.

Table 6: Ratio (%) of the Small Intestine to the Total Length of the Large Intestine

No.	Small intestine (cm)	Total length of the large intestine (cm)	Proportion of the length of the large intestine to the length of the small intestine (%)
1	1305.00	437.00	33.49
2	1080.00	377.00	34.91
3	1044.00	417.00	39.94
4	1042.00	382.00	36.40
5	930.00	407.00	43.76
6	860.00	421.00	48.95
7	800.00	406.00	50.75
8	796.00	398.00	50.00
9	712.00	351.00	49.30

The data, as previously mentioned, show that the shortest small intestine measures 54.56% of the length of the longest small intestine. Considering the total lengths of all parts of the large colon, the smallest value (351.00 cm) represents 80.32% of the largest value (437.00 cm).

DISCUSSION

Freund (1917), who describes the digestive tract of domestic animals, states that the small intestine of donkeys is 9-14 metres long, consistent with our results.

Smith and Wood (2008) state that the length of the intestine is about 24 m, while in our study, the maximum length of the entire intestine was 1742 cm. In general, the length of the intestine in horses is considered to be ten times the body length (König and Liebich, 2007).

Interestingly, the authors do not specify the height at the withers or the breed or group of donkey breeds for which this was determined. Furthermore, the sample size is not mentioned. They also state that the total capacity of the digestive tract is about 160 liters. Despite the clear indication that they are referring to the intestine when they mention length, the authors include the esophagus in this group. The esophagus accounts for about 9% of the total volume, the small intestine for about 30%, and the cecum for about 16%. About 38% of the volume is accounted for by the large intestine, and about 7% by the rectum. Interestingly, the authors do not specify the stomach's volume.

Jerbi et al. (2014) are the only authors to have provided a detailed analysis. Their study was conducted on a sample of 4 female and seven male donkeys. The examined donkeys had large stomachs. In the female specimens, the minimum value for the greater curvature of the stomach was 70.00 cm, while the maximum value was 83.00 cm. In males, the greater curvature of the stomach had a minimum of 51.5 cm and a maximum of 77.5 cm. They found that the jejunum length in females ranged from 607.00 cm to 1,020 cm, while in males it ranged from 476.00 cm to 790.0 cm.

With regard to the length of the ileum, the authors found that the variation interval in females was between 21.00 cm and 26.00 cm, while in males it was between 15.00 cm and 31.00 cm. The length of the *cecum* was between 56.00 cm and 79.5 cm in females and between 54.5 cm and 94.5 cm in males. The length of the ventral part of the colon was between 119.00 cm and 135.00 cm in females, while this value was between 97.0 cm and 150.00 cm in males. Regarding the dorsal part of the colon, the authors found that the minimum value for females was 92.00 cm and the maximum was 114.00 cm. In males, the minimum length of the dorsal colon was 92.00 cm, and the maximum was 136.00 cm. The straight intestine (the remaining part of the colon) leading to the rectum had a minimum length of 97.00 cm and a maximum length of 123.00 cm in females, while in males, the minimum was 86.00 cm and the maximum 128.5 cm.

Regarding the length of the individual parts of the digestive tract, Polidori and Vincenzetti (2017) report that the jejunum is 799.25 ± 84.7 cm in females and 631.576 ± 35.4 cm in males. The average length of the ileum in females is 22.5 ± 1.9 cm, while in males it is 20.1 ± 2.12 cm. The length of the *cecum* is 68.0 ± 6.10 cm in females and 76.35 ± 5.05 cm in males. The length of the ventral colon is 125.62 ± 3.48 cm in females and 124.28 ± 6.0 cm in males. The length of the dorsal colon averages 104.5 ± 4.85 cm in females and 108.2 ± 5.57 cm in males. These measurements correspond to our study regarding the length of the cecum and the ventral and dorsal colon. In contrast, the lengths of the individual parts of the small intestine were not measured and remain a topic for our subsequent study.

Thiemann and Sullivan (2019) report that a donkey weighing 180 kg can ingest 3 litres of fluid. The authors state that the length of the small intestine is about 6 m per 100 kg body weight, compared to 5 m in horses. The length of the small colon is about 1 m. In our study, we observed that the small intestine and the small colon were up to 50% longer.

When examining the gastrointestinal tract of donkeys, Sikandar (2020) states that the mass of an empty stomach is about 1.5 kg and that its shape is similar to that of a horse's stomach. The author states that the capacity of the *cecum* and colon is about 80 liters. For comparison, he mentions that ruminants (without specifying which ones) have a capacity of only 13 liters for the *cecum* and colon. He states that the jejunum is the longest part of the small intestine, but does not give an absolute value for its length, nor is there any other length measurement for specific parts of the digestive tract.

Wissdorf et al. (2020) report that the capacity of the stomach of the African wild donkey averages $815 \text{ ml} \pm 36.20 \text{ ml}$. The authors note that the length of the duodenum in female African wild donkeys (measured on a sample of 4 individuals) was 41-46 cm, while this value ranged from 38 to 54 cm in 7 male specimens. The length of the jejunum in females was 607-1020 cm, whereas in males it was between 476 and 790 cm. The continuation of the small intestine, the ileum, has a length of 21.00 cm to 26.00 cm in female African wild asses, and in 7 male specimens, this value was between 15.00 cm and 31.00 cm.

Regarding the *cecum* length, the authors found that the average length in female specimens was 68 cm, with a range of 56.00 cm to 79.50 cm. In males, the average length of the *cecum* was 76.00 cm, with a range of 54.00 cm to 94.00 cm, which is quite similar to our results with an average length of the *cecum* of 74.00 cm and a range of 65.00 cm to 88.00 cm, suggesting its role as a relatively conserved anatomical site for microbial fermentation. As a known site for the breakdown of complex carbohydrates by cellulolytic and hemicellulolytic bacterial populations, the anatomical uniformity of the *cecum* may reflect a functional imperative to support consistent fermentation capacity across individuals (Zhang et al., 2022). In our studies, the lengths of the ventral and dorsal colon were shorter than in the Wissdorf study. They found that the ventral colon reached up to 240 cm in females and 286 cm in males. The length of the dorsal colon to the rectum ranged from 97.00 cm to 123.00 cm in females, while it ranged from 86.00 cm to 128.00 cm in males.

CONCLUSION

In the group of nine male donkeys analysed, the length of the small intestine was strikingly inconsistent. The longest small intestine recorded was almost twice as long as the shortest. When the parts of the large intestine were examined, the smallest differences in length were found in the *cecum*. Overall, the difference between the shortest and longest total length of the large intestine was 19.68%, a stark contrast to the variability in the length of the small intestine.

This underlines and confirms the physiological importance of certain parts of the large intestine in the digestion of food, especially in the processing of bulky, cellulose-rich fibres. The relatively small variance in the length of the large intestine compared to the small intestine suggests a crucial role in maintaining a consistent digestive efficiency for coarse fibres, which is critical for donkey digestion.

CRedit AUTHOR STATEMENT

Milivoje Urošević: Conceptualization, Methodology, Investigation. **Dejana Čupić-Miladinović:** Conceptualization, Methodology, Investigation. **Panče Dameski:** Resources, Methodology, Investigation. **Ivana Nešić:** Data curation, Formal analysis, Writing – Original draft preparation. **Mimi Ristevski:** Resources, Validation. **Miloš Blagojević:** Writing – Original draft preparation. **Nikola Cukić:** Writing – Reviewing and Editing. **Milena Đorđević:** Writing – Reviewing and Editing

All authors have read and agreed to the published version of the article.

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The authors acknowledge the use of AI tools—specifically ChatGPT-5—to assist in translating and enhancing the clarity and quality of the English language in this manuscript. These AI tools were employed solely for language refinement and were not involved in the conceptualization, analysis, or development of the scientific content. The authors assume full responsibility for the manuscript’s originality, accuracy, validity, and integrity.

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