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Preliminary Results of Stable Isotope Analysis on Bone Collagen Samples from the Avar-Age Cemetery Privlaka-Gole Njive

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A R T I C L E I N F O

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A B S T R A C T

The material culture of the Avar era is considered to be one of the best documented Early Medieval material cultures of central Europe. The nomadic Avar community settled in the Carpathian basin at the end of the 6th century and remained as rulers until the Frankish wars at the end of the 8th century. Unlike the neighbouring communities, there is no evidence of the Avars being Christianised, and their relatively conservative burial customs, in which great importance is attached to the costumes of the deceased, have enabled archaeologists not only to create a precise typological-chronological framework but also to analyse the different ways of life of the Khaganate population. Among other things, stable carbon and nitrogen isotope analyses have recently been undertaken to establish and better understand the dietary practices of certain communities. This represents an important factor in social organisation. The authors of this paper conducted a stable isotope analysis of 22 selected bone samples from the Privlaka-Gole njive site, to this date the largest Avar-age inhumation cemetery in Croatia with 231 excavated graves. Overall, it seems that there are no major differences in diet regarding sex, age and social stratification, although females do exhibit slightly lower $\delta^{15}N$ values than males, while non-adults and older adults exhibit slightly higher $\delta^{15}N$ values than younger adults.

1. Introduction

In the second half of the 6th century, a new community of people emerged on the very edge of the Byzantine world: they called themselves the Avars. The core of the community, especially the warriors, led a nomadic lifestyle. They were initially fleeing from the Turkic tribes that had recently overthrown their government in the Central Asian steppes. While looking for an area suitable for settlement with relative protection from the Turks, the Avars, first in cooperation with the Byzantine Empire, and then independently, travelled from the Black Sea steppes, the Transcarpathians and finally managed to settle in the Carpathian basin, *i.e.* the former Roman province of Pannonia: they gained entrance as Lombard allies (western part of Pannonia) in a transgenerational conflict with Gepids (eastern part of Pannonia and Transylvania) in 567 (Pohl, 2018, pp.47–50, p.54, pp.60–62). By the end of that year, Gepid rule was completely toppled and by the Easter of 568, when the Lombards had emigrated to Italy, the Avars established themselves as rulers of Pannonia and the area east of the river Tisza, including Transylvania (Pohl, 2018, pp.62–68). Their status as rulers of the Carpathian basin was confirmed by the conquest of Sirmium in 582, the last Byzantine stronghold in the Pannonian area. They had an impact on the history of the region throughout the next two centuries, until the end of the 8th and the beginning of the 9th century, when their state organisation ceased to exist due to the victory of Charlemagne in the Frankish-Avar conflicts of 796. (Pohl, 2018, pp.83–89, p.100, pp.376–389). The Avar era can be divided into three periods, which more or less correspond archaeologically and historically – to the Early Avar (568–630.), Middle Avar (630–680.) and Late Avar (680–800/822) periods (Stadler, 2005). Each period is characterised by a significant change in the clearest form of self-representation: the structure, morphology and motives on the elaborate belt-sets of men

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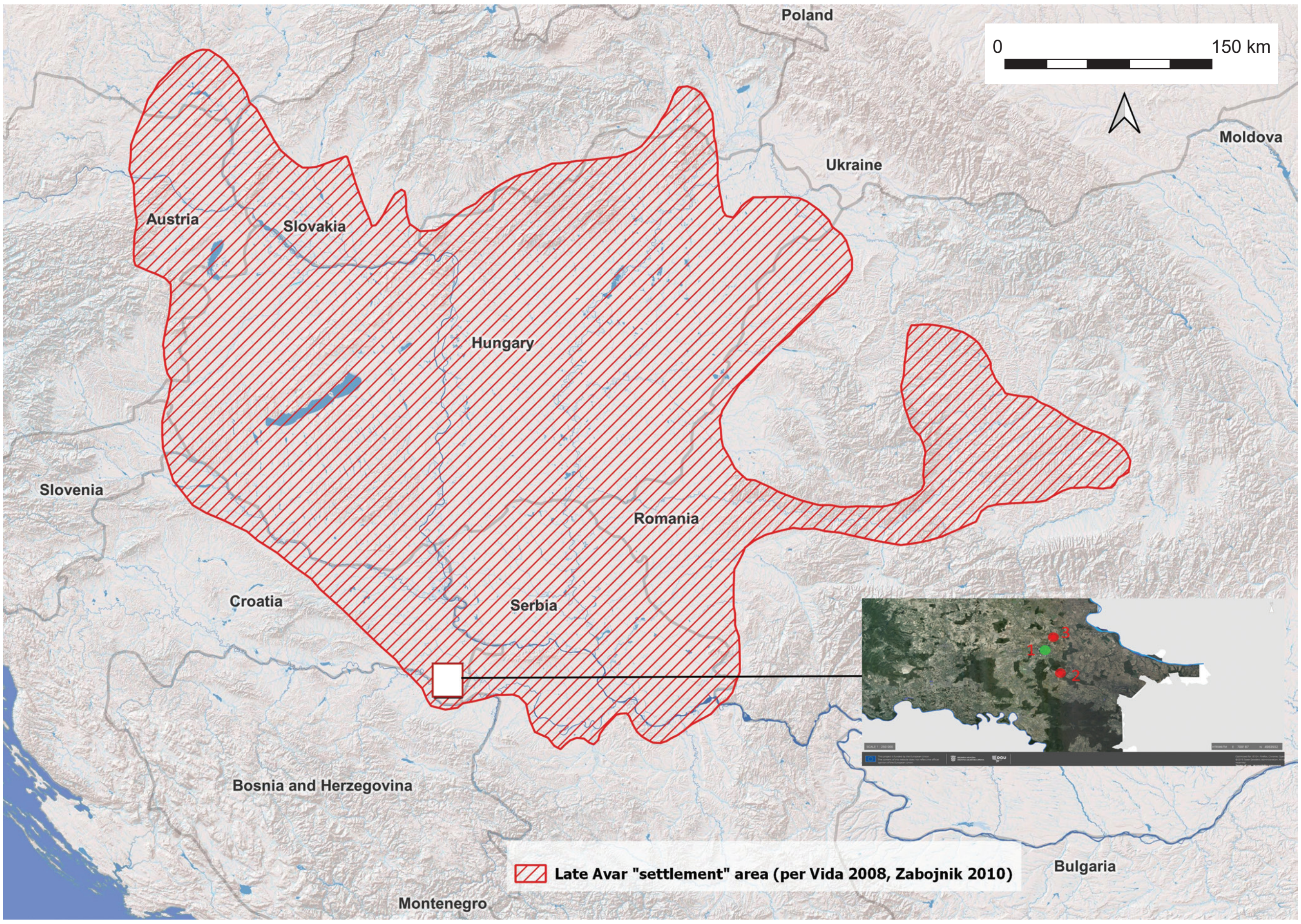

Figure 1. General map of the Late Avar Khaganate with positions of Privlaka-Gole njive (2) and Nuštar-Khuen Belassy sites (3), Avar-age cemeteries in the vicinity of Vinkovci – former Roman Cibalae (1) – and two Western Syrmia sites where stable isotope analyses have been conducted so far (created in QGIS and geoportal.dgu, by Jere Drpić).

with higher social status, and in the way of life (nomad/warrior; upheaval of the state/social organisation; sedentary lifestyle) (Stadler, 2005, p.84, p.116).

Presumably, by the time they migrated to Pannonia, the community was already mixed, largely composed of a core which truly seems to have been of nomadic origin (Gnecchi-Ruscone *et al.*, 2022), and members of different communities and identities they met along the way. It seems that the Avars brought with them innovations in the technique of warfare: first of all, this is exemplified by the iron stirrup, which enables more accurate shooting, even while galloping on a horse. Also introduced were heavy three-edged arrows, a double recurve bow and, it seems, lamellar armour/body armour for both rider and horse (Hofer, 1996, pp.351–352; Csiky, 2015; Pohl, 2018, pp.38–47, pp.209–215).

It seems that the Avars never became Christianised (Bóna, 1985, p.20), so their archaeological legacy (considering their tendency to signal the status of the deceased not only through the richness of the costume, but also through other grave accessories) allows an insight into their way of life in the Carpathian basin (Gnecchi-Ruscone *et al.*, 2022, p.1403). Their astounding archaeological heritage, consisting of over 100,000 excavated graves and at least 600 sites, certainly represents one of the best documented Early Medieval cultures in Europe (Gnecchi-Ruscone *et al.*, 2022, p.1403). It is therefore not surprising that the social aspect of the Khaganate is an unavoidable topic in almost every serious publication of Avar-age sites (*e.g.*, László, 1955; Kovrig, 1963; Garam, 1995; Breuer, 2005). However, considering the large number of graves and finds, it is unfortunate that a detailed analysis of Avar-age society has not yet been carried out[1]: we still do not know the exact percentage of horsemen or graves containing weapons, *etc.*, in the total number of Avar-era graves. There are no comprehensive statistics that would give us specific data from which we could draw broader conclusions about Avar-age society. In this respect, the initiative of Peter Stadler, who presented the Montelius database in 2005 aiming to catalogue and synthesise all known research results of Avar-age sites in the Carpathian basin, is commendable (Stadler, 2005; 2008). However, precisely because of the extent of the

[1] To be accurate, in recent years, there has been a significant effort to tackle some questions related to the social organisation of Avar-age people, for example: Distelberger, 2004; Bede, 2012. For more on the state of research of the social history of the Avars, see Curta, 2021.

known archaeological heritage of the Avar era, as well as the influence of the Khaganate itself on the subsequent history of the area they inhabited (Takacs, 2015), it is crucial in future research, where possible, to pay attention to various indicators of social organisation in Avar-era communities and present them to the scientific community.

The saying "you are what you eat" is indicative of the role of diet in determining social status within communities, especially in Europe (Bourbou, 2011). Social organisation is the result of the human need to form social identities within the community and the aspiration to improve social status, which manifests itself through the choice of food – the generally accepted thesis is that individuals choose food acceptable and/or desirable by the community they belong to; for example, domestic animals require more time and resources for successful breeding, so their consumption signals that the consumer can afford such expense. By analysing the eating habits of a certain community, we can gain further insights into its social organisation (Vidal-Ronchas *et. al.* 2018, p.1). Taking all of this into consideration, we decided to present the preliminary results of the analysis of stable carbon and nitrogen isotopes of certain members of the community from the Late Avar-age cemetery "Privlaka-Gole njive"[2] and start a discussion about the possible social implications of the results, given that it is located in an area of the southern (-eastern) periphery of the Khaganate, and that one such analysis has already been carried out in the microregion at the Nuštar-Khuen Belassy site, allowing us to make a comparison (Vidal-Ronchas *et. al.*, 2018).

The Privlaka-Gole njive site is located in the Bosut lowland (Figure 1), which can be considered a natural, well-defined and isolated microregion of eastern Croatia. The landscape's forest and marshland nature has restricted human settlements to the more favourable marginal areas throughout history (Sić, 1975, p.177). Small areas of the marginal and more elevated places of the lowland contain soils with characteristics which make them more suitable for agriculture, such as climatogenic soil. This is also prevalent on the neighbouring loess plain (Sić, 1975, p.180). The site of Gole njive was discovered by chance in 1972, situated on the left bank of the Bosut River, near the village of Privlaka (Šmalcelj, 1973). Excavations were carried out in several campaigns from 1973 to 1980 and resulted in a total of 231 graves, establishing the site as the largest Avar-age cemetery in Croatia. However, the site was not excavated in its entirety and the research results were not published, only summarised in short field reports (Šmalcelj, 1973; Šmalcelj, 1976; Šmalcelj, 1981; Šmalcelj, 1992).

2. Methodology

Of the 231 archaeologically-excavated graves, and graves A and B from private collections (whose inventories are known to us), 197 skeletons in various states of preservation were analysed for the purpose of this study. A basic anthropological analysis determined that the burials consisted of 71 non-adults (which included double graves 68, 82+82a, 133, 183, and the only one with the burial of 2 sub-adults, G180), 80 men (of which double graves 20, 53, 82+82a, 133), 75 women (of which double graves 20, 53, 68, 183) and 15 individuals of unknown sex[3], a very balanced picture. Basic anthropological analyses have been conducted on the osteological remains of the deceased (Šlaus, 1990; 1992; 1993; 1996). As more up-to-date anthropological methods have been developed, in 2018 the Anthropological Centre of the Croatian Academy of Sciences and Arts began a revision of the skeletal material. So far, 40 skeletons have undergone anthropological revision analyses. Anthropological analyses included determining the sex and age at death within adult individuals, subadult mortality, and pathological changes. Determining the sex of the skeletons was done according to basic anthropological criteria based on the morphological differences between males and females in both the cranial (Krogman and Iscan, 1986), and the postcranial skeleton (Kimura, 1982; Phenice, 1969; Sutherland and Suchey, 1991; Weaver, 1980), especially taking into account the differences between male and female skeletons in the coxal bone (Bruzek, 2002; Bruzek *et al.*, 2017). No attempt was made in determining the sex of non-adults of less than 15 years of age at the time of death as the sex of subadult skeletons cannot be determined with certainty (Majo *et al.*, 1993; Holcomb and Konigsbere, 1995; Saunders, 2000). Pathologies observed by macroscopic analyses include *cribra orbitalia*, *periostitis*, Schmorl's nodes, antemortem fractures, and possible vitamin C deficiency (scurvy) (see Table 1).

Morphologically, *cribra orbitalia* appears as sieve-like lesions or pitting on the orbital roof. It is thought to be a skeletal symptom of hereditary or acquired iron deficiency anaemia (Huss-Ashmore *et al.*, 1982; Mensforth *et al.*, 1978). Similar bone alterations that affect the skull vault (porotic hyperostosis) are thought to be a feature, or an early stage, of this condition (Carlson *et al.*, 1974; Cybulski, 1977; Stuart-Macadam, 1985; Mittler and Van Gerven, 1994; Fairgrieve and Molto, 2000).

Degenerative osteoarthritis is characterised by the progressive formation of osteophytes around the edges of an articular joint surface. The gradual development of osteophytes around an articular joint surface is a feature of degenerative osteoarthritis. In contrast to traumatic arthritis, which is brought on by a disruption of the biomechanical functioning of a joint, these alterations are related to the wear and tear of daily activity.

A generalised bacterial infection causes *periostitis*, a fundamental inflammatory reaction (Ortner, 2003). It can be seen macroscopically as osseous plaques with distinct

[2] The exact coordinates of the site are: HTRS96 E685778 N501019 (per https://geoportal.dgu.hr/).

[3] The authors emphasize that, due to the fact that the anthropological analysis of both Privlaka and Stari Jankovci is undergoing a revision in which discrepancies have been found, we will not use specific age groups outside the basic adult-subadult division, except in visible cases (newborn, infant, *etc.*).

Table 1. Pathologies of individuals selected for analysis.

Site	Grave No	Sex	Age	Macroscopically observed pathologies
Privlaka	15	Female	40–45	Osteoarthritis in the knees and spine
Privlaka	16	Male	45–50	Antemortem fracture of the left humerus; osteoarthritis in all major joints and spine
Privlaka	22	Female	60+	Antemortem fracture on the frontal bone and right radius; generalised osteoporosis; osteoarthritis in major joints
Privlaka	27	Subadult	6.5–7.5	Mild active cribra orbitalia
Privlaka	53	Male	17.5–18.5	Spondylolisis (L5)
Privlaka	66	Male	55–60	Shmorl's nodes; osteoarthritis of the spine; porosity on both sphenoidals (possible vitamin C deficiency)
Privlaka	100	Female	25–30	Mild healed cribra orbitalia; osteoarthritis in the left elbow; mild healed periostitis on the left tibia
Privlaka	104	Subadult	11.5–12.5	Mild healed cribra obitalia
Privlaka	123	Male	20–25	Schmorl's nodes; osteoarthritis of the spine
Site	Grave	Sex	Age	Perimortem injuries
Privlaka	124	Male	30–35	Schmorl's nodes
Privlaka	133A	Male	30–35	Osteoarthritis in the knees, elbows and spine
Privlaka	133B	Subadult	8–9	Mild healed cribra orbitalia; mild heald periostitis on the left temporal bone
Privlaka	150	Male	30–35	Osteoarthritis in the right elbow and wrist
Privlaka	151	Male	30–35	Antemortem fracture of the left clavicle; osteoarthritis in the major joints and spine
Privlaka	164	Subadult	6–7	Healed periostitis on the left mandibular ramus; severe LEH
Privlaka	197	Subadult	11–12	None
Privlaka	204	Female	17.5–18.5	None
Privlaka	205	Female	20–25	Subperiosteal hematoma on the left tibia
Privlaka	214	Female	35–40	Antemortem fracture on the frontal bone; mild healed cribra orbitalia; porosity on the right sphenoidal and temporal bone; osteoarthritis in the right hip
Privlaka	220	Male	40–45	Antemortem fracture on the frontal bone; mild healed cribra orbitalia; osteoarthritis in the knees and spine
Privlaka	225	Female	30–35	None

borders or uneven bone surface elevations (Larsen, 1997). Periostitis can be brought on by trauma, certain infectious diseases including leprosy, TB, and treponemal disease, as well as other ailments like fluorosis (Larsen, 1997; Ortner, 2003).

Schmorl's defects are lesions that appear as a result of intervertebral disc tissue herniating and moving into the vertebral body adjacent to it. Degenerative alterations are the most typical cause of Schmorl's nodes, according to Schmorl and Junghanns (1971).

Scurvy is a metabolic condition brought on by vitamin C deficiency. The foundation of connective tissues including skin, artery walls, cartilage, and bone is vitamin C (Lewis, 2004).

Burials at Privlaka seem to have begun at the beginning of the Late Avar age (culturally, the first graves reflect the end of the Middle Avar period) and the cemetery was functioning throughout the 8th, until the start or first decades of the 9th century, as per horizontal stratigraphy and results of typochronological analysis (Šmalcelj Novaković, 2022). While it seems to have been a resting place of the typical Late Avar age rural community, the site contains several interesting phenomena, one being the existence of a somewhat separate group of burials with a different concentration of the deceased buried with belt-sets, a horseman's grave with a set of damascened phalerae (one of the rarest examples of such a find in a Late Avar age context; Garam, 1987; Kiss, 1995) and a slight difference in burial customs (very sparse food offerings), when compared to the rest of the cemetery.

The analysis of carbon (^{13}C) and nitrogen (^{15}N) stable isotopes in collagen extracted from the bones of the deceased reveal information about their diet during a specific time in the person's life, depending on the type of bone sample. As different bones have varying turnover phases, they record their diet from different periods of the individual's life. Therefore, bulk sampling of the tissue can only capture an average of dietary sources over the last 10–25 years of life, in effect providing an overall model of foods consumed (Henriksen *et al.*, 2009; Fahy *et al.*, 2017). The isotopic values of carbon from human tissue reflect the different photosynthesis paths of the two distinct kinds of plants, C_3 and C_4, whereas nitrogen values primarily reflect relative protein intake during life; *i.e.*, meat and milk, though a distinction between such types still cannot be discerned. In the Avar age, millet was the only domesticated C_4 plant (its $\delta^{13}C$ range falling between –9‰ to –16‰ with an average –12‰ (van der Merwe, 1982; Noche-Dowdy, 2015) in the Carpathian basin, while wild C_4 plants are still very rare in that region today. Additional differences in $\delta^{13}C$ values can also occur as a result of seafood intake due to the difference in isotopic base values of marine and terrestrial ecosystems, but in the case of Eastern Slavonia such deviations are unlikely (Vidal-Ronchas *et al.* 2018, p.4). Isotope variations can occur as a result of diverse environmental factors in different areas; therefore, it is crucial to analyse and establish a faunal baseline to act as a reference to the primary (human) samples. Human bone collagen $\delta^{13}C$ is enriched by 5.1‰ over dietary sources (Ambrose and Norr, 1993). Likewise, the $\delta^{15}N$ of herbivores, carnivores, and omnivores is enriched by approximately 3‰ (Schoeninger and DeNiro, 1983; Hedges and Reynard, 2007; Fuller *et al.*, 2006).

Since animal bones from Privlaka could not be located until recently, the isotopic analysis values of animals from nearby Nuštar were used as a baseline (Table 4). The analysis included a total of 22 human samples from Privlaka, which made up approximately 10% of the preserved anthropological material. During sample selection, an attempt was made to follow certain criteria: the intention was to include samples originating from different locations in the cemetery (Figure 2); that the samples belonged to male and female individuals and all age groups; and that the samples included members of the community of different social status.

The samples were comprised of ribs, and were analysed on two occasions: in 2018 at the Center for Applied Isotope Studies, The University of Georgia, USA; and in 2020 at the Isotoptech Zrt laboratory, Debrecen, Hungary. The preparation process was identical in both laboratories, using the modified Longin method (1971). During pre-treatment, all samples were inspected and all visible marks on their surfaces were noted along with the initial mass. After repeated ultra-sonication in ultra-pure water, the bones were dried at 60°C overnight. The outer surface of the bones was removed by thorough abrasion. Then, larger bone fragments were ground and sieved to the adequate size fraction of 0.5–1.0 mm. For chemical pre-treatment, 500–1000 mg (min. 100 mg) of the ground powder was placed in a specially-designed Omnifit™ glass column. These columns were used as flow cells in our semi-automatic system which was constructed for performing the acid-base-acid cleaning method for bone samples (Molnár *et al.*, 2013). The pH was adjusted to 3 to eliminate any ambient CO_2 that may have been absorbed during the pre-treatment phase. Afterwards, the acid-insoluble collagen was transferred to a test tube containing 5 mL of HCl solution at pH 3, and was put into a block heater at 75°C for 24 hr. Dissolved gelatine was filtered via a 2 µm glass fibre filter (Milles AP20) into a 20 mL vial pre-cleaned by nitrogen gas, and after freezing was freeze-dried for at least 2 days. Gelatine samples were then combusted using a modified sealed-tube combustion method where the sample and MnO_2 reagent were together placed in a borosilicate combustion tube. After flame sealing, the closed tubes were placed in a muffle furnace at

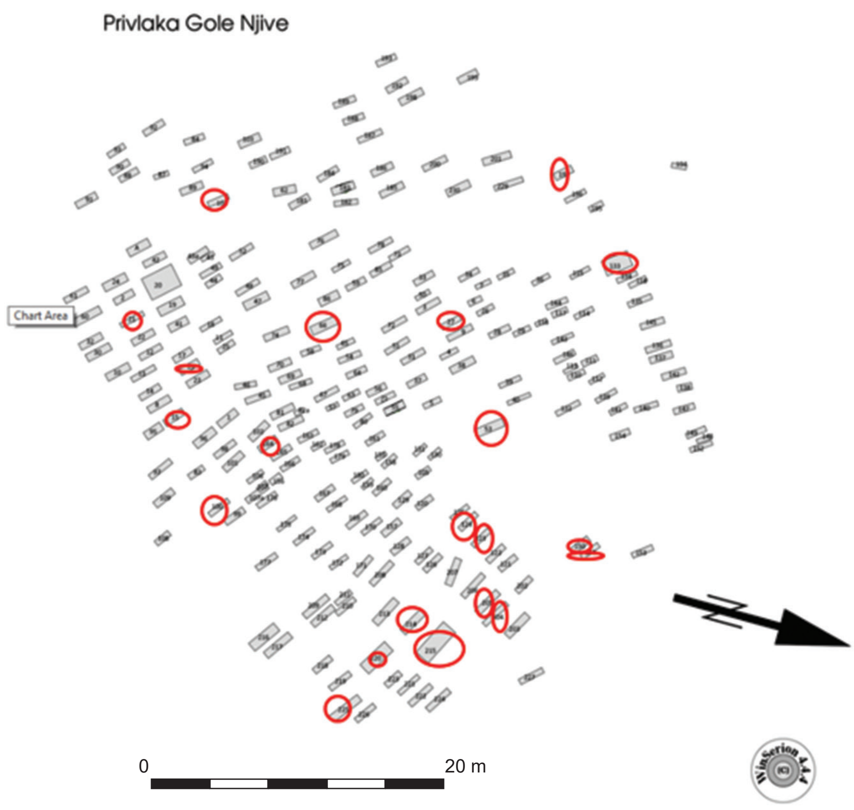

Figure 2. Map of Privlaka-Gole njive cemetery with positions of sampled burials indicated.

550°C for at least 12 hrs to combust the gelatine. The CO_2 gas produced was transferred and purified from any other by-product gases using a dedicated vacuum line (Janovics *et al.*, 2018).

Carbon and nitrogen stable isotope measurements were calibrated by control measurements of IAEA 600 (caffeine) and sulfanilamide standards after every fifth unknown sample. Measurements were performed by a Thermo Finnigan Delta Plus XP isotope ratio mass spectrometer. Gelatine sub-samples (~0.3 mg) were packed into ultra-clean aluminium cups and combusted by an elemental analyser (Thermo Scientific™, EA IsoLink CNSOH). Stable isotope ratios and percentages were determined in the same run. All $\delta^{13}C$ and $\delta^{15}N$ values are reported in standard ‰ notation with respect to VPDB and atmospheric nitrogen, respectively. Sample quality was evaluated with %C, %N and C:N ratios before further analysis. C:N ratios fell between 3.0 and 3.3 and reflect good preservation for stable isotope analyses (DeNiro, 1985; van Klinken, 1999).

Descriptive and analytical statistics using MS Excel® and SSPS® 27 were used to evaluate the results, and the nonparametric Mann-Whitney-U test was applied for group comparisons since the number of samples was relatively small.

It should be noted that this was a preliminary analysis; hence the relatively small number of samples. The primary interest was to find out if the samples were eligible, considering that osteological material from archaeological excavations in Eastern Croatia is usually in bad, or very bad condition due to the soil characteristics, and we were dealing with remains excavated almost 50 years ago. Of course, we wanted to find out more about the functioning of the Privlaka-Gole njive community itself and the analysis provided answers to several questions.

3. Results

The overall results are shown in Table 2 and Figures 3 and 8: the $\delta^{13}C$ values vary from –14.5 to –16.9‰, while the $\delta^{15}N$ results vary from 9.1 to 12.1‰, and the C:N ratio varies from 3.0 to 3.3, respectively. According to the inferential statistical analysis for 7 female and 10 male samples (non-adults are not included in this particular statistic test), there is no statistical significance for $\delta^{13}C$ (Mann–Whitney U=128. p=0.3446) nor for $\delta^{15}N$ (Mann–Whitney U= 125.5 p=0.3121).

With regard to age stratification, the samples were divided into general age groups: non-adults (up to 15 years), younger adults (15–33 years), and older adults (34 years and up). For the paired comparison of adults and non-adults, statistical analysis indicates no significant statistical difference for both $\delta^{13}C$ and $\delta^{15}N$ (Mann–Whitney U=153.5 p=0.4880; U=154

Table 2. Results of stable isotope analysis of selected samples from Privlaka-Gole njive site.

Site	Grave #	Lab #ID	Sample	Sex	Age	δ13C (‰)	δ15N (‰)	C:N
Privlaka-Gole Njive	15	I/2502/1	rib	F	43	–15.5	9.4	3.1
	16	37473	rib	M	48	–16.0	11.3	3.3
	22	37472	rib	F	65	–15.3	10.4	3.0
	27	I/2502/2	rib	I	7	–14.3	12.1	3.2
	53	37470	rib	M	18	–14.7	10.1	3.1
	66	37467	rib	M	58	–15.2	10.6	3.2
	100	I/2502/3	rib	F	28	–15.5	9.4	3.2
	104	I/2502/4	rib	I	12.5	–16.9	10.0	3.1
	123	I/2502/5	rib	M	23	–15.6	9.7	3.1
	124	I/2502/6	rib	M	33	–15.3	10.2	3.1
	133A	I/2502/7	rib	M	33	–16.2	9.9	3.0
	133B	I/2502/8	rib	I	6.5	–14.5	9.4	3.1
	150	I/2502/9	rib	M	33	–16.4	9.9	3.3
	151	I/2502/10	rib	M	33	–16.1	10.3	3.1
	164	I/2502/11	rib	I	6.5	–16.6	9.1	3.1
	197	I/2502/12	rib	I	12	–15.6	10.7	3.1
	204	I/2502/13	rib	F	18	–16.9	9.7	3.1
	205	I/2502/14	rib	F	23	–16.6	10.0	3.1
	214	37469	rib	F	38	–14.8	9.8	3.2
	215	37466	rib	M	45+	–16.0	10.6	3.2
	220	37468	rib	M	43	–14.9	10.3	3.2
	225	37471	rib	F	23	–15.4	11.2	3.2

p=0.4341, respectively) – Figure 5[4]. Regardless of the social status signalled in the afterlife, there are no isotopically detectable differences in diet (Figure 6)[5]; the same can be said when comparing the somewhat outstanding group of burials "G202+" from the eastern end with the samples from the rest of the cemetery (Figure 7)[6].

When the $\delta^{13}C$ average bone value of –15.6‰ is adjusted for tissue to dietary source fractionation, the result is –10.5‰, which falls within the $\delta^{13}C$ of C4 plant range (–9‰ to –16‰ with an average of –12‰) (van der Merwe, 1982; Noche-Dowdy, 2015), thus confirming a C_4 plant component, most probably millet, according to historical and archaeological data regarding the Avar diet (Vidal-Ronchas *et al.*, 2018; Gyulai, 2014). Upon adjusting the $\delta^{15}N$ average bone value of 10.2‰ for tissue to dietary source fractionation, the result is 13.2‰, which might suggest a limited fish intake in the diet, given the proximity of the Bosut River. Several studies had previously shown the $\delta^{15}N$ values of carp ranging from 7.8‰ to 8.8‰ with Danube fish such as sturgeon and catfish showing $\delta^{15}N$ values around 8.5‰ and 10‰, respectively (Borić *et al.*, 2004; Nehlich *et al.*, 2010; Svyatko *et al.*, 2013).

4. Discussion

The results of the analysis divided by sex (Figure 4) are interesting because the results from the Late Avar age sites of Lower Austria show a difference between men and women in diet, where men consumed more animal-based food than women; this is considered to be the result of the influence of Frankish social structures in that area (Herold, 2008). The difference between average values in Lower Austria and in Privlaka is the same: males have a 0.3 ± 0.1‰ higher value for $\delta^{15}N$. Considering the number of samples from Austria (four sites, more than 100 samples of both sexes, Herold, 2008) this is a significant difference, but in the case of Privlaka (a very small number of samples), we may treat it as an indication only (the results do not show statistical significance). The closest previously analysed site, Nuštar-dvorac Khuen Belassy, yielded similar results as Privlaka (Vidal-Ronchas *et al.*, 2018, see Table 3), though when compared to Privlaka as a whole, it does exhibit more negative $\delta^{13}C$ values, suggesting a more abundant C_3 plant consumption. The case was similar to the Sajópeteri site in Hungary (Noche-Dowdy, 2015, Table 5).

Regarding age stratification when comparing the results of the analysis, the sample is too small to draw any certain conclusions. It should be noted that any influence of breastfeeding on the results of the analysis in non-adults is excluded because all the samples are from individuals who were certainly no longer breastfed.

As for the social status being any indicator of difference in diet, the samples were divided according to the archaeological context of the burial into 4 groups – by looking at the statistics of the most common finds according to gender and age (category: man, woman, non-adult) as representative of average costume/grave equipment of the members of the community, burials with more elements than the average were determined as "well-to-do", those with less than average finds or no finds as "poor", while "rich" graves as those that bear clear signs of a higher social status compared to other sites and significantly different from the average[7].

[4] For 5 non-adults the results are: 15.6 $\delta^{13}C$ (‰), 10.3 $\delta^{15}N$ (‰) with 1.2 SD. $\delta^{13}C$ (‰) and 1.2 SD $\delta^{15}N$ (‰); for 10 younger adults the results are: 15.9 $\delta^{13}C$ (‰), 10.0 $\delta^{15}N$ (‰) with 0.7 SD $\delta^{13}C$ (‰) and 0.5 SD $\delta^{15}N$ (‰) and the results for older adults are: 15.4 $\delta^{13}C$ (‰), 10.3 $\delta^{15}N$ (‰) with 0.5 SD $\delta^{13}C$ (‰) and 0.6 SD $\delta^{15}N$ (‰).

[5] The results for 9 samples from the rich graves are: 15.7 $\delta^{13}C$ (‰), 10.3 $\delta^{15}N$ (‰) with 0.9 SD $\delta^{13}C$ (‰) and 0.5 SD $\delta^{15}N$ (‰); results for 5 samples from the well-to-do graves are: 15.7 $\delta^{13}C$ (‰), 10.1 $\delta^{15}N$ (‰) with 0.5 SD $\delta^{13}C$ (‰) and 0.3 SD $\delta^{15}N$ (‰); results for 4 samples from average graves are: 15.7 $\delta^{13}C$ (‰), 10.2 $\delta^{15}N$ (‰) with 0.2 SD $\delta^{13}C$ (‰) and 1.0 SD $\delta^{15}N$ (‰) and the results for 4 samples from poor graves are: 15.4 $\delta^{13}C$ (‰), 10.1 $\delta^{15}N$ (‰) with 1.2 SD $\delta^{13}C$ (‰) and 1.4 SD $\delta^{15}N$ (‰)

[6] The results for 6 samples from group "G202+" are: 15.8 $\delta^{13}C$ (‰), 10.3 $\delta^{15}N$ (‰) with 0.9 SD $\delta^{13}C$ (‰) and 0.6 SD $\delta^{15}N$ (‰), while the results for 15 samples from the rest of the cemetery are: 15.6 $\delta^{13}C$ (‰), 10.1 $\delta^{15}N$ (‰) with 0.8 SD $\delta^{13}C$ (‰) and 0.7 SD $\delta^{15}N$ (‰).

[7] *Rich* graves, with belt-sets and their female counterparts (women with jewelry made of precious metal); *well-to-do* graves (graves in which a male has a belt or at least one buckle found in the waist area and more than one knife, while the female has crescent-shaped bronze earrings, which represent a slightly more demanding product than ordinary ones); *average* graves (individuals with average accessories like a knife and arrow for males and earrings and necklaces for women, and two knives for a child in G197); and *poor* graves (individuals without accessories or with very modest finds , for example, the G27-pottery fragment).

Table 3. Results of stable isotope analysis of selected samples from Nuštar-khuen Belassy site (Vidal-Ronchas *et al.*, 2018).

Group	n	δ13C (‰)		δ15N (‰)	
		Mean	St. dev.	Mean	St. dev.
Adults	29	–16.4	0.5	10.2	0.6
Subadults	14	–16.4	0.8	10.1	0.7
Average	43	–16.4	0.6	10.2	0.6
Group	**n**	**δ13C (‰)**		**δ15N (‰)**	
		Mean	**St. dev.**	**Mean**	**St. dev.**
Females	15	–16.6	0.5	10.0	0.6
Males	14	–16.3	0.4	10.4	0.6
Subadults	14	–16.4	0.6	10.2	0.6

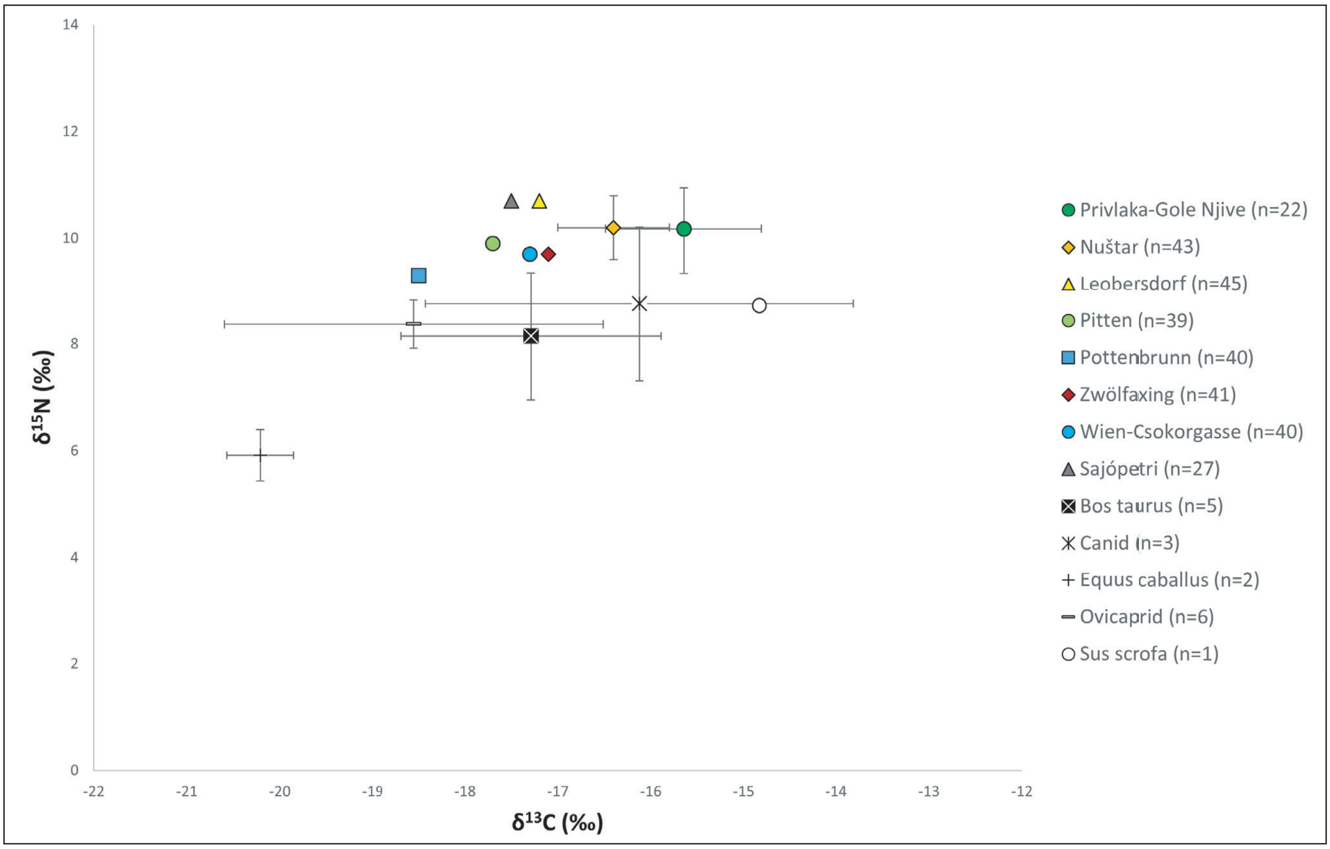

Figure 3. Comparison of stable isotope analysis results of the sites mentioned in text: Privlaka-Gole njive, Leobersdorf, Pitten, Pottenbrunn, Zwölfaxing, Wien-Csokorgasse (Herold, 2008), Sajópetri (Noche-Dowdy, 2015), and Nuštar-Khuen Belassy (Vidal-Ronchas *et al.*, 2018).

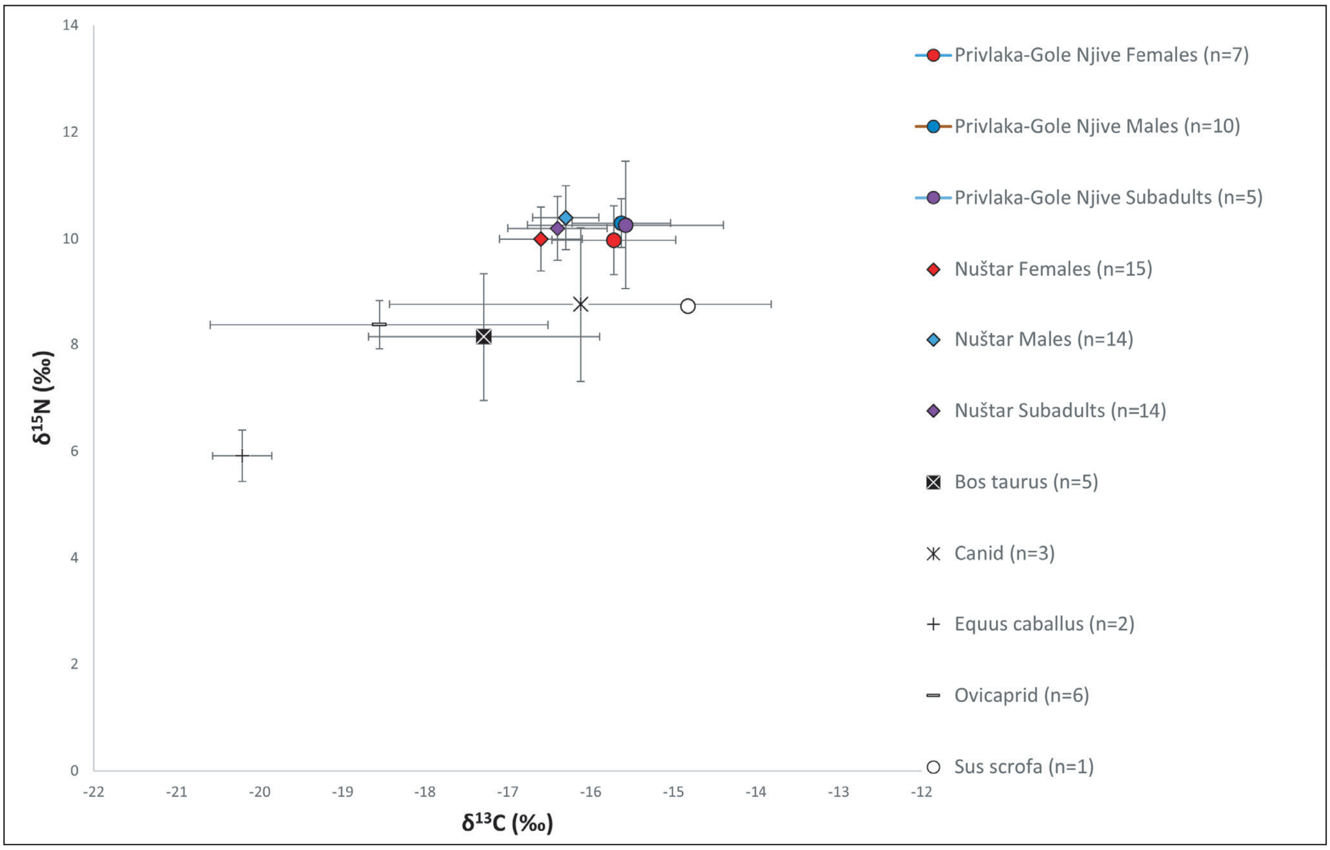

Figure 4. Average values of stable isotope analysis of selected samples from Privlaka-Gole njive, divided by sex, compared to Nuštar.

Table 4. Results of stable isotope analysis of selected faunal samples from Nuštar-khuen Belassy site (Vidal-Ronchas *et al.*, 2018).

Animal	Element	$\delta^{13}C_{VPDB}$ (‰)	$\delta^{15}N_{AIR}$ (‰)	C:N	$\delta^{13}C_{VPDB}$ (‰) st. dev.	$\delta^{15}N_{AIR}$ (‰) st. dev.
Bos taurus	rib	–16.7	7.5	3.1		
Bos taurus	rib	–17.3	8.0	3.1		
Bos taurus	rib	–17.5	7.7	3.1		
Bos taurus	rib	–15.5	10.3	3.1		
Bos taurus	rib	–19.5	7.3	3.1		
Bos taurus Mean (n=5)	–	–17.3	8.1	3.1	1.4	1.2
Ovicaprid	rib	–15.9	8.8	3.1		
Ovicaprid	skull	–17.2	8.7	3.1		
Ovicaprid	rib	–17.7	8.8	3.1		
Ovicaprid	occipital	–21.6	8.0	3.1		
Ovicaprid	talus	–19.2	8.1	3.1		
Ovicaprid	femur	–19.7	7.8	3.0		
Ovicaprid Mean (n=6)	–	–18.6	8.4	3.1	2.0	0.5
Canid	vertebra	–15.5	10.2	3.1		
Canid	metatarsal	–18.7	7.3	3.1		
Canid	phalanx	–14.2	8.8	3.1		
Canid Mean (n=3)	–	–16.1	8.8	3.1	2.3	1.4
Equus caballus	rib	–20.5	5.6	3.0		
Equus caballus	rib	–20.0	6.3	3.1		
Equus caballus Mean (n=2)	–	–20.2	5.9	3.0	0.4	0.5
Sus	Dentine	–14.8	8.7	3.1		

Table 5. Overall results of stable isotope analyses of Avar age sites in the rest of the Carpathian Basin, with general data: Leobersdorf, Pitten, Pottenbrunn, Zwölfaxing, Wien-Csokorgasse (Herold, 2008), and Sajópetri (Noche-Dowdy, 2015).

Site	Period	Location	Ethnicity	δ13C (‰)	δ15N (‰)	n
Leobersdorf	Mid 7–8th century	Southwestern Lower Austria	Avars	–17.2	10.7	45
Pitten	9th century	Southern Lower Austria	Slavs	–17.7	9.9	39
Pottenbrunn	First half of 9th century	Lower Austria	Slavs	–18.5	9.3	40
Zwölfaxing	680–830 A.D.	Southwestern Lower Austria	Avars	–17.1	9.7	41
Wien-Csokorgasse	7–8th century	Southwestern Lower Austria	Avars	–17.3	9.7	40
Sajópetri	568–895 A.D.	Northwestern Hungary	Avars	–17.5	10.7	27

Our results show no difference regardless of the implied social status of the deceased; of course, the question remains whether the more prominent members of the community may have had access to certain, more desirable animal parts or dairy products. Also, a relatively larger number of samples from the eastern end of the cemetery, graves from "Group 202+" (G215, 220, 204, 214, 225) were deliberately included in the analysis, as we have already mentioned. This group of burials stands out when compared to the rest of the cemetery: it has a different spatial distribution (higher concentration) of graves with belt sets (including an equestrian grave) and their female counterparts are clearly recognisable, a slightly different repertoire of finds (different motifs of belt sets, damascened decorations of horse harness, occurrence of different types of earrings, beads) and funeral customs (sparse food offerings), and the reason(s) for this being undetermined as of yet (Šmalcelj Novaković, 2022, p.365, p.391). We wanted to find out if any difference in isotopic values would be shown between these and the rest of the samples, but ultimately found none. This indicates that, if the differences we stated previously and which may signalise stratification in social status between graves with belt sets from the "core" of the cemetery and "Group 202+", they were not as great as to include significant variations in diet.

The overall stable isotope results indicate that the community buried at Privlaka cemetery had a fairly standard, moderate diet based on proteins mostly originating from land animals (with potentially – and, if so, a very limited – fish intake) and carbohydrates, most probably in the form

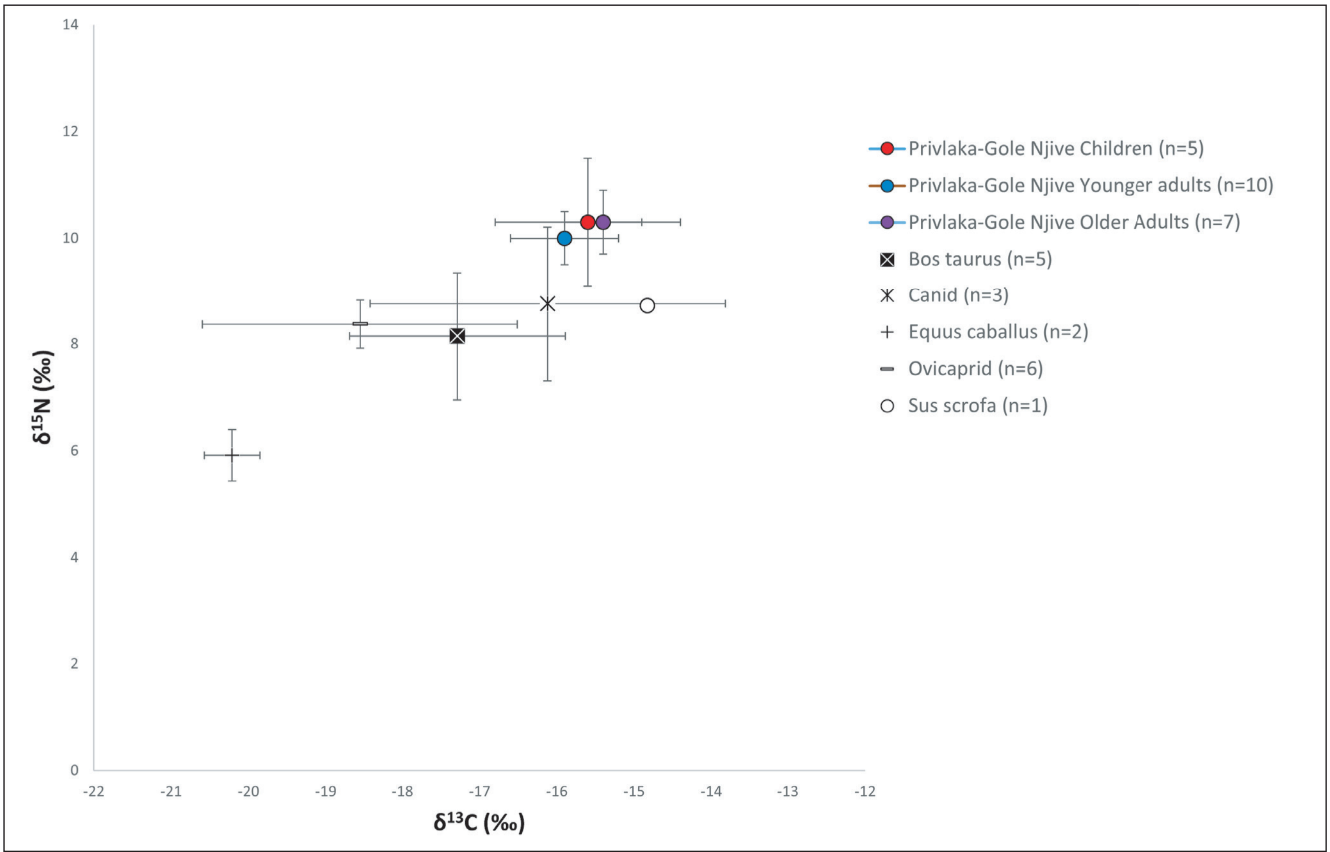

Figure 5. Average values of stable isotope analysis of selected samples from Privlaka-Gole njive, divided by age.

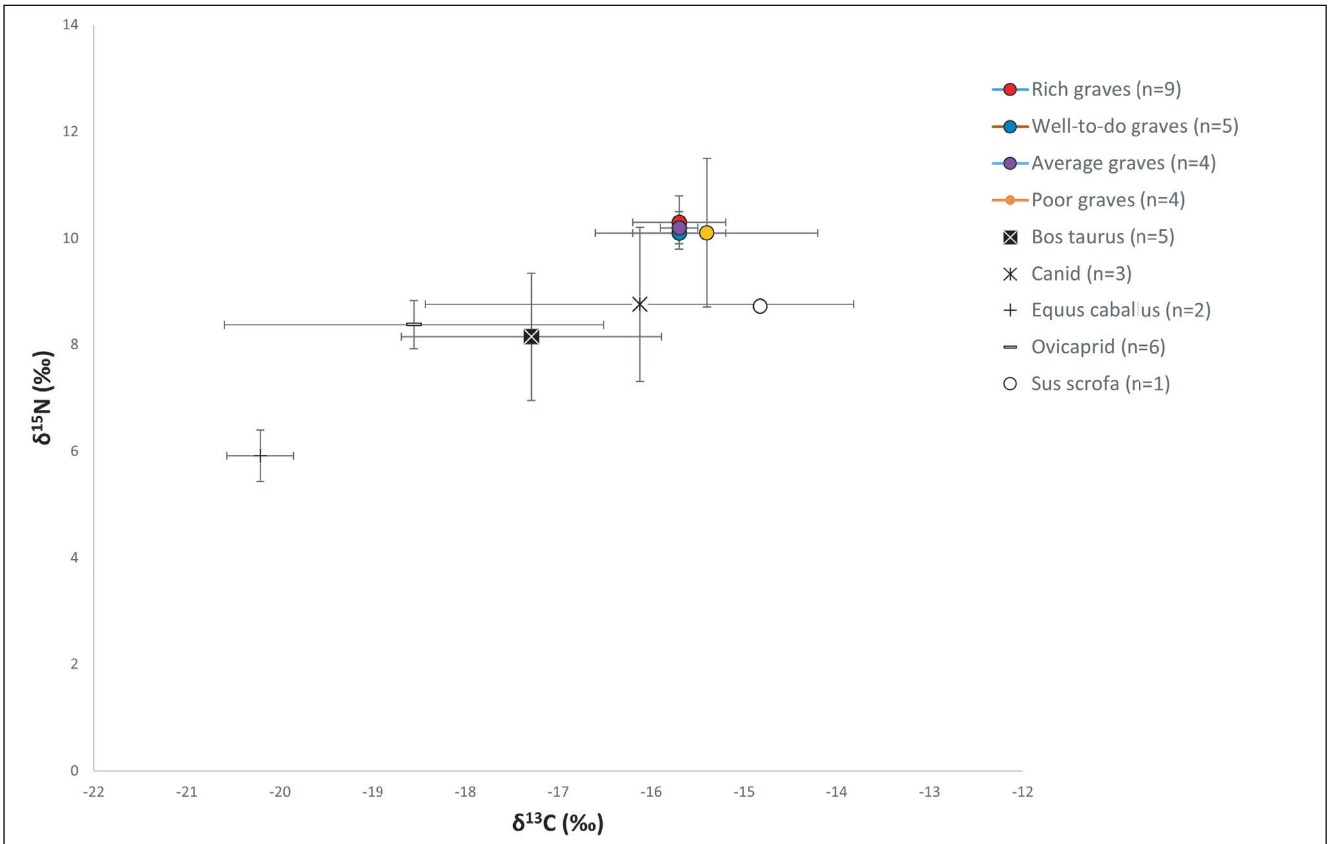

Figure 6. Average values of stable isotope analysis of selected samples from Privlaka-Gole njive, divided by social status.

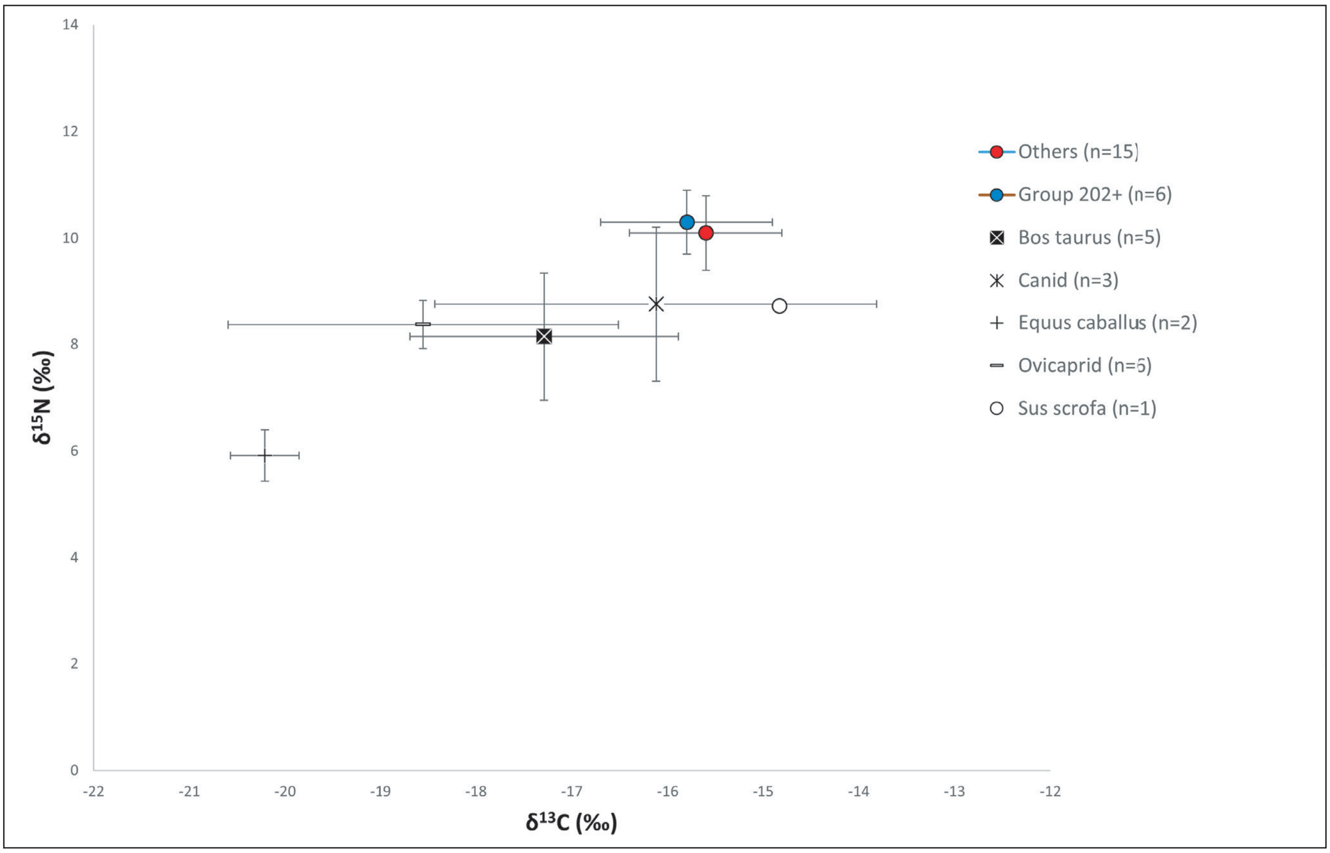

Figure 7. Average values of stable isotope analysis of selected samples from the Privlaka-Gole njive "separated group" and samples from the rest of the cemetery.

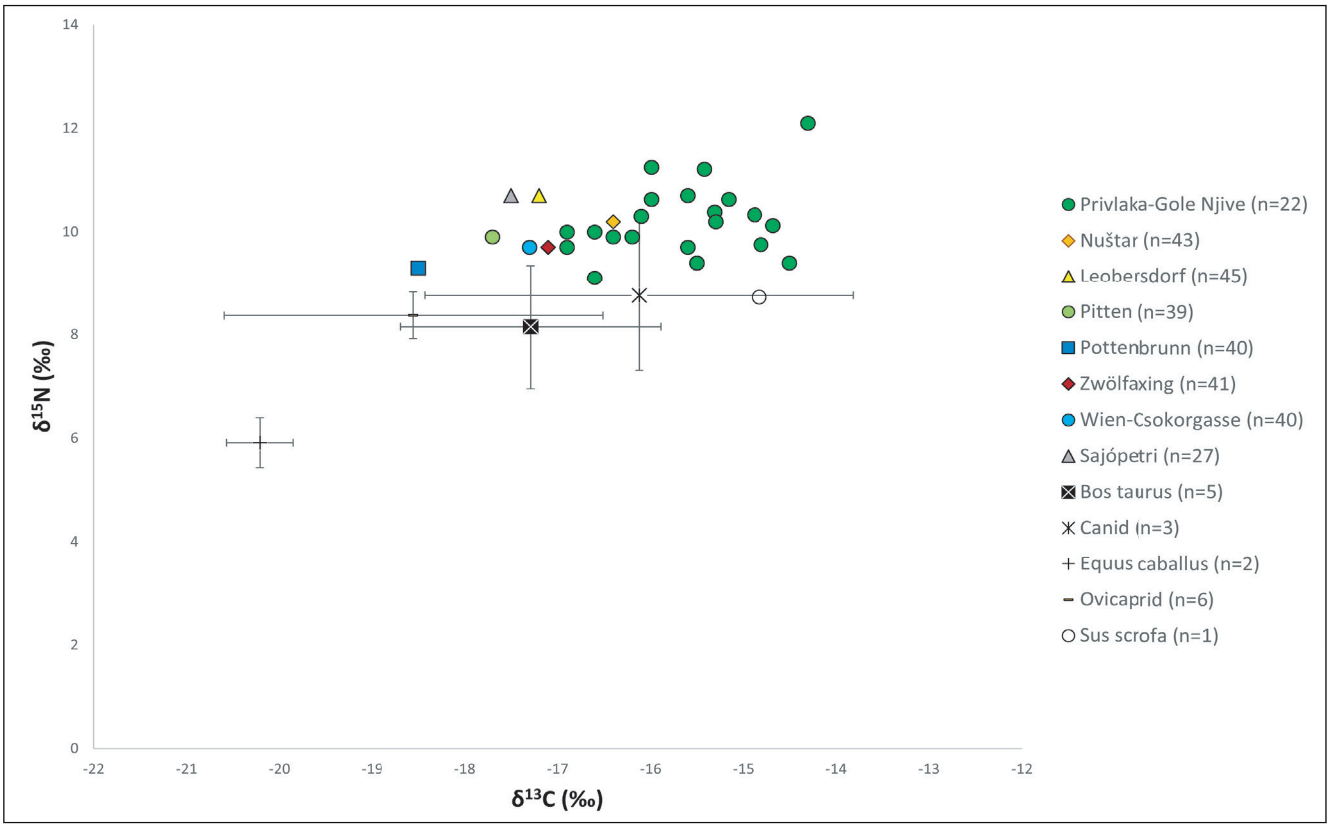

Figure 8. Comparison of stable isotope analysis results of Privlaka with average isotopic values of the sites mentioned in text: Privlaka-Gole njive, Leobersdorf, Pitten, Pottenbrunn, Zwölfaxing, Wien-Csokorgasse (Herold, 2008), Sajópetri (Noche-Dowdy, 2015), and Nuštar-Khuen Belassy (Vidal-Ronchas *et al.*, 2018)

of porridge, with a presence of a C_4 type plant therein. Considering millet was (Filipović *et al.*, 2020) the only such C_4 plant whose history of cultivation reaches all the way to the Middle Bronze Age in these areas, it asserts itself as the likeliest candidate.[8] The results of the analysis are very similar to the results from Nuštar (Vidal-Ronchas *et al.*, 2018). Compared to the results from Nuštar and Privlaka, average values of the isotopic analyses at several similar sites from Lower Austria show lower-trophic-level protein values, which implies a higher consumption of protein by the communities of Privlaka and Nuštar. Such a result allows one to entertain the aforementioned fish intake consumption potential which might explain the higher trophic position (Figure 3 and Figure 8). However, when considering these higher values, the smaller number of samples from Privlaka must also be taken into account, a detail which can distort the overall dietary conclusion. The general archaeological data complies with the stable isotope analysis results: clay pots and cooking cauldrons for porridge-type meals (ideal for millet), and baking bells for baking bread/meal or fish, dominate the archaeological material of the Late Avar age settlements (Vida, 2016, pp.261–264).

5. Conclusions

In general, the results of the analysis show that a degree of equality was present in the practical, everyday life of the community, without visible social stratification overall, and significant differences in isotopic values analysed were not detected. Although it is possible (and we would daresay, probable) that some members of the community had access to different parts of the available food sources (*i.e.*, those with higher status to better parts of the animal, for example, or parts of the plants which were easier to prepare or tastier), it seems that the final dietary result was identical or nigh-identical for all members of the community**.** The slightly more positive $\delta^{13}C$ results show a mixture of a C_3–C_4 plant-based diet, where the C_4 component most probably originated from the then widely-domesticated millet in this region of Europe. An interesting fact is the same difference in average values of $\delta^{15}N$ regarding adult females and males that was found in Privlaka was also found in Lower Austria, but we should not mistake Privlaka's results for a definitive argument that the situation was the same as in Lower Austria; Privlaka's sample size is too small for any definitive conclusions. The results from Austria have been explained by the stronger Frankish cultural influence on those areas after the Frankish invasion, when the western part of the Khaganate fell under Frankish domination, whilst the east and southeast remained under Bulgarian influence, with the possibility that the Syrmia region was a kind of peripheral pocket which was not imposed on by anyone's rule until the early 9th century (Curta, 2006; Vidal-Ronchas *et al.*, 2018, p.9). Given the average $\delta^{15}N$ values, the possibility of a limited fish intake in the diet of the analysed population (further backed by the proximity of the Bosut River) can be entertained, although there is not enough evidence to draw any concrete conclusions. In any case, for any kind of definite conclusions about possible stratification regarding dietary habits, a new analysis of stable isotopes should be conducted, with a larger number of samples from this site, as well as other sites in the region, at least one of comparable scope to the one conducted at Nuštar (Vidal-Ronchas *et al.*, 2018). We must emphasise: considering the number of Avar age sites (Late Avar age cemeteries make up at least 50% of them (Szentpeteri, 2002) and the confirmed regionality of the Late Avar Khaganate, for any kind of conclusions about the dietary habits of its people in general, we need more stable isotope studies from all over the Khaganate itself. This analysis represents just a small part of that mosaic (this is also true for any kind of conclusions about dietary habits in any individual region). There is one, very important, "bonus" in the perspective of stable isotope analyses of dietary habits in Late Avar age research: considering the fact there are at least two social strata we can safely recognise on Late Avar age cemeteries (individuals with belt sets and those without them) we can easily check if there was a correlation between dietary habits and social stratification in these communities.

No matter the fact that we cannot say there is no difference in dietary habits, or better said, available dietary choices, the fact that generally there is no crucial difference in the analysed isotopic values overall shows that the end nutritional impact was more or less the same: there were no real differences in the nutritional values of overall dietary habits of different members of the community. Historians might take this information into account whilst discussing the attractiveness of life in the Khaganate, where all members of the community, regardless of social status, appear to have the same access to one of the basic necessities. The assumption that after the Frankish-Avar conflicts (Curta, 2006), short-term independent communities exhibiting traits derived from the Avar culture existed in the south-eastern periphery, may or may not be correct. However, this could be an explanation as to why such a cultural milieu was so attractive to the members of simple, small, rural communities, as exemplified by this most common form of settlement in the Late Avar Khaganate (Szentpeteri, 2002; Zabojnik, 2004).

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[8] Unfortunately, paleobotanical analyses have not been done on samples from Privlaka. We know that the samples were collected with that purpose during the excavations (archaeological field documentation), but it seems the samples were lost during the years or remain misplaced.

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