The diet and social paleostratigraphy of Neolithic agricultural population of the Lengyel culture from Osłonki (Poland)

Krzysztof Szostek,¹  Henryk Głęb,¹  Wiesław Lorkiewicz,²  Ryszard Grygiel,³  Peter Bogucki⁴

¹ Department of Anthropology, Jagiellonian University, Krakow, Poland; E-mail: szos@zuk.iz.uj.edu.pl
² Department of Anthropology, University of Łódź, Poland
³ Archaeological and Ethnographical Museum, Łódź, Poland
⁴ School of Engineering and Applied Science, Princeton University, USA

ABSTRACT The archaeological site Osłonki is situated in central Poland in the Kujawy region. It dates back to the early Neolithic period between 4300 and 4000 B.C. (recalibrated dating), and the individuals that are the subject of our study represent the Lengyel culture. The main purpose of our study was to determine the nutritional strategy of that population on the basis of the physicochemical studies of teeth, whether the quality of nourishment depended on the sex and age, and to estimate the kind of diet on the basis of the strontium, zinc and calcium content in human and animal teeth. The interaction between the soil and the odontological material that has been present in it for ca 6000 years was also examined. In order to reconstruct the modes of nutrition and the access to specific food ingredients, a discrimination analysis of micro- and macro elements in the trophic chain from the region inhabited by the Neolithic rural population under study was carried out. To this end, comparative studies on the concentration of the elements examined (Sr, Zn and Ca) in human teeth were conducted with reference to typically herbivorous animal species that used to co-inhabit the explored site.

A multi-variate analysis of clusters showed that the described representatives of the Neolithic rural population of the Lengyel culture probably consumed only small amounts of protein of animal origin. With regard to the sex and age differences in the context of a social paleostratigraphic analysis, it was observed that men differed from women neither in the Sr/Ca ratios nor in the direct concentrations of Sr and Zn. These findings may testify to low sex and age social-diet paleo-stratigraphy in the population under study.

KEY WORDS trace elements, paleodiet, neolithic populations, Kujawy region

**Introduction**

Humans have always been an integral part of ecosystems. They have had a smaller or greater influence on the flow of energy and matter in both the animate and inanimate world; moreover, they have also occupied a specific position in the food chain (trophic pyramid). Human access to natural resources (food – both its variety and quality) has undergone profound changes in time, determined above all by the degree of cultural advancement, mode of life, but predominantly by the abundance and type of a populated natural environment [SCHUTKOWSKI 2000]. Particularly significant differences occurred between the adaptive strategies related to the transition from a gathering-hunting system to an agricultural one, with all transitional forms of activity directed towards obtaining nourishment. The period ascribed to permanent settlement is characterized by the strengthening of the human position in a particular place of the trophic pyramid (food chain), determined by more or less by permanent access to nourishment containing specific ingredients (menu) [SCHOENINGER 1982]. Under such economic, social and living conditions, human energy was concentrated mainly on productive activity [KRENZ-NIEDBALA 2000, PIONTEK 1999, LARSEN 1997]. That process, commonly known as neolithization, did not take the same course everywhere. This does not mean, however, that during the transition from the hunting-gathering system (the phase of assimilable economy) to the agricultural one (productive phase) both those strategies could not have been employed simultaneously. The very transition phase of the biocultural development of human populations is of particular interest to the archeologist and the anthropologist. To spot the differences, one should study in detail the nutritional strategies of Paleolithic and Neolithic populations [SCHOENINGER 1982].

Within the past 20 years remarkable advances have been made in anthropology regarding the physicochemical analyses of bones and teeth. Studies of the content of such trace elements as strontium (Sr), barium (Ba), calcium (Ca) and zinc (Zn) permit us to draw conclusions about the nutritional strategy (type of diet) of historic populations. These four substances can therefore be referred to as diet-indicating trace elements [BUKSTRA et al. 1989, RADOSEVICH 1993, SILLEEN 1989, SILLEEN and KAVANAGH 1982, SCHOENINGER 1982, PÉREZ-PEREZ and LALUEZA 1992, SCHUTKOWSKI et al. 1999, SZOSTEK et al. 2003], even though the predictive value of the Zn is somewhat disputed.

Calcium is the main constituent of bone and it is always incorporated into the bone mineral lattice in preference to any other element. Since trace elements, for example Sr and Ba, compete with Ca for position in mineral lattice, they will get into the bone only if the diet contains sufficiently large amount of these. Thus, higher levels of strontium or barium in bone are indicative of higher amounts of dietary plant food. Low levels of these elements do not automatically indicate a high meat diet, but may indicate other protein rich foods containing high amounts of calcium but low levels of Sr or Ba, such as milk products. Meat is a food item that practically defies detection because of its low min-
eral content as long as it is a part of a diet containing higher amounts of dietary minerals, for example seafood. The types of protein-rich foods consumed can be differentiated by analysing the Zn content in bone for example [SCHUTKOWSKI 2000]. The analyses of osteal zinc concentration in respect of diet reconstruction have been widely discussed in the literature. The significance of different bone Zn levels is controversial, mainly because the metabolic pathways of Zn in bone are still not fully understood at present [EZZO 1994]. However, different Zn concentrations in human and in animal bones seem to reflect trophic level differences, thus indicating variation according to feeding habits [SCHUTKOWSKI 1995, GRUPE 1998]. On the other hand, SANDFORD and VEATHER [2000] reported that the relationship between the final Zn concentration in bones and the mode of nutrition was questionable and not fully objectively documented. At the same time, however, they pointed to a positive correlation between the quantity of accumulated zinc and protein diet. While describing the usefulness of strontium and barium for determining the kind of consumed food, SCHUTKOWSKI et al. [1999] insisted that in this aspect the analysis of zinc changeability was controversial, and also proposed that the zinc accumulated in bones reflected the diversification of trophic levels which, despite its not fully recognized role in bone metabolism, could be an indicator of the diverse modes of nutrition under analysis. Similar conclusions were drawn by HERRMANN and GRUPE [1988] who reported that both Sr, Zn and Sr/Zn, in relation to the Sr/Ca ratio, could be used for determining the prevailing diet constituents in intra-population studies. WOLSPERGER [1992] and SCHUTKOWSKI [1995] indicated that the Zn/Ca and Sr/Ca ratios helped differentiate individuals in regard to consumption of main food constituents and their social position. GILBERT [after SANDFORD 1992] demonstrated that osteal Zn concentrations clearly indicated the proportion of animal protein in the diet.

Translated into main dietary components, a substantial portion of high-calcium (low Sr/Ca ratio) foods such as milk, dairy products and certain vegetables, are generally provided by dairy farming and horticulture. On the other hand, low-calcium food (high Sr/Ca ratio) shows a mixed diet derived from both agriculture and pastoralism or substantial cereal consumption, as indicated by predominant supply of food items with a lower calcium content.

The correct interpretation requires a knowledge of the concentrations of the examined elements in the soil, as well as in the bones and teeth of animals living contemporaneously with the population under study. It cannot be discounted that, in the course of their deposition in the soil, elements penetrated into bones and vice versa (diagenesis) [EZZO et al. 1995, PATE and HUTTON 1988, SILLEN 1981], yet the hitherto obtained results indicate a very low degree of probability that this phenomenon had occurred, especially in the case of strontium and zinc [PATE et al. 1989, KATZENBERG 1992]. Animal material is an excellent reference to man’s position in the food chain in the context of specific environmental, time- and culture-related conditions. Extrapolation of the content of particular elements in the material of animal origin to their concentrations in
human remains makes it possible to assess the position of individuals of the examined population in relation to herbivorous and carnivorous animals.

A detailed analysis of the concentrations of the elements under study using different statistical techniques also helps to determine social stratigraphy – position in the group and sexual dimorphism and age differentiation with respect to access to the main dietary components within the examined historical populations [Wolfesberger 1992, Schukowski 2002, Perez-Perez and Lalueza 1992, Szostek and Glab 2001]. Studies have also been conducted into the relationship between the occurrence of stress determinants and the concentration of particular elements in bones and teeth [Glen-Haduch et al. 1997].

Our study was aimed at determining the biological condition (nutritional strategy) of the Lengyel culture population from Osłonki on the basis of a physico-chemical assay of teeth, as well as ascertaining whether a relationship between the quality of nutrition and the sex and age existed, assessing the type of diet on the basis of the Sr, Zn and Ca content in human and animal teeth, and determining the interaction between the soil and the odontological material deposited in it for a period of ca 6000 years.

Materials and methods

The Neolithic population under study is represented by the remains of Lengyel culture members of the Brześć-Kujawy group. The settlement at Osłonki was dated by 24 radiocarbon dating which, when calibrated to calendar years, indicates a dating between 4300 and 4000 B.C. [Grygiel and Bogucki 1997].

The homestead constructions discovered and the preserved elements of the fortification system testify to a sedentary lifestyle of the representatives of this cultural milieu. The abundance of bovine, pig and game remnants (wild deer and wild boar, beavers, elk and fowl), together with the collected soil samples, permitted complex physicochemical studies, comprising the determination of the biological status (nutritional strategy) of the examined early Neolithic population from the region of Central Poland, to be conducted.

An abundant collection of animal bones dating back to a period earlier than 4000 B.C. was discovered within the settlement at Osłonki. An analysis of the discovered animal remains showed – apart from domesticated animals (cattle, sheep/goats, pigs) – the presence of wild species such as deer, beavers, small furry animals and water fowl. In addition, vestiges of fresh-water fish were found. In numerous pits were discovered huge quantities of artefacts (ceramics, stone tools) and carbonized grain. Studies showed that cattle were prevalent among the domesticated animals. Substantial amounts of those remains belonged to older individuals, which suggests their use as dairy animals [Grygiel and Bogucki 1997].

The Lengyel subsistence strategy in the Polish lowlands was probably based on the cultivation of grain and the keeping of domestic livestock. Domesticated pigs, well suited to the forest environment, markedly rose in their economic importance though cattle were still predominant.

The material for analyses was the whole M1 teeth of adults and children of different ages. Samples found were 27
male individuals in the age range from juvenis to senilis, 17 females (juv. – sen.), and 9 juvenile individuals at an age of infans II; a total of 53 samples. The teeth of the herbivores and omnivores represented the animal osteological samples: elk, ox, sheep and goat and pig or wild boar.

Prior to analyses, each tooth was washed in an ultrasonic washer with pure deionized water obtained from the Millipore Water Purification System in order to remove impurities in enamel microcracks/fissures. After drying in a thermostat at 60°C, the teeth were weighed using an analytic balance of accuracy 0.001 g, and were then subjected to wet mineralization in a 1:4 mixture of spectrally pure acids: perchloric (65% Suprapur, Merck) and nitric (70% Suprapur, Merck). Blind (zero) tests constituting the analysis background were also prepared with the same reagents. Weighed preparations from the soils were also made.

When the mineralization was completed, samples were quantitatively transferred to measuring flasks and diluted 25-fold with spectrally pure water.

Sr, Zn and Ca levels were then determined for the above-mentioned samples using an ICP AES ‘PLASMA 40’ spectrophotometer (Perkin Elmer). In each sample, the concentration under study was the result of three independent measurements whose error did not exceed 1%. Following weight conversion, Sr and Zn concentrations were expressed in µg/g, while Ca content was shown as a percent.

Statistical evaluation was conducted by means of the ‘STATGRAF 5 plus’ statistical package using a distribution fitting tests, analysis of variance, a regression analysis and a multivariate-cluster analysis.

**Results and discussion**

Problems with interpretation of trace elements derived from the historical osteological or odontological material are largely dependent on the processes of diagenesis. It is commonly known that the exchange of elements between the osteological material and the soil depends on a number of factors such as, e.g., the pH of soil, its absorptive properties, occurrence of micro-organisms, chemical properties (concentrations of elements) or water conditions. In this regard – depending on the burial site – bones or teeth can change their primary chemical profile to a smaller or larger extent.

Owing to physical and chemical processes, bones undergo changes in their chemical composition after death, hence examination of the grave vicinity considerably increases the efficacy of interpretation of the chemical analyses [AMBROSE 1993, PATE et al. 1989, PATE and HUTTON 1988].

Amongst the factors affecting post mortem modifications, the pH of soil plays an important role. Both too high and too low acidity may be the cause of changes in the concentrations of trace elements within mineral salt structures in teeth. Hence the neutral or close-to-neutral pH of soil is a critical condition for conducting further analyses. In order to exclude the significant effect of diagenesis on the chemical composition of the teeth under analysis, soil samples were collected and analysed according to international standards and guidelines for the analyses of trace elements in
bones [Sandford 1992]. Soil samples obtained from the direct grave vicinity had a pH value approximating neutral (6.8 – 7.2).

The collection of information about this mostly unpredictable process and the interpretation of its influence on the examined material are based (apart from the analysis of soil pH) on bone-soil interaction studies. The present study thoroughly investigated the correlation between osteal concentrations and their nearest burial environment. As a result of this analysis, no linear relationship was found between the total soil content of the examined elements and their concentration in teeth. In addition, no curvilinear relations were found. Only in the case of strontium concentration was the curvilinear regression approximate to $p = 0.1$. This result may suggest a curvilinear relation between strontium levels in the soil derived from each analysed grave and bone concentrations of this element in the teeth of individuals under study.

Diagrams 1-3 show the concentrations of the elements analysed in the present study, found in each individual’s teeth, in relation to the soil from particular burial pits. It is noteworthy that the highest levels of elements detected in the soil samples examined in no instance correspond to their higher values in the teeth of individuals from these graves.

The present study has shown for soil with a pH of soil approximating neutral, a lack of linear and curvilinear relationships (except for a curvilinear, statistically insignificant relationship in the case of strontium) between the concentrations of elements in the teeth under analysis and in the soil from the corresponding burial pits. In addition, no relationships for the soil-tooth pairs were found. Obviously, these findings do not entirely exclude the process of diagenesis, yet it can be concluded, with due caution, that the probability of changes in the tooth chemistry post-mortem was very low. Moreover, such changes – if they exist at all – do not preclude the odontologic material from any further analyses, especially as the general state of preservation of the skeletons was very good.

Prior to the statistical analyses, the normality of distributions was studied with respect to both particular elements and interelemental ratios. It was found that in the odontological material under study – irrespective of the site and species – no normalizing transformation is required, since the distributions were normal in both the Chi2 and the K-S tests.

The mean concentrations of the analysed elements and their ratio values are shown in Table 1.

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Sr</th>
<th>Zn</th>
<th>Ca</th>
<th>Sr/Ca</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human teeth</td>
<td>53</td>
<td>192.9±54.0*</td>
<td>125.8±23.7</td>
<td>29.4±4.1</td>
<td>6.57±1.63*</td>
</tr>
<tr>
<td>Animal teeth</td>
<td>10</td>
<td>340.3±81.6*</td>
<td>108.0±43.2</td>
<td>30.9±2.3</td>
<td>11.07±2.88*</td>
</tr>
<tr>
<td>Soil</td>
<td>53</td>
<td>33.5±18.5*</td>
<td>37.6±10.5*</td>
<td>1.7±0.5*</td>
<td>29.54±11.0*</td>
</tr>
</tbody>
</table>

* Statistically significant differences (ANOVA, Bonferroni test, $p < 0.05$).
Fig. 1. Strontium concentration (µg/g) in human teeth and soil from the same graves.

Fig. 2. Zinc concentration (µg/g) in human teeth and soil from the same graves.

Fig. 3. Calcium concentration (%) in human teeth and soil from the same graves.
ratios referring to both human and animal teeth from the respective sites differ significantly from those determined in soil samples. Sr, Zn and Ca concentrations in the soil are an order of magnitude lower (tab. 1, figs. 1-3) than in the osteological material and obviously differ from the latter in a statistically significant manner. Significant differences between human and animal teeth can be observed only in the case of Sr content and Sr/Ca ratio.

In order to reconstruct the modes of nutrition and access to particular food constituents, an analysis of the discrimination of particular micro- and macro elements was carried out in the trophic chain from the region where the agricultural Neolithic population under study originated. The most precise determination possible is when a full range of fauna co-occurs with human skeletal burials.

In the present study, despite the occurrence of a great number of animal remains, the authors had no typically carnivorous animal at their disposal. Therefore, it was necessary to conduct a direct comparative analysis of the concentrations of the elements examined in human teeth with reference to typically herbivorous species such as cattle, goat/sheep and elk, as well as a species regarded as relatively omnivorous, i.e., pig/wild boar. In order to determine whether the ecological niches of nutritionally homogeneous herbivorous animals and the pig/wild boar were different from the homogeneous nutritional niche occupied by a co-occurring human population, a multivariant cluster analysis was used (Fig. 4). By homogeneity is meant the stability of the elemental composition contained in food, which – due to food chains – manifests itself in final animal and human osteal concentrations.

How can an interspecies analysis of variables contribute to further interpretation?

As was actually assumed, it was found that typical, obligate herbivores were distinguished as a separate cluster (cluster 2) and had the highest values of Sr/Ca and lowest Zn levels, which significantly diverged from the mean value of cluster 1, as represented by humans.

![Fig. 4. Distribution of human and animal dietary habits represented by elements values.](image)
Besides, as is widely known, high values of the above-mentioned parameters are related to a typically vegetable diet. The distribution of clusters clearly shows that cattle and goats form a separate cluster. The cluster formed by values characteristic of a representative of the *Sus* species may testify to a diverse, more varied diet. The human cluster shows the highest variability of Zn concentration.

The biochemical background of translating nutrient intake into bone trace elements signals implies that the consumption of animal protein (meat) can only be detected indirectly in multi-component diets typical of humans by combining trace element studies with various specimens. Such specimens are routinely measured together with the human samples and are necessary for a proper paleodietary reconstruction.

In order to reconstruct the paleodiet, the Sr/Ca value can be successfully used for calculating the ratio proposed by Schoeninger (the so-called Observed Ratio; OR). The Observed Ratio represents the relation between the Sr/Ca ratios derived from determinations in humans and in animals occurring contemporaneously with them (OR = Sr/Ca human bone: Sr/Ca animal bone). The ratio clearly shows the share of products of plant and extra-vegetable origin in the diet.

In the case of herbivorous animals and omnivorous non-predators (pig/wild boar), analysed as a background to human diet, the OR Sr/Ca approximating 1.0 denotes a diet with an extremely large proportion of plants. The lower the ratio, the fewer ingredients of plant origin in a diet [Schoeninger 1982, Perez-Perez and Laluzza 1992]. In the present study, the OR in relation to all the animals examined equalled 0.59. With respect to herbivores it amounted to 0.60, and in relation to the pig the OR was 0.55.

It may therefore be proposed that the level of the analysed ratio, represented by the human population under study, amounts to ca 60% of the Sr/Ca ratio characteristic of the herbivorous fauna of that time.

In order to determine the structure and homogeneity of the human population under analysis with respect to the availability of particular diet constituents, a multivariant cluster analysis was used (Figure 5). The statistical procedure applied permitted us to distinguish three groups.

Cluster 1 consists of male individuals only, cluster 2 comprises individuals of both sexes, whereas juvenile individuals represent cluster 3. The multivariant cluster analysis indicated the possibility of existence of diverse nutritional profiles in terms of age. In regard to the Sr/Ca ratio, the cluster comprising children and main group of males and females shows the lowest concentrations, as it is known that a substantial portion of high-calcium (low Sr/Ca ratio) food to be their nutritional base, eg., milk, milk products and certain vegetables, provided generally by dairy farming and horticulture. Irrespective of age, it may also testify to the lack of both sex- and age-related social-diet paleostratigraphy in the examined group. These results are consistent with reports on diet – the egalitarian social structures found in Neolithic agricultural cultures. The group of male individuals representing cluster 3 significantly diverges from the remainder in respect of the Sr/Ca ratio. Increased low-calcium food
(high Sr/Ca ratio) in this case, showed a mixed diet derived from both agriculture and pasture or substantial cereal consumption, as indicated by predominant supply of food items with lower calcium content. This cluster is distinguished by highest Zn values. The elevated Zn concentration detected in cluster 1 does not contradict this interpretation. This conclusion is supported by comparative measurements on teeth of a pig from the site, generally believed to be an omnivorous animal. Its shows Sr/Ca ratios and Zn values very similar to the human data (see Fig. 4). This corresponds to the suggested subsistence pattern of the investigated Neolithic human group with relatively lower proportion of Zn-enriched foods, such as meat, but not excluding Zn-enriched foods such as legumes or cereal products. Possibly, the latter individuals came from different, satellite populations, which adopted diverse, mixed pastoral-agricultural feeding strategies. Hence a hypothesis about infiltration of typically agricultural cultures by the neighbouring groups with mixed adaptive strategies cannot be excluded.

The findings presented above are not in conflict with the bioarchaeological background (see: Material and Methods). A large collection of animal remains, discovered on the site at Oslonki, might at first glance suggest that the diet of Neolithic farmers who had been living there was exceptionally rich in high-protein products of animal origin (meat). The extent of animal breeding for meat compared to that aimed at obtaining dairy products is still in dispute. In the light of the performed analyses, a great amount of remains of old individuals (cattle, sheep/goats) suggests that they were not kept with the intention of eating their meat. More probably, they were suppliers of milk and milk-derived products and wool. The inhabitants of Oslonki hunted wild animal species (deer, beavers, wild fowl) and went fishing. Wild animals effectively supplemented their diet with protein which – in all probability – was however not the basic constituent of the “menu”.

Fig. 5. Social variation in dietary patterns at Oslonki denotes dietary groups based on diet-indicating trace elements of the adult and sub-adult individuals.
Conclusions

In summary, on the basis of the cluster analysis and the comparison of the OR’s obtained from archaeological sites of diverse time origin, it may be concluded that the diet of the Neolithic agricultural population, as represented by the Osłonki site, was fairly poor in protein of animal origin. It is likely that the main food constituent were plants and bulbs grown at the time, whereas milk products obtained from cattle and goat breeding added variety to that diet. It is thus assumed that domesticated animals were not the main source of nutrition of the Neolithic agricultural population from the examined site.

References


HERRMANN B., G. GRUPE, 1988, Trace element content in prehistoric cremated human remains, [in:] Trace Elements in Environmental History, G. Grupe, B. Herrmann (ed.), Springer-Verlag, Berlin, pp. 91-103


KRENZ-NIEDBAŁA M., 2000, Biologiczne i kulturowe skutki neolityzacji w populacjach ludzkich na ziemiach polskich, Monografie Instytutu Antropologii UAM, 8, Poznań

LARSEN C.S., 1997, Bioarchaeology, interpreting behaviour from the skeleton, Cambridge University Press


PATE F.D., J.T. HUTTON, K. NORRISCH, 1989, Ionic exchange between soil solution and bone: Toward a predictive model, Applied Geochemistry, 4, 303-316

PEREZ-PEREZ A., C. LALUZEA, 1992, Dietary reconstruction from historical information and trace element analysis in a medieval population from Catalonia (Spain), Int. J. Anthrop., 7, 51-57

PIONTEK J., 1999, Body size and proportions in Upper Paleolithic-Neolithic transition: Evidence from Central Europe, Monografie Instytutu Antropologii UAM, 4, Poznań


Streszczenie

Analizy makro i mikroelementów w materiale kostnym stały się ważnym narzędziem badań w antropologii fizycznej. Stworzyły one możliwość rekonstrukcji paleodziety, a dzięki temu różnych aspektów ekologii populacji historycznych i pradziejowych. Jedną z tego typu analiz jest opis koncentracji Sr, Zn i Ca w ludzkim materiale osteologicznym oraz w szczątkach zwierzących z tych samych terenów archeologicznych. Pozwala to określić proporcje zwierzęcych i roślinnych zasobów środowiskowych wykorzystywanych przez dane populacje ludzkie w aspekcie ich żywieniowych strategii adaptacyjnych.

Niniejsze badania miały na celu rekonstrukcję paleodziety grupy neolitycznych rolników z kręgu kultury lendzielskiej z Osłonek. Podjęto próbę określenia kondycji biologicznej (strategii żywieniowej) tej populacji na podstawie badań fizykochemicznych zębów, zdania czy istnieje zależność pomiędzy jakością odżywienia a płcią i wiekiem, oszacowania rodzaju diety na podstawie zawartości pierwiastków Sr, Zn i Ca w zębach ludzkich i zwierzęcych oraz określenia interakcji pomiędzy glebą a materiałem odontologicznym w niej zalegającym przez czas około 6000 lat.

Osada w Osłonkach datowana jest na 4300-4000 BC (daty kalibrowane) [GRYGIEL, BOGUCKI 1997]. Materiał do analiz stanowiły całe zęby M1 27 mężczyzn i 17 kobiet w wieku od juvenis do senilis, oraz 9 osobników młodocianych w wieku infans I i infans II, w sumie 53 próbki. Zwierzęcy materiał osteologiczny reprezentowany był przez zęby roślinożerców: losia, wołu, owcy/koszy oraz wszystkożernej świń. W próbkach oznaczono poziomy Sr, Zn i Ca przy użyciu spektrofotometru ICP AES „PLASMA 40” firmy Perkin Elmer. Koncentracja każdej próbki była wypadkową trzech niezależnych pomiarów, których błąd nie przekraczał 1%. Koncentracje Sr i Zn po przeliczeniu wągowym wyrażono w µg/g, natomiast poziom Ca w procentach.
Pobrano również próbkę gleby i poddano je analizie, zgodnie z międzynarodowymi wytycznymi i standardami dotyczącymi analiz pierwiastków śladowych w kościch [SANDFORD 1992]. Próbki gleby pochodzące z bezpośredniego otoczenia grobów posiadały pH zbliżone do obojętnej (6,8 – 7,2). Przeprowadzono dokładną analizę korelacji prosto i krzywoliniowej pomiędzy koncentracjami analizowanych pierwiastków w kościch i w glebie pochodzącej z ich najbliższego otoczenia. Nie stwierdzono żadnego związku pomiędzy całkowitym poziomem analizowanych elementów w glebie i ich koncentracją w zębach (Fig. 1-3).

W celu rekonstrukcji sposobów odżywiania i dostępu do poszczególnych składników pokarmowych zastosowano wieloziemienową analizę skupień (Fig. 4). Okazało się, zgodnie z założeniami, że typowi, zdeterminowani roślinnożercy wydzielili zostali jako osobne skupienie 2 i posiadały najwyższe, istotnie odbiegające od średniej wartości skupienia 1, reprezentowanego przez człowieka, wartości wskaźnika Sr/Ca. Jak wiadomo, wysokie poziomy wymienionych parametrów związane są z typowo roślinną diety. Na rozkładzie skupień wyraźnie widać, że było i kozy tworzą osobne skupienie. Skupienie utworzone przez wartości charakterystyczne dla świńskiej świadczy o odmiennej, bardziej urozmaiconej diecie. Skupienie reprezentujące badaną grupę neolitycznych rolników wskazuje na dużą zmienną Zn.

W celu zbadania związku struktury płciowej i wiekowej analizowanej grupy z dostępnością do poszczególnych składników diety zastosowano wieloziemienową analizę skupień (Fig. 5). Zastosowana procedura statystyczna pozwoliła na wydzielenie trzech grup. Skupienie 1 składa się jedynie z kilku osobników płci męskiej, skupienie 2 zawiera osobniki obu płci natomiast skupienie 3 reprezentowane jest przez osobników młodocianych. Najniższą wartość wskaźnika Sr/Ca przedstawia skupienie reprezentowane przez wszystkie młodociane osoby, kobiety i większość mężczyzn. Jak wiadomo, wysokowapniowa dieta (niski wskaźnik Sr/Ca) wynika z dużego udziału mleka, przetworów mlecznych i nieokreślonych produktów pochodzenia roślinnego posiadających relatywnie wysokie koncentracje Ca a niskie Sr. Skupienie reprezentujące pozostałych osobników płci męskiej odbiega istotnie pod względem wartości wskaźnika Sr/Ca. Jego podwyższenie jest najprawdopodobniej związane ze wzrostem niskowapniowej diety (wysoki wskaźnik Sr/Ca). Mogła to być dieta mieszańca z dużym udziałem produktów zbożowych, które charakteryzują się niskowapniowym profilem chemicznym oraz być może produktów pochodzących z pasterstwa. Podwyższone koncentracje Zn w obrębie tego skupienia nie mogą definitwnie sugerować dietę silnie wzbogaconą produktami pochodzenia zwierzęcego, bowiem koncentracja tego pierwiastka w wszystkożernej świń jest niemal identyczna (Fig. 4), najprawdopodobniej więc opisany poziom cynku nie jest związany z wysokoproteinową dietę męską.

Podsumowując możemy stwierdzić, że mężczyźni nie odbiegają od kobiet w zakresie wskaźnika Sr/Ca oraz bezpośrednich koncentracji Sr i Zn. Może to świadczyć o wysokim eglitycznym żywieniowym w aspekcie płci i wieku badanej grupy.