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ANIMAL BONES AS A SOURCE OF CALCIUM FOR MESOLITHIC MAN

Animal bone remains in most Mesolithic sites on the terrain of Poland are very often highly fragmented and burned. It seems that after having been burned they were ground or pulverised. Such state of bones suggests that Mesolithic man produced bone powder, which might have been consumed in order to supplement calcium level in diet. Calcium contents in water and nutritive products achievable in Mesolithic period was too low to cover the demand of the organism for this element. In medicine and veterinary there are also examples for use of untypical sources of calcium.

From a general evaluation of a state of Mesolithic bone remains and probable calcium deficiency in diet we hypothesise that for Mesolithic man animal bones were a supplementary source of calcium.

KEY WORDS: Mesolithic, diet, calcium, bone fragmentation

1. INTRODUCTION

This work had been inspired by a so far unexplained fact that animal bones from the Mesolithic period are very often highly fragmented, burned and their external surface is damaged. This fact applies to most Polish sites but also sites in western Europe.

A probable cause of such state of bones was their burning, grinding and pulverisation.

There has been a preliminary hypothesis saying that these actions aimed at obtention of bone powder, whose consumption would supplement calcium in diet.

2. THE ROLE OF CALCIUM IN AN ORGANISM

Calcium (Calcium, Ca) is a permanent component of human and animal organisms. It constitutes around 40% of total amount of mineral compounds in an organism (Malinowska, 1986). In a body of an adult man weighting 70 kg there is about 1200 g of calcium (Szczygieł, et al., 1987). Up to 99% of calcium is a part of bones and teeth. The rest is found in cells and tissue fluids, participating in metabolic reactions. For example, calcium is inevitable for proper action of skeletal and cardiac muscles. It participates in nerve impulses conduction as well as blood coagulation process.

In case of calcium deficiency in an organism, the development of skeleton and teeth is disturbed. In children, calcium deficiency may lead to rachitis. In adults, bones are resorbed which leads to osteoporosis and bone fragility.

An organism is provided with calcium contained in food. Absorption takes place in alimentary duct and depends on many factors: composition and digestibility of the food, kind of compounds containing the element, presence of substances binding or facilitating its absorption as well as proportion of calcium and phosphorus in gastric content (Szczygieł, et al., 1987). In the efect, calcium absorption is not higher than 40% of its contents in food (Ziemlański, et al., 1994).

3. OCCURRENCE OF CALCIUM IN NATURE

Calcium occurs in nature in the shape of very common compounds rock-forming minerals, mainly calcite, aragonite, dolomite, gypsum, anhydrite, fluorite, apatite. From the rocks calcium gets into passing-by water as well as, directly and indirectly, into soil. From soil and water calcium is taken by plants, and from plants and water – by animals.

Man can consume calcium with water, plants and nutritive products of animal origin.

1. Water

Calcium contents in water depends on many physical and chemical factors as well as biological life. Current data suggest that water in Polish rivers contains average of 50 to 130 mg of calcium per litre. Higher an lower values are also reported (Państwowa Inspekcja Środowiska, 1955). Calcium contents in lakes is even lower. It is known that because of higher content of phosphates and higher number of bacteria in water, current calcium concentration is lower than in the past.

2. Plants

Calcium in plants appears mostly in the shape of carbonates which are easily assimilated by man. However, in some plants (e.g. in spinach) calcium occurs in the shape of non-assimilative calcium oxalate (Chroboczek, 1964). Grains, seeds and underground parts of plants (root crops) contain the smallest amount of calcium. More calcium occurs in green parts of plants (leaves and stalks) (Table 1). Nettle (Urtica) contains the highest amount of calcium. Also green parts of lupin, lucerne and leaves of beet, carrot and rutabaga contain a lot of calcium. Of course, these data apply to currently cultivated plants, however, these values allow us to estimate probable level of calcium in wild plants.

3. Animals

Calcium occurs in organisms of all animals, however, for a man its only important source is skeletons of vertebrates and some invertebrates.

In the bodies of vertebrates calcium occurs mainly in bones. Soft tissues contain much less of this element (Table 2).

Also milk is a very important source of calcium. Assimilation of this element from milk is very good thanks to a proper proportion of calcium and phosphorus. Quite a lot of calcium is found in hen's eggs. According to Ruszczyc (1985) in 100 g of eggs there is 55 mg of calcium. Also egg-shells are an important source of calcium.

Skeletons of many invertebrate are mainly formed by calcium carbonate. Such skeletons are found in some Protozoa (Foraminifera, Radiolaria), in Coelenterata (Spongia), in Anthozoa as well as Mollusca (snails, molluscs) and in some Echinodermata.

Table 1. Calcium and phosphorus contents (in g) in 1 kg of dry matter of different plants (cited after R. Ryś, 1981)

Occurrence	Calcium	Phopshoru
GREEN PARTS		
Pea and field pea	14.4	3.5
Rutabaga	20.0	4.7
White cabbage	5.6	3.0
Beet	11.5	3.3
Carrot	20.3	2.6
Lucerne	20.3	3.0
Lupin	23.1	2.8
Nettle	34.8	5.5
ROOTS		
Rutabaga	4.6	3.8
Beet	3.1	1.6
Carrot	4.0	3.5
Turnip	6.0	4.3
Potato	0.7	2.6
SEEDS AND GRAINS		
Horse bean	1.5	5.7
Pea	1.5	4.7
Buckwheat	1.0	3.7
Barley	0.8	4.2
Plax	2.5	5.7
Oat	1.2	3.8
Millet	0.5	3.5
Wheat	0.6	4.0
Sunflower	2.5	6.9
Soya bean	2.8	6.6
Rye	0.8	3.6
Acorn	1.3	1.3

Table 2. Calcium and phosphorus contents in some body parts, in blood and cattle milk (g in 1000g of a substance) cited after D. Kellmer and M. Becker, 1978)

Occurrence	Calcium	Phosphoru
Blood	0.05	0.18
Cartilage	0.96	0.19
Muscles	0.02	2.70
Liver	0.32	2.78
Brain	0.16	4.33
Bones	82.70	37.90
Milk	1.21	0.92

4. MAN'S DEMAND FOR CALCIUM AND POSSIBILITY OF DIET COVERAGE

Man's demand for calcium is quite stable, does not depend on age, sex, physiological state and physical activity (Table 3). Daily demand of children aged 0 to 9 years is only slightly lower than adults. Considering small body weight, relative demand in children is high. Women have similar demand as men and only in the pregnancy and breast-feeding period their diet should be richer in calcium.

Usually man should consume 1-1.2 g of calcium daily. Szczygieł's (1956) estimates say that to obtain this level man should daily eat 1.3 kg flour or 45 eggs, 10 kg potatoes, 2,6 kg cabbage, 4 kg meat, but only 1 litre milk or 10 dag meat-and-bone meal (Ruszczyc, 1985).

Because of ecological and cultural differences in diets of many nations big differences in calcium supply are observed. For example Japanese consuming mainly rise obtain 0.4 g calcium daily, while Fins, for whom dairy products are the basic nutrition, obtain up to 5,3 g (Nyrek, 1987).

In Mesolithic period milk and its products were not accessible for people beyond babyhood. Thus, the most important source of calcium did not exist. Meat and blood, because of low calcium contents were not able to cover the daily demand. There is no doubt that man ate birds eggs, but coverage of daily demand for calcium would have been possible if 2 kg eggs had been eaten. Achievement and consumption of such amount of eggs would have been very difficult. Besides, eggs could only be found in birds' nesting period. We should remember that egg-shells which after pulverisation could have been eaten, are also a very important source of calcium.

Surely fruit and plants' seeds such as nuts, acorns, seeds and soft fruits were eaten. Calcium contents in these products is so low that they could not constitute an important source of this element. The same applies to plants' roots. Green parts of plants, e.g. leaves of nettle or pulse crops were better. However, because of the climate during the bigger part of year this source could not be achieved.

In case of non-freezing water reservoirs, water was a good source of calcium. However, it had a supplementary meaning, because the contents of calcium in water is too low to cover the daily demand. In the climate of central and northern Europe water in rivers and lakes freezes. Drinking water from snow did not have any meaning for covering calcium demand because such water is called „soft" and does not contain high amounts of elements.

Table 3. Recommended daily consumption of calcium and phosphorus for humans (in mg) (according to A. Szczygieł et al., 1987 and Ziemlański et al., 1994)

Age group, sex and physiological state	Calcium	Phosphoru
Children 0-0.5	600	300
Children 0.5-1.0	800	500
Children 1-3	800-1000	1000
Children 4-9	800	800
Adolescents 10-25	1200	900
Adults over 25	900	700
Women over 60	1100	900
Pregnant and feeding women	1200	900

Summarising the above considerations we might assume that Mesolithic people living on the terrain characterised by short period of vegetation were exposed to calcium deficiency effects. Deficiency might have been periodical, but this period in geographical width of Poland and central Europe was long, as it lasted at least for 8 months. Such situation might have resulted in pathological states.

In literature describing pathological changes on human bones in primeval history there are reports of occurrence of rickets in the skeletons of Mesolithic period (Brothwell, 1967, cited after Gładykowska-Rzeczycka, 1989). This may not however be treated as a prevailing finding. For example in numerous Mesolithic human skeletons from the terrain of Denmark there were no traces of rickets. It is suggested that these people's diet based mainly on sea fauna (Nielsen and Petersen, 1993).

During the time of inability to balance the diet with standard food, people could use untypical sources, very rich in calcium. These might have been shells of molluscs and bones of vertebrates. These would be bones of mammals, eventually reptiles, amphibians and fish. Birds' bones do not seem so good because of their hardness and sharp edges in the place of fracture.

5. REASONS FOR CONSUMPTION OF BONES BY MAN

From the point of view of a contemporary consumer a bone is not tasty and its view does not whet appetite. However, people's taste in the past might have been different than it is now. Even if we assume that there is eternal taste, we have to consider different reaction in case of serious dietetic deficiencies. High deficiency of calcium in an organism gives a stimulus for searching for food rich in calcium, which may even

be strange for daily diet. Paediatrics knows the phenomenon of eating school chalk by poor children or making holes in walls in order to eat calciferous mortar. One of the authors of current article (A. L.-M.) also had such experiences during the period of her childhood which fell on years right after the Second World War. In the 60's, the author observed similar inclination in country children in neglected regions of Poland (Kurpie and Suwalszczyzna).

In veterinary medicine there is a phenomenon of osteophagia, which means eating bones. Stankiewicz (1960) reports that it is especially common in southern and western Africa in cattle but also sheep and goat, mainly in the pregnancy and feeding period, eventually in case of drought and lack of green plants. One of authors, being a veterinary doctor (H. K.) met this phenomenon on the terrain of Poland. In pathological states resulting from calcium, phosphorus and D vitamin deficiency (osteomalacia) in animals there is a symptom called „salt-lick". Animals lick different object in their environment, especially walls covered with mortar (Hutyra et al., 1962). Periodically grass-eating animals lick or gnaw bones. Literature describing this phenomenon has been summarised in Lyman's work (1994). From time to time rodents gnaw bones. Hansson (1990) says: „Bones and antlers of moose and reindeer found on the ground in northern Sweden are often heavily gnawed by small rodents. This bone gnawing, supplying no energy, has been suggested to depend on body deficients of phosphorus or possibly calcium or sodium".

After gnawing bones, the animals leave traces so typical that on their base it is often possible to determine construction of teeth of the gnawing animal. In archaeozoologic materials there are no traces that would prove the fact that man gnawed bones. Binford (1981) says that Eskimos he evaluated loved to gnaw cartilage on the edge of scapula and spinal processes but after this action no teeth traces were left.

There is a possibility that animal bones could have been ground and eaten in the shape of powder. To evaluate this suggestion we closely studied bone remains from three Mesolithic sites from the terrain of northern and eastern Poland: Miłuki (Brzozowski and Siemaszko, 1996), Łajty (Sulgostowska, 1996), Luta (Chmielewska, Więckowska, unpublished). Animal remains were evaluated by one of authors (A. L.-M.). Bones originating from these sites looked similar and had the following features:

1. They were seriously burned. This feature applied to 60-70% of remains from the Miluki and Luta sites. In the Łajty site there have been bones greatly differing in their state. In one set of bones 100% of them were burned, in another only 57%. It has been stated that the colour of burned bones was usually black, there has been a slightly lower number of white bones and some grey. Black bones were burned in low temperature (300-400^{0}C) while white and grey colour proves burning in high temperature (800-1000^{0}C). The difference might have been a result of bones' localisation in fire or many kinds of wood burning at the same time.

2. There has been great percentage of fragmented bones (Fig. 1). About 90% of bones in Miłuki and Luta could not be identified which proves their fragmentation beyond the possibility of evaluation of their anatomical and species specific features. Fragmentation applied equally to burned and non-burned bones. In Łajty this percentage was smaller because there has been about 8% of unbroken bones or bones broken into big pieces of a few centimetres. These bones were not burned and were found on the slopes of an island, where water coverage enabled good conservation. There were obviously not used remains after consumption of meat.

3. The look of bones suggested that they must have been ground which resulted in destruction of their external surface. Lack of this sculpture differed them from burned, non-ground bones. Burned, non-ground bones are an often finding in cremation cemeteries, e.g. in Kamieńczyk and Nadkole (archaeozoologic studies of A. L.-M.), and their degree of fragmentation is very similar to Mesolithic bones.

Lack of external sculpture on the bones originating from Mesolithic sites has been found on burned bones as well as non-burned bones. Only big and non-burned pieces of bones from Łajty had an intact surface.

Bone fragmentation in Mesolithic sites is a phenomenon exceeding the terrain of Poland. It is reported by Chaix (1991), researcher of osteologic material from the terrain of Switzerland and France. Describing material from the terrain of Alps, he says: „The Mesolithic material is always very fragmented, with a low identification rate. On the other hand, the faunal remains from large Neolithic sites have better preserved bones, which are always less fragmented".

There are also Mesolithic sites in which animal bones are not very fragmented. The example is Chwalim (province of Zielona Góra) (Gautier, Kobusiewicz, 1992). On another site, in Dudka, bones were not burned although they were fragmented. The author wrote: „These bones are intensively fragmented", adding however that „the fragmentation is the result of processes of degradation" (Gumiński, 1995).

Considering described above features of bones from three evaluated sites as well as undoubtedly appearing locally and periodically calcium deficiencies in diet the following hypothesis seems logical: man in Mesolithic period used animal bones as a source of calcium. In order to prepare bones for consumption,

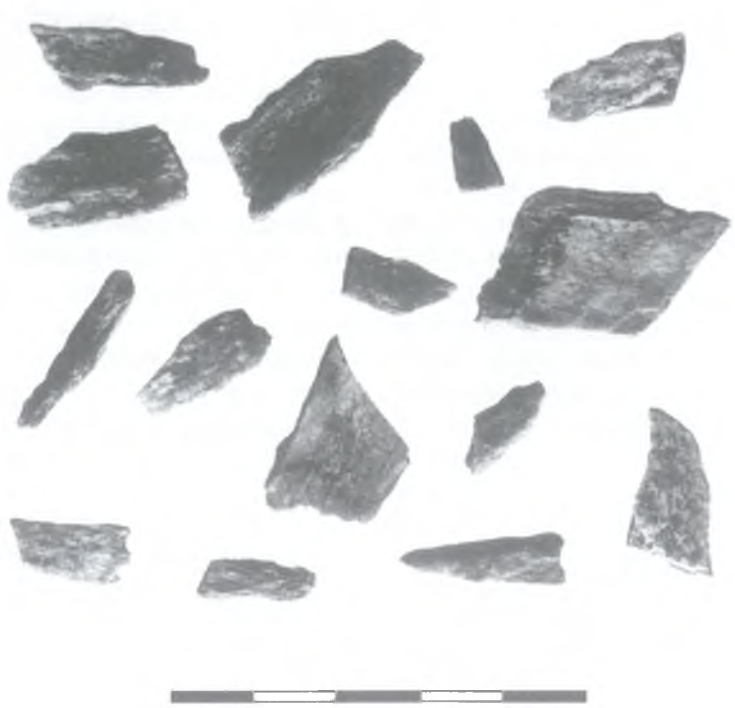

Fig. 1. Fragmented animal bones from the Mesolithic site in Miłuki (Photo by M. Kowalewski)

man had to pulverise them. This could have been achieved with use of stones. In Łajty, among a few dozens of stones purposefully brought on the island there were hammer stones, polishers and cutting tools. Similar types of stone tools were also found in Miłuki. However, there are no proves that they were used to pulverise bones. Stones found in Mesolithic sites should be especially studied for traces from grinding. Macroscopic observations are not fully reliable. Stones that look like they were used by man should be subjected to a microscopic study.

It is hard to say if often bone burning was connected in any way with their preparation for grinding. Eventual connection is proven by the fact that a bone during burning fragments and loses its organic matrix giving it flexibility. This is why burned bone is fragile and may be ground more easily. This connection does not reject quite common hypothesis that bones were used as combustibles. They might have been burned in order to obtain energy and then small pieces after burning might have been pulverised. However, the concept of use of bones as combustibles has another weak point: Mesolithic man on the terrain of Poland could not suffer lack of combustibles. As wood could have been found all around, the need for burning bones did not exist. On the Preboreal sites in Miluki and Łajty, great amounts of charcoal were found. If we accept the suggestion that bones were burned in order to be prepared for grinding we still have to take into consideration that their burning was not obligatory.

Considering the reasons for burning bones we should remember that burning for hygienic purposes could also be an option. However, lack of this habit in Neolithic age would be strange in settlement functioning much longer than camps or other living places of Mesolithic people.

It seems very probable that an additional source of calcium, except bones, were shells of molluscs. They are easily accessible because they appear in the sea as well as fresh, lentic and lotic water. At the moment pulverised oysters' shells are administered to people with osteoporosis (Fujita et al., 1996). Shells must have been collected before winter, when water was not frozen, and then they could have been stored on the terrain of the camp. Storage holes were the most common places where shells could have been collected.

Peat and lake water samples were taken from the surrounding of two Mesolithic sites: Łajty and Miłuki. Water from the lake placed near Miłuki had 27 mg Ca in 1 litre of water. In 1000 g of fresh mass of peat from Łajty there was 266.7 mg of soluble calcium. The contents of calcium in the evaluated sample of water is too low to constitute an important source of this element. Peat contains much more calcium but its accessibility for man is problematic.

6. SOURCES OF CALCIUM IN THE DIET OF PALAEOLITHIC AND NEOLITHIC MAN

Palaeolithic man's diet must have been very similar to the diet in Mesolithic period, because sources of food were the same: collecting and hunting. Periodically there were only differences in composition of fauna and flora. However there is no reason to think that reindeer's or mammoth's meat contained much more calcium than horse's or deer's meat. For sure, in Palaeolithic as well as in Mesolithic age, there have been periodic calcium deficiencies. In palaeontologic sites of Poland and central Europe we should expect fragmented bones, just like in Mesolithic sites.

In limited archaeozoologic literature concerning this age, there are few reports of fragmented bones. On upper Palaeolithic site in Dolne Vestonice (Moravia) in fire-places there were many, small bones of a mammoth. They were burned. Besides, researchers found figures made of clay with an addition of burned bones (Klima, 1983). Most animal remains from Palaeolithic age originate from cave sites. In caves, the state of remains was usually very good. This was the case of Obłazowa cave (Nadachowski and Wolsan, 1987) as well as Zawalona cave (Alexandrowicz et al., 1992). There are also other situations. In a late Palaeolithic site in Jaskinia Maszycka (Maszycka cave), animal bones were mostly big or quite big (Lasota-Moskalewska, 1993). Only a part of bones found on the terrace in front of the cave was very fragmented and had damaged external surface. In the case of Maszycka cave there is certainty that animal bones are remains after meat consumption by people living in the cave. If there are no traces of carcass partitioning, or they were not evaluated, we may not be sure as to post-consumption character of the remains. Because of high contents of birds', insect-eating mammals', rodents' and small carnivores' bones, this may be problematic.

In the period of younger stone age, in Neolithic age, sources of food changed radically: plant cultivation was started and first animals were bred. Plant cultivation could ameliorate calcium supply if there was a possibility of storage of plants' green parts for winter time. However, it seems quite improbable, although desiccation of leaves and their consumption cannot be excluded. Nevertheless, the most important was breeding, which gave the possibility of full supply with calcium by the means of animal milk. There is a question if milk has been used in diet since the beginning of breeding or even raising. Some prehistoric diet researchers question the role of milk in Neolithic period because of impossibility of digestion of a carbohydrate occurring in it – lactose. This carbohydrate is resolved by an enzyme – lactase. At our times some people have lactase deficiency and cannot use milk. In their case drinking milk results in gastric problems. We should consider reasons for which this metabolic disorder occurs and possibility of its occurrence in Neolithic people. Lactase occurs in all children and is necessary for mother's milk digestion. About 4-5 year of life its activity falls down, and in some cases appears the state called in medicine hypolactasia. Such state occurs with different frequency in different populations. It ranges from 5% up to nearly 100% (Sahi, 1994). The lowest occurrence is found in north-western Europe , and the highest, in Far East. Changing lactase activity is connected with culture factors. In populations, where there is no drinking milk tradition, hypolactasia occurrence is very high.

There are no reasons to suspect that in Neolithic age there were culture reasons for milk avoidance. If there were no such reasons, the occurrence of hypolactasia should be low. The whole problem applies to sweet milk. Sour milk as well as milk products may be digested no matter what is the activity of lactase (Tamm, 1994). That is why we can suspect that Neolithic man used milk as a source of calcium. The only problem could have been milk supply. In early breeding cattle might not give much milk, as we do not know since when lactation period has been prolonged. In this topic we may only speculate. Wild cattle's ancestor – aurochs used to give as much milk, as it needed to feed its calf. It could be 300-400 litres a year. Lactation period lasted 6 months, as this is how long it lasts in currently living animals of the same family. Lactation prolongation must have been connected with a serious change in animals' physiology. In animal organism there must have occurred deficiency of calcium and phosphorus. According to current rules of cattle feeding, a cow giving 4500 litres of milk a year excretes from its organism 5.5 kg calcium and 4.4 kg phosphorus (Gancarz, 1972). As both elements constitute the most important component of bones, offspring of milked cows should have an undeveloped skeleton because of calcium deficiency in mother's organism. The size of cattle from the beginning of Neolithic age was smaller than the size of aurochs. In Linear Pottery culture, average withers height was about 20-30 cm smaller than average height of wild animals (Lasota-Moskalewska, 1989). This result lets us think that in Neolithic cattle there could be a serious deficiency of calcium resulting from necessity to give milk for a period longer than in nature, with unchanged conditions of feeding. We know very little about cattle feeding in this period. Theoretically it could be the same as aurochs feeding, as we are sure that pasturage took place in forests and not meadow. It was experimentally proven that in rats diet with small contents of calcium and phosphorus deteriora-

tes skeleton development, leading to smaller size of animal and rickets (Abugassa and Svensson, 1990). It was also stated that bad feeding during the period of pregnancy results in slower development of foetus (Luke, 1994). Although the research applies to people, basic physiological mechanisms are similar in all mammals. Early breeders surely obtained milk mainly from cattle, but we should not forget that also goats and sheeps gave milk. Osteologic materials show that very high numbers of cattle were bred on the terrain of Polish low-land. However, because of the early stage of domestication, it did not have to be a sufficient source of milk. Cows that calved in spring gave milk during 6 months plus several months forced by man. There were surely 2-3 winter-spring months, when calcium deficiency in diet could have occurred. It seems that such a short-term deficiency was unnoticeable. Sporadically, it could have been covered by another, untypical source, like pulverised mollusc's shells. Shells are found in many Neolithic sites on the terrain of Poland. In some of them, like for example Kamień Łukawski, several thousand shells were found in deep holes (Krysiak and Lasota, 1970). In Neolithic sites no fragmented, ground bones similar to Mesolithic remains, are found. Thus, we might suspect that man stopped using bones as a source of calcium.

7. CONCLUSIONS

On the base of the above reasoning it seems probable that Mesolithic (as well as Palaeolithic) man suffered calcium deficiency in his diet. The deficiency was highest during winter, when no plants' green parts could have been found and water was frozen. Calcium deficiency could have been covered by eating pulverised bones and locally, pulverised molluscs' shells. Fragmented, ground bones are found in most Mesolithic sites in Poland. Bones were no longer supplementary source of calcium in the Neolithic period, when domestic animals' milk has been introduced into man's diet.

SUMMARY

This work had been inspired by a so far unexplained fact that animal bones from the Mesolithic period are very often highly fragmented, burned and their external surface is damaged (Fig. 1). A probable cause of such state of bones was their burning, grinding and pulverisation.

There has been a preliminary hypothesis saying that these actions aimed at obtention of bone powder, whose consumption would supplement calcium deficiency in a human organism.

We have discussed main sources of calcium in nature, their availability and possibility of use by Mesolithic people. For comparison, we have also discussed the possible diet of people in Palaeolithic and Neolithic age.

In nature there are three main sources of calcium: water, plants and animals. Calcium contents in water of all natural reservoirs is very low. Besides, in the climatic zone of European depression water is frozen for several months a year. In plants, calcium is mainly found in green parts. With short period of vegetation, there are only few months when this source does not have any important role.

In animals' bodies calcium is accumulated in bones, teeth, egg-shells and skeletons of some invertebrates.

From the review of all calcium sources in nature, as well as their availability for Mesolithic people we may conclude that during the winter and spring period there could be a serious deficiency of this element in diet. Such deficiency could have been balanced with use of untypical sources, like bones. During the same seasons of year all herbivorous animals and rodents gnaw bones, saving their skeletons from decalcification.

On the base of archaeozoologic materials from three Mesolithic sites: Miłuki, Łajty and Luta, we described bones which might have been ground into powder.

Economical similarities show that the diet of Palaeolithic people should be similar to Mesolithic man. However, there are no archaeozoologic materials that would prove such hypothesis.

In Neolithic sites animal bones are different: they are not fragmented in a similar degree; there are many unbroken bones and burning is quite rare. It is sure that these bones were not fragmented after consumption of meat, so they also could not have been eaten. This change may be connected with the fact of domestication of animals and the possibility to use their milk, being the most important source of calcium among nutritive products.

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