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New Aspects to the Diet of the Neolithic Tyrolean Iceman "Ötzi"

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Abstract

Three surgical interventions on the Tyrolean Iceman "Ötzi" conducted in 1995, 1997 and 2000 resulted in the collection of five ingesta samples. These samples constitute a sequence from different consecutive locations of the intestinal tract: the ileum, the transverse and descendent colon, as well as the rectum. The samples encompass at least three different meals consumed of the Iceman during his last two days, which is shown by numerical analysis of the pollen flora and muscle fibres incorporated in the different ingesta samples. The macro and pollen analyses of these samples reveal that the Iceman consumed a well balanced omnivore diet. Surprising is the strong correlation between bracken (Pteridium aquilinum) spores and human whipworm (Trichuris trichiura) eggs as well as wheat (Triticum) pollen. This indicates an intentional consumption of bracken as anthelminthic or as starch plant.

Introduction

The Neolithic Iceman "Ötzi", discovered in the permanent ice of the Tyrolean Alps (Lippert and Spindler 1991, Spindler 1993), discloses a new and exciting dimension for the prehistory of the Alps. The unique state of preservation of the glacier mummy enables a detailed study of his way of living by different disciplines. This includes also the investigation of his food residue in his intestines to reveal information about his nutritional status, the bodily constitution and to gain new insights into the diet of Neolithic man. First analyses of an ingesta sample from the transverse colon showed that the Iceman had consumed a farinaceous dish made of einkorn (*Triticum monococcum*), vegetables and meat reflecting a well balanced omnivorous diet (Oeggl 1999, 2000, Dickson et al. 2000). These results disagree with the conclusions drawn of the stable nitrogen and carbon isotopic analysis of the Iceman's hair (Macko et al. 1999). They suggest that the stable nitrogen composition is consistent with that observed of modern vegans. Thus four new ingesta samples of Ötzi´s intestines are investigated by pollen and macro remain analysis to reveal whether his consumption of an omnivorous diet was an exception to his usual nutrition regime.

Material

The ingesta samples were extracted from Ötzi´s intestines by separate surgical interventions in 1995, 1997 and in September, 25th, 2000, on the occasion when the Iceman was defrosted for the first time since his discovery. This resulted in the collection of four new ingesta samples from the terminal small intestine (named "ileum" in this paper) about 10 – 15 cm before the iliocaecal valve, the transverse colon (named "colon 1" in this paper), the colon sigmoideum (named "colon 3" in this paper) and one from the rectum. These samples were kept in deep-freeze for the analysis of pollen and macro remains. The sample preparation techniques for pollen and macro remain analyses were carried out according to the method described by Oeggl (2000). The "colon 2" sample derives also from the transversal section of the colon: It was removed endoscopically and analysed already in 1995 (Oeggl 1999, 2000). The light microscope investigations were carried out under magnifications of x750 and x1200 with the aid of phase contrast and interference contrast.

Results

Pollen

The pollen composition of the ingesta samples is complex and may have derived from different sources. Thus, for a better understanding of the ingesta pollen spectra it needs some explanations to understand how pollen becomes incorporated in the food residues of the Iceman´s intestines. One way much pollen becomes ingested is by adherence to the consumed food plants. Such pollen types

are classified as "economic pollen" and they yield information about the diet or other ethnobotanical usage of the plant. On the other hand, the pollen content of the atmosphere is unintentionally incorporated in the food residue by breathing or drinking water. These pollen are defined as "background pollen" which reflect the general composition of the vegetation in which the man lived. This classification proposed by Bryant (1974) is also used in the following.

The results of the pollen analysis of the five ingesta samples are given in Figure 1. The most prominent economic pollen is that of wheat (*Triticum*-type), which is found in recognizable quantities in all samples. Only in the colon 2

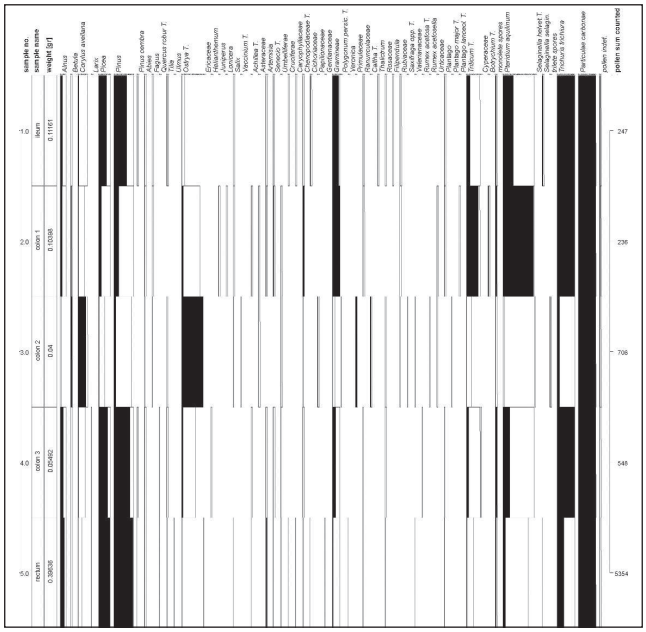

Fig. 1 - Pollen analyses of the sequential ingesta samples. The results are presented as a percentage diagram.

sample this pollen shows minor quantities, which is most probably due to the highly processed cereals in this meal (Oeggl 2000). Also bracken (*Pteridium aquilinum*) achieves remarkable high values in all samples showing nearly a concurrent curve like the *Triticum*-type. Additional the chenopods (Chenopodiaceae) in the ileum and colon 1 samples, as well as the primrose family (Primulaceae), the legumes (Papilionaceae) and the kingcup pollen (*Caltha*-type) in the colon 2 sample may have been part of his meals, because they exceed the limit of 2% in the food residue indicating intentional consumption (Sobolik 1988). Besides these diaspores the high amount of carbon particles is noticeable in all samples (Fig. 1). A lot of them are identified as charred fragments of coniferous wood, but some are cindery and unidentifiable. Nevertheless, they are consumed with the food and indicate its preparation on open fire.

At least many eggs of the human whipworm (*Trichuris trichiura*) are detected in the intestine samples, which are the oldest evidence of whipworm in a human corpse so far (Aspöck et al. 2000). The highest values occur in the ileum, the colon 1 and colon 3 sample (Fig. 1); parts of the intestine where this endoparasite preferable lives.

Macro remains

The majority of the plant macro remains in the ingesta belongs to cereals (Fig. 2). The lots of fragments of bran, glumes and awns derive from wheat (*Triticum*) and a closer investigation of the pericarp and testa remains revealed that they belong to einkorn (*Triticum monococcum*). In small quantities but worth to mention is a chenopod seed (Chenopodiaceae) in colon sample 1 as well as the consistent occurrence of bracken (*Pteridium aquilinum*) sporangia in all samples. Both evidences confirm the pollen analysis and thus suggest an intentional consumption of these plant remains.

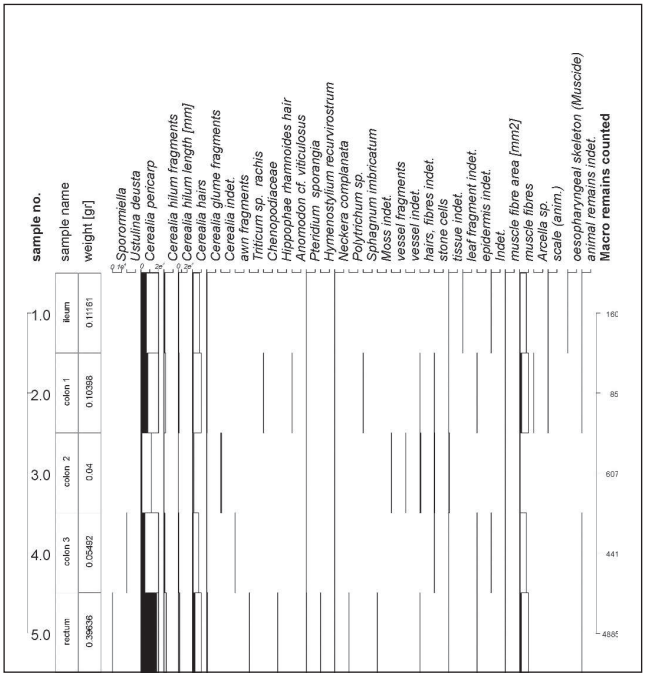

Fig. 2 - Macro remain analysis of the sequential ingesta samples. The results are given in their absolute numbers.

Furthermore, several other tissues and cell types like vascular bundles, vessel elements, stone cells, etc. are also recorded. They are difficult to determine to the species level, because they occur in several families with edible plants (e.g. Rosaceae, Papilionaceae, etc.), but nevertheless they document that vegetables have been also part of his meals.

Alongside these remains also diatoms (Rott 2000), mineral particles, mosses, and muscle fibres are identified. Mineral particles are consumed unintentionally either by drinking water or as grinding residue of the cereal processing. Several mosses (*Anomodon* cf. *viticulosus, Hymenostylilum recurvirostrum, Neckera complanata, Polytrichum* sp., *Sphagnum* sp.) are recorded from the intestine samples (Dickson et al. 2005), which are certainly accidentally consumed, because there is no evidence that humans have ever eaten mosses. *Neckera complanata*, which was used commonly for wrapping, packing, stuffing and wiping in prehistoric times, is found consistently in the samples and Dickson (1997, 2000) suggests that the Iceman used it as wrapping for provisions. Muscle fibres are recognized in all samples (Fig. 2) documenting the consumption of meat. High absolute values are recorded in all samples with the exception of

the colon 2 sample. Anyway it has to be considered that the fibres may be fragmented in the course of the chemical treatment of the samples. Therefore beside the number of fibres also the muscle fibre area for each sample was determined, due to possible fragmentation and a resulting overrepresentation of this feature. The curve of the muscle fibre area shows that respectively in the ileum and the colon 1 sample a lot of muscle fibres occur, although a rarefaction due to digestion in the other samples from the lower parts of his intestines has to be included.

Discussion

The results from new investigated ingesta samples from the Iceman confirm the conclusions drawn from the single test specimen analysed in 1995 (Oeggl 2000), that the Iceman fed on a well balanced omnivorous diet based on cereals, vegetables and meat. However, the question is, if all these investigated sequential samples reflect one or more meals. According to the mean gastrointestinal transit times of about 14 – 55 h for a middle aged healthy man (Graff et al. 2001), it is highly probably that they reflect more meals. To test this hypothesis a hierarchical cluster analysis of the ingesta pollen spectra is carried out, because the background pollen of the individual samples will be different if the meals were consumed in different habitats. This cluster analysis reveals, what is clearly visible to the naked eye (Fig. 1). The ileum and colon 1 samples are very similar in their predominance of spruce (*Picea*) and pine (*Pinus*) pollen as well as the colon 3 and rectum sample. These samples are separated by the colon 2 sample, which is predominated by hop hornbeam (*Ostrya carpinifolia*) and hazel (*Corylus avellana*) pollen indicating a complete different habitat of meal consumption. This suggests that the five sequential samples reflect at least three different meals, which seems plausible in consideration of the gastrointestinal transit times mentioned above. Additional weight is added to this assumption by DNA analyses of two separate intesta samples from the ileum and sigmoid colon conducted by Rollo et al. (2002). They reveal that the meat in the ileum originates from red deer (*Cervus elaphus*) and in the sigmoid colon from ibex (*Capra ibex*). This corroborates that the ingesta from upper and the lower parts of his intestines derive from different meals, and thus the consistent occurrence of meat in all ingesta samples documents that animal protein was an essential part of his diet in his last days. Remarkable are the high proportions of bracken (*Pteridium aquilinum*) in the ingesta samples (Fig. 1). The evidence of spores and sporangia indicates that bracken was ingested intentionally. Such a consumption would be no surprise, because bracken (*Pteridium aquilinum*) is found all over the world except the extreme north and south and has the most varied ethnobotanical use of all the ferns (May 1978). It is and was used by indigenous people as food, medical plant as well as for technical purposes. The young fronds and the starchy rhizomes were and are eaten still by natives in Australia, Japan, New Zealand and Northern America. The rhizome was also collected, dried and ground into flour, which was mixed with cereal meal to produce bread. The technical uses of entire fronds were for thatching houses, bedding for both humans and life-stock, a source for a yellow dye as well as for packing provisions to prevent decay. The astringent properties of the rhizome were utilised as an anthelmintic as well as for the dressing and preparation of kid and chamois leather, but also the green leaves were eaten as purgative in case of dyspepsia.

Anyway, the ingestion of bracken (*Pteridium aquilinum*) spores and sporangia in connection with food is supported by the high correlation (Fig. 3) of bracken (*Pteridium aquilinum*) spores with pollen of wheat (*Triticum*-type). In case of the consumption of the starchy rhizome or its products only a small amount of bracken (*Pteridium aquilinum*) spores is expected, because the fronds with the sporangia are cut off before processing the rhizomes (Norton 1979). The high quantities of the bracken remains require a direct contact with bracken fronds in case of its use as a packing material for provisions or direct consumption of the leaves. The latter seems the most plausible explanation because no remains of bracken (*Pteridium aquilinum*) could have been detected in hundreds of sediment samples investigated from the discovery place investigated so far. Its medical indication is supported also by the high correlation between bracken (*Pteridium aquilinum*) spores and the eggs of the human whipworm (*Trichuris trichiura*).

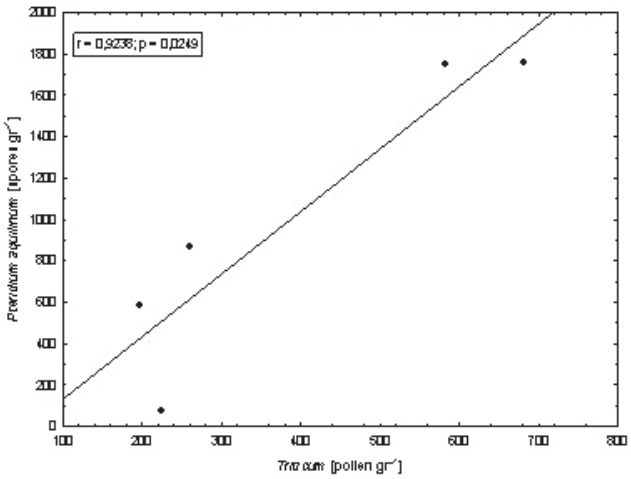

*Fig. 3 - Positive correlation between wheat (*Triticum*) pollen and bracken (*Pteridium aquilinum*) spores.*

Conclusion

The analyses of the new sequential ingesta samples reveal that they derive from at least three different meals. All these meals consumed by the Iceman in his last days reflect a well balanced omnivorous diet consisting of cereals, vegetables and meat.

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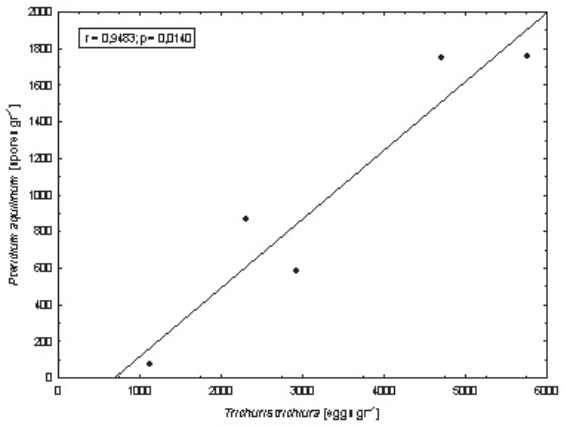

*Fig. 4 - Positive correlation between bracken (*Pteridium aquilinum*) spores and the eggs of the human whipworm (*Trichuris trichiura*).*

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