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Food plants in anthropogenic sediments as represented in pollen and macrofossil spectra: a case study on waterlogged Roman sediments from Switzerland and Alsace, France

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Abstract The present study combines results of pollen and macrofossil analysis to examine the preservation of food plants in on-site archaeological deposits from various Roman waterlogged sites in Switzerland and Alsace (France). Through the integration of pollen and macrofossil analysis a much wider range of food plants is recorded, and it is clear that the plant spectra of both proxy data sets are complementary. The combined analyses enables new insights into food consumption and preparation, and issues of local cultivation and/or the import of food plants can be approached.

Keywords Archaeobotany · Pollen · Macrofossils · Food plants · Roman

Introduction

The analysis of macro- and microbotanical remains has a long tradition in archaeological research, providing important information for the interpretation of settlements. In this regard, on-site plant macrofossil analyses are often used to answer questions about diet, agricultural practices and trade contacts of the former residents while on- and off-site pollen records are primarily used for environmental reconstructions.

The combination of these two lines of evidence in archaeobotanical research is established in Central and Southern Europe. Its potential was already recognised in the 1980s by Greig (1982). Likewise, Dimbleby (1985) drew attention to the potential of pollen analysis as a research tool in archaeology and stressed it as a source of information for studying human activities. Combined studies have been undertaken, e.g. on well deposits (Gaitzsch et al. 1989; Knörzer and Meurers-Balke 1990; Knörzer et al. 1995; Kalis and Meurers-Balke 1998; Meurers-Balke et al. 1999; Zach et al. 2010), shipwrecks (Pals and Hakbijl 1992; Robinson and Aaby 1994), latrines (Van den Brink 1988; Brinkkemper and De Man 1996; Kuijper and Turner 1992; Kalis et al. 2005) and pits (Mariotti Lippi et al. 2009). These very often serve palaeoenvironmental reconstructions (Van Geel et al. 2003; Mercuri et al. 2006; Sadori et al. 2010; Bosi et al. 2011; Święta-Musznicka et al. 2013; Van den Bos et al. 2014) in connection with agricultural practices, e.g. the beginning of viticulture before the arrival of the Romans in Valais (Curdy et al. 2009).

Unlike the previously mentioned publications, the current study does not aim to give a detailed description of the archaeobotany of the studied structures and the palaeoenvironment of the sites. Our goal is to compare the results of pollen and macrofossil analysis of the same on-site archaeological deposits, with regard to the preservation of food crops. Food plants were chosen as their pollen and macrofossils most probably reached the archaeological deposits in similar ways. By comparing the list of food plants, we expect to explore the added value of combined analyses with respect to food consumption and preparation. In addition issues of local cultivation and/or import will be addressed as was recently done at the Roman settlement of Cham Hagendorn (ZG) where the local growth of a peach tree was established (Vandorpe and Wick 2014).

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Studied period and sites

With the arrival of the Romans, many new food plants were introduced north of the Alps (for Central Europe, mainly the region of Switzerland, see e.g. Jacomet et al. 2002; Bakels and Jacomet 2003; Vandorpe and Jacomet 2011), including nuts, fruits, spices, vegetables etc. The majority of those new food plants are native to the Mediterranean basin, but some are from further afield (e.g. black pepper from Southwest Asia). The Romans did not only bring new commodities, they also brought knowledge. The optimal climatic conditions during the Roman period (Holzhauser et al. 2005) favoured the cultivation of fruit trees, vegetable gardens and the production of wine north of the Alps (e.g. Kreuz 2004). The change in nutritional patterns, as well as the local cultivation of newly acquired food plants, is largely reflected in the archaeobotanical record. For that reason archaeobotanical material from the Roman period was chosen.

Four sites were selected for this study. Three of them are situated on the Swiss Plateau, namely Kempraten (SG), Ennetbaden (AG) and Oberwinterthur (ZH). The final site, Oedenburg/Biesheim-Kunheim (dép. Haut-Rhin) is located in the Alsace in France. Besides the similar time period, these sites share the same favourable waterlogged conditions, where a continuously high groundwater table facilitated the excellent preservation of organic material. In such deposits seeds and fruits are mainly preserved as waterlogged remains. As has been previously acknowledged (Święta-Musznicka et al. 2013), archaeobotanical material from such deposits is most effective for combined pollen and macrofossil analyses.

The archaeological background for each of the studied sites is summarised in the following:

- Kempraten (Rapperswil-Jona), excavation Fluhstrasse 8/10 (53.053) (Canton St. Gallen) (Ackermann 2013): The Roman *vicus* of Kempraten is located on the north shore of Lake Zürich; it was founded in the middle of the 1st century AD and inhabited till the 4th century AD, and was built on a strategic location at the intersection of several roads which favoured its development into an important trading centre. The excavation Fluhstrasse covers a residential quarter, which, through its exceptional architecture affirms the economic strength of this small Roman town. The studied material originates from the phase of timber construction in the 1st century AD.

- Ennetbaden, excavation Grendelstrasse (Canton Aargau): The Roman *vicus Aquae Helveticae* was founded at the beginning of the 1st century AD and was inhabited until the late 3rd century AD. The reason for the emergence of the settlement is probably the proximity of the military camp *Vindonissa* as well as hot-water healing sources (Flutsch et al. 2002). The excavation Grendelstrasse covers part of a residential and artisan quarter; the studied material is dated to the 1st century AD.

- Oberwinterthur, excavation Kastellweg (Canton Zurich): The Roman *vicus Vitudurum* was founded at the beginning of the 1st century AD, and inhabited until the Early Middle Ages. In the 1st and 2nd centuries AD the settlement was an important stopover on the way from the military camp of *Vindonissa* towards Lake Constance (Flutsch et al. 2002). The excavation Kastellweg is characterized by longhouses each with a backyard, distributed over different plots; the studied material is dated to the 1st and 2nd centuries AD.

- Oedenburg/Biesheim-Kunheim (Alsace, FR) (Reddé 2009, 2011): The Roman civil agglomeration Oedenburg/Biesheim-Kunheim dates from the 1st to the 4th centuries AD. Its archaeology is very complex and includes a military occupation confined to the 1st century AD, a large temple complex and a Late Roman occupation. Oedenburg was founded on a strategic location in the lower plains of the river Rhine along one of the important routes heading north. The studied material comes from an artisan quarter in the civil settlement directly to the east of the military camp (Vandorpe and Jacomet 2011); the studied material is dated to the 1st and 2nd centuries AD.

Materials and methods

From a large assemblage of examined samples, 13 were selected; they come from nine different structures excavated in four distinct Roman sites (Table 1). All four settlements are characterized by waterlogged soil conditions, and the majority of the studied sediment comes from cesspits or structures where cess has been identified. These deposits were selected as they contain predominantly waste material related to kitchen activities and food consumption (Kalis et al. 2005) providing a direct insight into the vegetable diet and eating habits of the population (Knörzer 1984; Hellwig 1989 and many others). It is clear that such archaeological deposits are of very mixed origin; most deposits represent different 'events' which are very hard to distinguish, other waste might be included in these deposits. It is, however, thought that they are related to kitchen activities. Therefore most pollen and macrofossils reached the deposits in the same way, through kitchen refuse and faecal material.

Table 1 Overview of the studied archaeological material

Site	Country	Date	Structures (*n*)	Structures (type)	Analysed samples
Ennetbaden, Grendelstrasse (Aargau)	CH	Early 1st cent. AD	1	Cultural layer	2
Oberwinterthur, Kastellweg (Zurich)	CH	1st and 2nd cent. AD	2	Latrine	2
Kempraten, Fluhstrasse 8/10 (53.053) (St. Gallen)	CH	1st cent. AD	1	Latrine	2
Oedenburg/Biesheim-Kunheim (Haut-Rhin, Alsace)	F	1st and 2nd cent. AD	5	Latrine, pits and cultural layers	7

Macrofossils

The 13 soil samples with an average volume of 10 l were processed using wash-over (Hosch and Zibulski 2003); this technique involves washing the sediment and separating the organic from the inorganic material. A column of sieves with mesh sizes 4, 1 and 0.35 mm was used. Seeds and fruits from each fraction were sorted and identified using a Wild M3Z binocular microscope with a 6 to 40× magnification. The 4 mm organic fraction was studied entirely; subsamples of the 1 and 0.35 mm organic fraction were analysed due to the richness of the material. Subsample sizes were chosen according to the formulae suggested by Van der Veen and Fieller (1982). Identifications of the plant material (seeds, fruits) were checked against the modern seed reference collection of the IPNA, University of Basel. The botanical nomenclature follows Aeschimann and Heitz (2005) for wild plants, Zohary et al. (2012) for cultivated plants. Each full and/or fragmented seed or fruit was counted as one find.

For analysis of the data, the density of individual taxa is calculated within the specified sample; this value corresponds to the number of items recovered per litre sediment. Plant taxa were first grouped into cultivated and wild plants; crops are classified according to usefulness. In the following the results of the wild plants will not be discussed as they do not contribute to the aim of this study.

Pollen

Two samples of 1 cm^3 volume were taken (before processing by wash-over) from the 13 soil samples. They were processed according to the standard palynological methods using hydrofluoric acid (HF 40 %) and acetolysis (Moore et al. 1991). The processed pollen samples were mounted in glycerine and analysed at 400–1,000× magnification; about 500–700 pollen grains were counted per sample. For the identification of the pollen grains the pollen keys of Beug (2004) and Punt (1984) are used, as well as the reference collection of IPNA and the Landesamt für Denkmalpflege Hemmenhofen (D). The results are presented as percentages of the total pollen sum.

Results

ESM 1 shows the results of the botanical analyses. Both pollen and plant macrofossils of all evidenced food plants are listed. All non-obvious wild food plants are not included in this list; similarly doubtful identifications are excluded. Food plants include cultivated plants and wild plants gathered for consumption.

In the following, the food plant spectrum as represented by pollen and macrofossils is described taking into account issues of preservation and identification. The majority of food plants found in the studied samples are cultivated plants, representing 50 taxa, with the wild gathered food plants representing seven plant species. Table 2 summarises the results of the main analysis, indicating which species have been found through pollen and/or macrofossil analysis.

- *Cereals*: Nine different cereal taxa were identified through macrofossil analysis (Table 2). They were found as charred grains, waterlogged threshing remains and mineralized grains. In addition waterlogged cereal bran has been observed in some of the samples. No effort was undertaken to identify the cereal bran fragments, this is a very time-consuming process (Dickson 1987) which could not be undertaken in the time span of this project. In the majority of the studied samples, more easily identifiable cereal remains form only a minor part of the plant macrofossil assemblage. This is presumably due to the type of deposit. Pollen analysis shows the presence of rye. All other cereal taxa are grouped under 'Cerealia' (Table 2). The relatively good state of preservation would allow the identification of different cereal pollen types using phase contrast at 1,000× magnification (Beug 2004). The original studies on the Roman material did not focus on the identification of the cereal pollen types; subsequent

Table 2 Summary of the obtained taxa from studying both pollen and macrofossils

Pollen	Macroremains
Cereals	
Secale cereale	*Secale cereale* L.
Cerealia	*Avena* sp.
	Hordeum vulgare L.
	Panicum miliaceum L.
	Setaria italica (L.) P. Beauv.
	Triticum monococcum L.
	T. dicoccum Schübl.
	T. spelta L.
	T. aestivum/durum/turgidum
Pulses	
Lathyrus-type	
	Lens culinaris Medik.
Pisum sativum	
Vicia faba-type	*Vicia faba* L.
Herbs and spices	
Anethum graveolens	*Anethum graveolens* L.
Anthriscus cerefolium	
Apium	*Apium graveolens* L.
Bifora radians-type (*Coriandrum*)	*Coriandrum sativum* L.
Capparis spinosa	
Pimpinella anisum	
	Piper nigrum L.
Mentha-type	*Origanum vulgare* L.
	Mentha sp.
	Satureja hortensis L.
Vegetables and salads	
	Foeniculum vulgare Mill.
Brassicaceae	*Brassica* sp.
	Camelina sativa (L.) Crantz
Chenopodiaceae	*Amaranthus* sp.
	Atriplex sp.
	Beta vulgaris L.
Daucus carota	*Daucus carota* L.
	Lagenaria siceraria (Molina) Standl.
Fruits and nuts - culivated	
Castanea sativa	
	Cucumis melo/sativus
	Ficus carica L.
Juglans regia	*Juglans regia* L.
Maloideae	*Malus/Pyrus*
	Pyrus communis/pyraster
	Malus sp.
Morus nigra	*Morus nigra* L.
Olea europaea	*Olea europaea* L.
Pistacia	
Prunus	*Prunus avium/cerasus*
	P. domestica L.
	P. insititia L.
	P. domestica/insititia
	P. persica (L.) Batsch
	P. spinosa L.
Vitis	*Vitis vinifera* L.
Fruits and nuts - gathered	
Corylus avellana	*Corylus avellana* L.
Fragaria vesca	*Fragaria vesca* L.
Sambucus nigra-type	*Sambucus nigra/racemosa*
Solanum nigrum-type	
	Physalis alkekengi L.
Rubus	*Rubus caesius* L.
	R. fruticosus agg.
	R. idaeus L.
Oil, fibres and dye plants	
Cannabis sativa	*Cannabis sativa* L.
	Carthamus tinctorius L.
Linum usitatissimum-type	*Linum usitatissimum* L.
Papaver rhoeas/somniferum	*Papaver rhoeas/somniferum*
	P. somniferum L.
	Papaver sp.

identification of the cereal pollen grains in the Oedenburg samples added up to about 90–95 % *Triticum*-type and a few grains of *Hordeum*-type and *Avena*-type. These random identifications are not specified in the tables.

- *Pulses*: Through macrofossil analysis, two pulses were identified (Table 2). *Lens culinaris* (lentil) was found as waterlogged and mineralized seeds, *Vicia faba* (broad bean) was found both as charred and mineralized seeds. The representation of pulses in archaeological deposits is largely dependent on the conditions of preservation. Seeds are mainly preserved through charring and mineralization; uncharred seeds of pulses are hardly ever preserved in waterlogged archaeological deposits and are possibly underrepresented. Furthermore, the identification of pulses to a species level requires a very good preservation of the determining characteristics; these characteristics are often destroyed during digestion, carbonization, or mineralization processes. Pollen analysis revealed the presence of *V. faba* and *Pisum sativum* (common pea). In some samples a *Lathyrus* pollen type (according to Beug 2004) was differentiated; this type includes *Lathyrus* (vetch) as well as *L. culinaris*. However, there exists a high variability in the pollen morphology of the Fabaceae family, and identification to genus level is often not easy.

- *Herbs and spices*: Through macrofossil analysis, six species were identified (Table 2). The large majority represents waterlogged seeds; charred and mineralized seeds are also among the findings. As with the pulses, mineralization often has a large impact on the preservation of the seeds which make them very difficult if not impossible to determine. This is especially so for the seeds of Apiaceae to which many of the herbs and spices belong. Seven species were identified by pollen analysis. They include five Apiaceae pollen types (Table 2). In addition, pollen of the *Mentha*-type was regularly found; this pollen type includes several herbs and spices besides *Mentha*, such as *Origanum vulgare* (oregano), *Satureja hortensis* (summer savory) and *Thymus* (thyme). At one of the sites (Oedenburg), relatively high amounts of *Capparis spinosa* (caper) were registered in several samples.

- *Vegetables and salads*: Macrofossil remains show the presence of seven different species (Table 2). They were almost exclusively found as waterlogged seeds; mineralized seeds are rare. Macrofossils of vegetables and salads are rarely preserved in the studied archaeological deposits. This could be due to the following reasons: first of all they are harvested before the seeds mature, and secondly those parts of the plants used for consumption (leaves and roots) are not usually preserved in archaeological deposits. Only one species was

identified through pollen analysis (Table 2). Pollen recorded as Chenopodiaceae or Brassicaceae do also include food plants, they cannot, however, be separated from the wild plants in these families. In many samples Brassicaceae pollen accounts for up to 50 % of the pollen sum, suggesting that this plant family made a significant contribution to the human diet. Beside *Brassica oleracea* (cabbage) and other plants, *B. nigra* (black mustard) may also have been used. In the samples from the latrine of Kempraten the sizes of the Brassicaceae pollen were measured. The sizes for almost all the grains range between 22 and 25 μm, fitting the measurements of 22.5–27 μm for *B. oleracea*, as reported by Beug (2004).

- *Fruits and nuts*: The largest group of food plants attested in the samples is the fruits and nuts. Both cultivated and wild plants gathered for consumption are found. Through plant macrofossil analysis 20 species were identified (Table 2). They include the cultivated plant species as well as wild gathered plant species. The large majority of plant species is preserved as waterlogged remains; very few remains are mineralized. Through pollen analysis 13 taxa were identified. However, the majority of these pollen types include several species. This is mainly due to the problems of pollen identification within the rose family. Beside *Prunus*, which includes domesticated as well as wild species, a Maloideae-type made up by *Malus* and *Pyrus* was determined using modern reference material. *Vitis vinifera* (grapevine) cannot be separated from *V. sylvestris* pollen; however, most of the *Vitis* pollen was recorded in samples rich in grapevine macrofossils. In addition to the indications from macrofossil analysis, there is evidence of *Castanea sativa* (chestnut) and *Pistacia* (pistachio).

- *Oil, fibre and dye plants*: Through macrofossil analysis, three species were identified (Table 2). Their seeds were preserved waterlogged and mineralized. Apart from *Papaver somniferum* (poppy), they represent rare admixtures in the samples. Pollen analysis revealed the presence of one species, *Cannabis sativa* (hemp) and two types. The *Linum usitatissimum*-type includes also *L. bienne* (pale flax), the suggested ancestor of the cultivated flax. Poppy pollen is included in the *Papaver rhoeas*-type.

Discussion

The combined analysis of pollen and macrofossils from archaeobotanical samples has great potential for the study of diversity of plant consumption. The discrepancy in taxa representation between pollen and macrofossil records is sometimes very large (Mariotti Lippi et al. 2009). This is possibly due to the differences in production, dispersal, and preservation of fruits/seeds and pollen of food plants (Greig 1982), as well as their harvesting season. However, the methodological basis of pollen analysis, specifically criteria of identification, has expanded in such a way in recent years that it can be paralleled to macrofossil analysis (Kalis et al. 2005). Our results show the range of information which can be obtained by studying each method separately as well as the added value of a parallel examination. It can be postulated that both proxy data sets are complementary (e.g. Greig 1982; Sadori et al. 2010; Święta-Musznicka et al. 2013). Altogether 57 food plants were identified, of which 51 were found as macrofossils and 31 as pollen grains. 32 were only found as macrofossils whereas six were found only as pollen. The number of species obtained from each set of proxy data is very diverse for the different groups of food plants.

Considering the individual groups of food plants, it can be inferred that cereals score much better in the macrofossil record. The taxonomic resolution of cereal pollen is much smaller, because only a few cereal pollen types are differentiated. Since it is not possible to clearly separate some of the cereals from wild grasses (e.g. *Panicum*, *Setaria*, *Sorghum*; Beug 2004) or to determine the various species of wheat, pollen analysis does not add much to the detail of macrofossil analysis in this context. Nevertheless, a systematic study of the different cereal pollen types and macrofossils in the same samples should be envisaged; it might reveal interesting new insights into the methods of harvesting and food processing.

In contrast to the cereals, pulses are generally better represented in the pollen studies. This is largely due to conditions of preservation of macrofossils (see above) but can also be related to food preparation. Pulses, e.g. *V. faba* and *L. culinaris*, were often coarsely ground to ease the cooking process, and *V. faba* was used to produce flour for bread-making (André 1998). These food preparations obviously destroy all the characteristics necessary for a detailed determination of the macrofossils, whereas the pollen grains are not affected. The problems arising in pollen analysis are pollen morphological limitations and the fact that the pollen probably ends up among the organic waste rather than in the pulses meal.

Herbs and spices are a heterogeneous group of food plants as both leaves and seeds are used for consumption. A similar number of taxa for each type of proxy dataset was obtained, and the spectra of both are complementary. Absence and/or presence of proxy data of these food plants can be explained through import, food preparation and consumption, rather than through conditions of preservation. In one sample from Oedenburg (14065) a corn of *Piper nigrum* (black pepper) was found. *Piper nigrum* is

native to southwest India and is an imported food plant (Van der Veen 2011); it would not therefore be represented in the pollen spectrum. *Capparis spinosa* pollen was found in two samples from Oedenburg; it is, so far, the only certain evidence of *C. spinosa* in Roman sediments north of the Alps. There are two doubtful findings of *C. spinosa* macro remains from two Roman sites in Belgium (Rivera et al. 2002; Cooremans 1999). Since the young buds of the *C. spinosa* flowers contain high amounts of pollen, we suggest that these buds were consumed as a spice like today. Interestingly, *C. spinosa* is native in the Mediterranean area and is therefore part of the imported food resources. Quite a few herbs and spices are not represented by macrofossils but only as pollen; this can be related to the consumption of the specific plant parts. Pollen grains of *Anthriscus cerefolium* (chervil) were found in seven of the studied samples. *A. cerefolium* is consumed as fresh or dried leaves (André 1998); these are collected before maturing of the seeds. In all of the studied samples relatively high percentages of *Mentha*-type pollen were found. Although this pollen type contains several plant species, these high values in all samples are remarkable and do suggest some kind of consumption. *Mentha* leaves were consumed fresh or dried, preserved in vinegar, and used for flavouring basic dishes (André 1998). Pollen of *Pimpinella anisum* (aniseed) is recorded in nine of the studied samples, and although its seeds were consumed, so far no macrofossils have been identified. The reason for its absence in the macrofossil record could be related to identification difficulties on the one hand, or to food preparation processes on the other. While macrofossils are destroyed through grinding, pollen is usually not affected. *P. anisum* represents a newly introduced food plant north of the Alps, where climatic conditions allowed its local cultivation. Roman findings of *P. anisum* are rare north of the Alps, but macro remains were found in the Iron Age salt mining site of Dürrenberg-bei-Hallein in Austria (Stöllner et al. 2003), and a pollen grain was identified in a Roman well in Weisweiler, Germany (Meurers-Balke 1989).

Within the vegetables and salads group the taxonomic resolution is much higher in the macrofossil than in the pollen record. As only the roots and leaves are consumed from the majority of these food plants, this is rather surprising. The problem is again difficulties in pollen identification; the majority cannot be identified to a species or even a genus level. However, pollen studies can add to the evaluation of plant consumption. Pollen of the cabbage family (Brassicaceae) was found in very large amounts in all of our samples; macrofossils of *Brassica* sp. are not common. Although no detailed identification is possible, these high percentages of Brassicaceae pollen suggest that *Brassica* might have been a substantial part of the diet. Even if the sizes of most of the Brassicaceae pollen

measure 22–25 μm, and thus fit into the size class of *B. oleracea* (Beug 2004), other taxa, such as *Camelina sativa* (false flax, 24–34.5 μm) and gathered plants like *Nasturtium* sp. (water cress, 17.7–23.9 μm) or *B. nigra* must also be considered. Leaves of the latter were often used in spinach dishes, and seeds were used for seasoning the dishes (André 1998). For *Lagenaria siceraria*, a newly introduced food plant, the absence of pollen has to be explained in a different way as they can be identified to the species level. Macrofossils (not only seeds, but almost whole fruits) were found in four samples from Oedenburg; so far, however, no pollen has been found. This might indicate that local cultivation of bottle gourds was not practised; yet local cultivation is possible and even probable based on the finds of fruits and fruit parts (Vandorpe and Jacomet 2011). Thus, considering that the record of Cucurbitaceae pollen generally is extremely poor, the absence of bottle gourd pollen does not reveal anything about local cultivation.

Within the fruits and nuts group, there is again a large dissimilarity between the two proxy data sets due to difficulties in pollen identification. Fruits and nuts (both cultivated and gathered wild) are much better attested through macrofossil analysis. Nevertheless, the combined analysis gives very interesting insights into issues such as local cultivation and import. In four samples from Oedenburg and one from Oberwinterthur, pollen as well as macrofossils of *Juglans regia* (walnut) is recorded. The combination of data from both proxies can be seen as evidence for local cultivation of *Juglans*. The absence of *Ficus carica* (fig) pollen in all of our samples does not give them import status; *F. carica* pollen does not leave the *Ficus* blossom and is still present in the ripe fruit. Rather, its absence is probably related to poor pollen production and preservation (very small, thin pollen grains). Fruit trees (Rosaceae family) and *Vitis* are usually poorly represented in the pollen data. It is likely that most of their pollen was brought into the settlements together with the fruits and other plant parts; the on-site pollen record therefore may only indicate local cultivation in the archaeological and archaeobotanical context (Vandorpe and Wick 2014). Local viticulture can be traced by off-site palynology (Curdy et al. 2009). Notable is the presence of *C. sativa*, *Pistacia* and *Olea europaea* pollen in part of the Oedenburg samples. Both *Olea* and *Castanea* pollen have been found in small amounts in off-site sediments north of the Alps since the Roman period (Wehrli et al. 2007). The presence of *Olea* pollen is obviously due to long-distance pollen dispersal from Italy and/or transport of goods linked with that country. In the case of *Castanea*, its local growth cannot be excluded. The presence of *Pistacia* pollen is difficult to explain, since its distribution by wind is very poor (e.g. Van Zeist and Bottema 1977). There is no

evidence of import of other *Pistacia* products, such as nuts or mastic resin from the wild growing Mediterranean mastic shrub (*Pistacia lentiscus*).

As to the oil plants, a similar plant spectrum is obtained by studying both proxy data sets. The absence of *Carthamus tinctorius* (safflower) pollen is possibly a result of its import as it can grow north of the Alps. In addition, findings of *C. tinctorius* seeds are very rare, if not absent, in Roman sites in Switzerland and its surroundings (Vandorpe and Jacomet 2011). For *Papaver somniferum*, there is again a problem of pollen identification as *P. somniferum* cannot be differentiated from *P. rhoeas* (corn poppy).

Conclusions

This study clearly shows the potential of combined macrofossil and pollen analyses for the recovery of food plants, and stresses the fact that additional aspects of the diet are elucidated by combining different methods of analysis. Both methods have their limitations when studying the food spectrum; these are mostly of a morphological as well as a taphonomic nature. Nevertheless, we think the added value of such analyses is proven.

First of all, through integration of pollen and macrofossil analysis a much wider range of food plants is recorded. Moreover, the plant spectra of both proxy data sets are complementary: the presence of *P. anisum, C. spinosa, Pistacia* and *A. cerefolium* would not have been registered without pollen analysis; identification of most fruits and cereals is, however, only possible through macrofossil analysis.

Secondly, combined analyses enable new insights into food consumption and preparation: plants from the cabbage family were an important part of the diet, they were possibly consumed as vegetables or for seasoning; aniseed was likely to have been ground before consumption.

Thirdly, issues of local cultivation and/or import of food plants can be approached. Pollen of *C. spinosa* indicates the import of this spice north of the Alps. The appearance of both pollen and macrofossil remains of *J. regia* in on-site sediments is a clear indication for its local growth; local cultivation of fruit trees and *Vitis*, in contrast, is barely evidenced. Within the studied sites, the issue of local cultivation versus import of many of the food plants is unresolved. This is partly due to the nature of the studied deposits, with green waste possibly more applicable than cess to address this type of question.

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