Journal of Archaeological Science: Reports 4 (2015) 596–604

Contents lists available at ScienceDirect

Journal of Archaeological Science: Reports

journal homepage: http://ees.elsevier.com/jasrep

Analysis of pollen and intestinal parasite eggs from medieval graves from Nivelles, Belgium: Taphonomy of the burial ritual

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ARTICLE INFO

Article history:
Received 4 August 2015
Received in revised form 5 October 2015
Accepted 21 October 2015
Available online xxxx

Keywords:
Middle Ages
Burial ritual
Straw
Hay
Taphonomy
Palynology
Parasitology

ABSTRACT

Pollen and intestinal parasite eggs of a number of burials from a medieval cemetery at Nivelles (Belgium) have been studied. The results of the pollen analysis provide indications for the use of straw and hay in the medieval burial ritual. Pollen assemblages from samples from the pelvic area of the skeletons, which are generally believed to represent the contents of the digestive tract, are potentially also influenced by this practice. The consequences for the palynological analysis and interpretation of pollen assemblages from medieval burials are discussed. The parasitological analysis shows a high infection rate of *Trichuris* and *Ascaris* in the medieval population of Nivelles.

1. Introduction

Pollen is generally not preserved in ancient burials as most graves are situated above groundwater level in well-drained soils and pollen is easily oxidised in such environments. In specific situations, such as burials in extreme arid climates (e.g. Berg, 2002) or in sheltered environments like rock shelters or caves, or in sarcophagi, crypts or other sealed environments (see references below), pollen can be preserved and its analysis can potentially provide a wealth of information. Samples representing the contents of the digestive tract document the composition of the last meals of the buried person (e.g. Arguelles et al., 2015; Reinhard et al., 1992; Reinhard and Bryant, 2008; Shafer et al., 1989; Shishlina et al., 2007), or identify medicinal plant use (e.g. Teixeira-Santos et al., in press). Samples from the burial environment can reveal embalming practices by identifying the plants used for this purpose (e.g. Bui Thi Mai and Girard, 2003; Charlier et al., 2013; Vermeeren and Van Haaster, 2002), the identification of grave goods including the ritual deposition of flowers (e.g. Iriarte-Chiapusso et al., 2015; Kvavadze et al., 2007; Lagerås, 2000) and point to other uses of plants related to burial practices (e.g. Girard and Maley, 1999; Kvavadze et al., 2008). Additionally, pollen samples from the grave can provide information on the vegetation at the moment of burial (e.g. Kvavadze et al., 2008) and even on the season of death (e.g. Arguelles et al., 2015; Szibor et al., 1998).

More exceptional are burials in the soil at open air sites, in the temperate climate of NW-Europe, that show good pollen preservation (e.g. Berg, 2002; Bunting and Tipping, 2001; Enevold, 2013).

Due to the taphonomic constraints of the burial environment, the origin of the pollen identified from ancient burials is not always straightforward and its interpretation has to be done with great care (e.g. Bunting and Tipping, 2001; Sommer, 1999). But also the many potential sources of pollen, related to both the intestinal contents of the buried body and to burial rituals involving plant material further complicate the interpretation of pollen assemblages from funerary contexts (e.g. Bui Thi Mai and Girard, 2003; Reinhard et al., 2007; Renault-Miskovsky et al., 2005).

In this paper the results are presented of the analyses of pollen from graves from a medieval cemetery at Nivelles (Central Belgium). At the site, the high level of humidity of the soil resulted in the exceptional preservation of organic material present in some of the excavated graves, providing a rare opportunity for the analysis of pollen associated with these burials. Samples from coprolites recovered from three burials from this site have been analysed for parasites (Rácz et al., 2015) and pollen in previous studies. This study now presents the results of pollen analyses of sediment samples from different locations within and around several of the excavated skeletons. Additionally, eggs of intestinal parasites present in the samples have been analysed.

This study helps to reconstruct past funeral rituals and provides information on the infection by intestinal parasites within the medieval population of Nivelles. At the same time, it is demonstrated that there

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http://dx.doi.org/10.1016/j.jasrep.2015.10.027
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is a risk of misinterpretation of pollen analyses of abdominal samples associated with human skeletons.

2. Materials and methods

2.1. Site

The graves studied were excavated and sampled between 2009 and 2010 by the archaeology department of the Public Service of Wallonia, during a rescue excavation in the historical centre of the town of Nivelles (Central Belgium) (Fig. 1). During this campaign, the remains of an abbatial complex have been found (Van Hove et al., 2012). This complex was founded in the 7th century and was composed of an abbatial quarter, three churches, Notre Dame, Saint-Paul, and Saint-Pierre/Saint-Gertrude, and two associated cemeteries (Fig. 1). The first cemetery is situated to the west of the Saint-Pierre/Saint-Gertrude church. Radiocarbon dates indicate that this cemetery was in use from the end of the 10th to the middle of the 13th century (Van Hove et al., 2012; Table 1). The second cemetery was situated at the eastern side of the complex and was associated with the Notre Dame church (Fig. 1). Radiocarbon dates from this cemetery range between the 10th and 15th century AD (Van Hove et al., 2012; Table 1).

Most burials contained a coffin although in a small number of burials the corpses were placed directly in the ground, without coffin. Historical sources and the preliminary results of the archaeological and anthropological studies indicate that both cemeteries were used for the burial of layman, including men, women and children (Van Hove et al., 2012).

The site is situated in the alluvial plain of the river Thines, on wet, loamy-clay soil. Due to local variations in the geological substrate and groundwater flows, the soil in some areas of the two cemeteries showed waterlogged conditions while other areas were better drained. As a consequence, some of the burials showed exceptional preservation conditions for organic material, with not only the wooden coffins and skeletons but in a few cases also brain tissue, hair, skin and coprolites preserved (Fraiture et al., 2014; 2015; Rácz et al., 2015; Van Hove et al., 2012). In one grave (F19), also the presence of a cushion of plant material under and around the skull was observed during excavation. Given the good preservation of some of these burials, it is very likely that local groundwater conditions have changed shortly after the burials have been dug, probably due to changes in local groundwater flows caused by the construction of the foundations of the Saint-Gertrude church (Van Hove et al., 2012).

2.2. Samples

The aim of the palynological and parasitological analyses was to investigate the abdominal content of the buried individuals. The sampling strategy followed the recommendations by Berg (2002) as far as

a

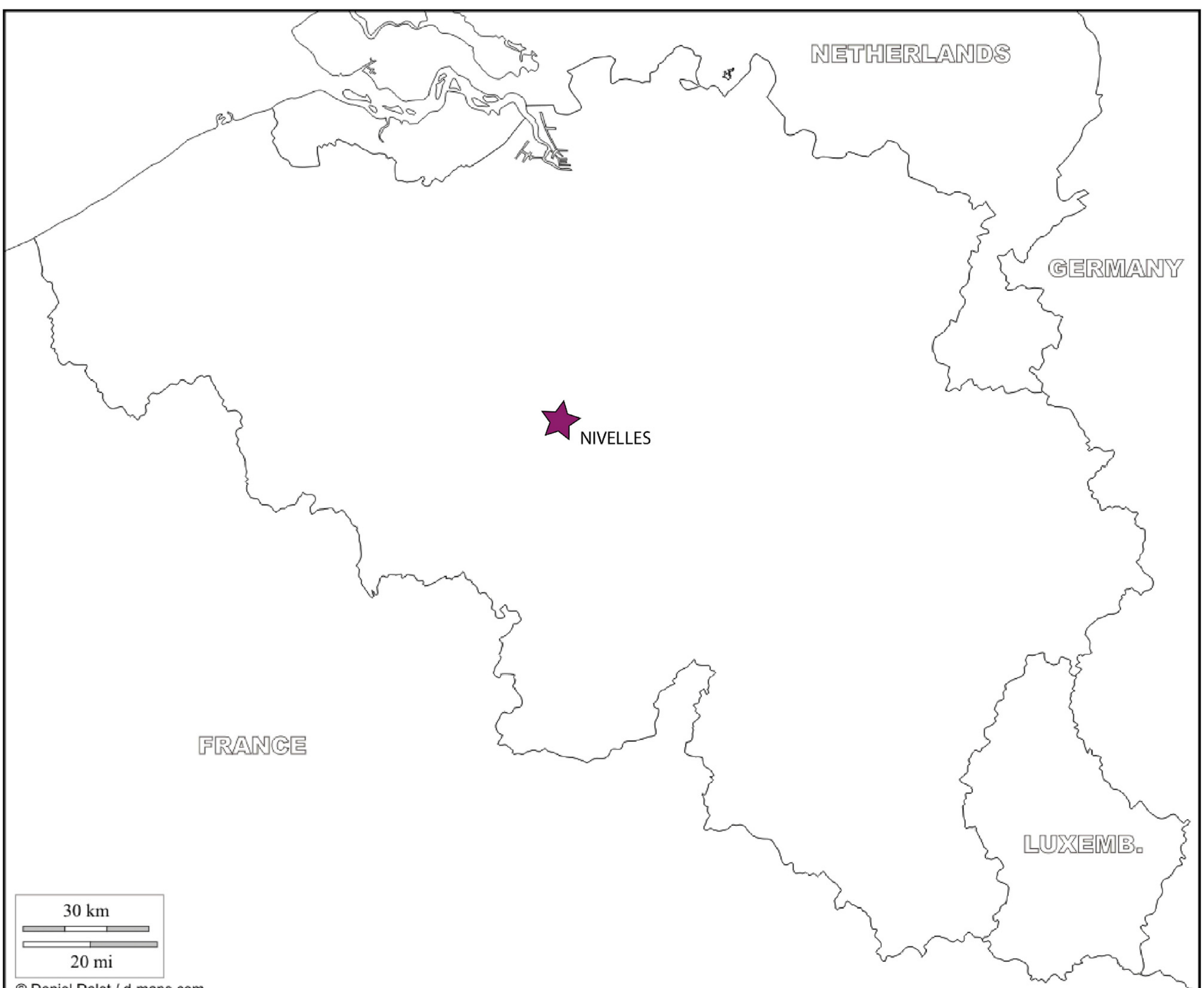

Fig. 1. a: Location of the site. b: Layout of the abbatial complex. A: Notre-Dame church; B: Saint-Paul church; C: Saint-Pierre/Saint-Gertrude church; D: western cemetery; E: eastern cemetery; F: abbatial quarter.

Fig. 1 (*continued*).

possible, although only a limited number of the excavated graves could be sampled due to the time constraints of the excavation campaign. From a selection of graves, samples were taken from inside the pelvic girdle and control samples were taken from sediment next to the skull, arms or legs of the same skeleton. Samples were processed using standard techniques for pollen analysis (Moore et al., 1991).

Table 1
Location, age and preservation condition of the analysed samples with indication of the presence of eggs of intestinal parasites.

Grave	Age AD[a]	Sample location	Pollen preservation	Intestinal parasite eggs		
				Ascaris	*Trichuris*	cf. *Capillaria*
Eastern cemetery						
F59	1322–1430 (B)	Pelvic gridle	Differential corrosion			
		Abdominal area	No pollen			
		Abdominal area	Differential corrosion			
F113		Pelvic gridle	Differential corrosion		v	
		Shoulder	Differential corrosion		v	
F154		Pelvic gridle	Good		v	v
		Head	Good		v	
Western cemetery						
F10	780–1012 (W)	Pelvic gridle	Good		v	
		Pelvic gridle	Good	v		
F14	784–1016 (W)	Pelvic gridle	Good	v	v	
		Right leg	Good			
F19	780–1020 (B)	Pelvic gridle	Good	v	v	
		Head	Good			
F51		Pelvic gridle	Good	v		
F77		Pelvic gridle	No pollen			
F95		Pelvic gridle	No pollen			
F96		Pelvic gridle	No pollen			
F119	1052–1274 (B)	Right upper arm	Good			
F164	999–1158 (B)	Pelvic gridle	Good		v	

[a] 2 sigma range of calibrated radiocarbon dates obtained on bone samples (B) or wood from the coffin (W).

Lycopodium spore tablets have been added to the samples to determine the concentration of pollen and intestinal parasite eggs (Stockmarr, 1971). Identifications of pollen and spores are based on Beug (2004) and a reference collection of modern pollen and spores, stored at the Royal Belgian Institute of Natural Sciences. Percentages are based on the sum of all pollen types (ΣP). Spores and intestinal parasite eggs are excluded from this sum.

Intestinal parasite eggs have been studied from the same slides as used for the pollen analysis. As most intestinal parasite eggs have dimensions comparable to pollen and are resistant to the chemicals used for pollen preparations (Bouchet et al., 2003a; Wharton, 1980), pollen slides can indeed be used for the study of intestinal parasites (e.g. Brinkkemper and van Haaster, 2012) although some taxa might be lost or underrepresented using the standard pollen preparation techniques (Dufour and Le Bailly, 2013). The identification of intestinal parasite eggs is based on Thienpont et al. (1979). The results of the identifications of intestinal parasite eggs are expressed as egg counts for each studied sample (Table 2).

Samples showing a high degree of corroded pollen grains and clear indications for differential preservation, i.e. with exceptional high percentages of corrosion resistant pollen grains like Asteraceae — Liguliflorae, *Centaurea cyanus* and *Calluna vulgaris* (Havinga, 1967, 1984) have not been analysed for pollen. In this case, a complete slide has still been scanned for intestinal parasite eggs but only presence/absence of intestinal parasite eggs has been recorded, without quantification (Table 1).

3. Results

3.1. Pollen analysis

A total of 19 samples, originating from 12 graves, was processed (Table 1). In 11 samples, originating from 7 different graves, pollen preservation was sufficient to allow full analysis (Table 2). Four samples showed clear indications of differential pollen preservation and were only scanned for the presence of intestinal parasite eggs. Four other samples were completely sterile.

From only 3 graves (eastern cemetery: F154; western cemetery: F14 and F19), samples from both the pelvic area and control samples were available with a pollen preservation good enough to allow analysis (Table 1) (Fig. 2). From 3 graves (western cemetery: F10 (2 samples), F51 and F164), samples from the pelvic area showed good preservation conditions and were analysed, while control samples were not available. From grave F119, a sample taken next to the right upper arm has been analysed but no sample from the pelvic area could be studied. In previous studies, coprolites recovered from the pelvic area of this skeleton have already been analysed for intestinal parasite eggs (Rácz et al., 2015) and pollen.

The pollen assemblages of all the samples from the pelvic area analysed are dominated by Poaceae (54.6–32.6%) and Cerealia (27.5–8.6%) (Table 2). Weeds characteristic for grassland, e.g. Asteraceae — Liguliflorae, *Matricaria* type, *Plantogo lanceolata*, *Rumex acetosa*, *Succisa pratensis*, *Trifolium pratense* type and *Trifolium repens* type, and weeds from arable fields, e.g. *Agrostemma githago*, *C. cyanus* and *Orlaya grandiflora*, also show high percentages or at least occur frequently in the samples analysed. Pollen percentages of trees and shrubs are low in all samples (8.6–2.7%).

Apart from Cerealia, other pollen types have been found that possibly reflect the remains of ingested food or drinks, i.e. *Anthriscus cerefolium* and *Vitis vinifera*. *A. cerefolium* (garden chervil) must have been a popular herb in medieval cuisine as its pollen is regularly recovered from medieval and postmedieval cesspits (e.g. De Clercq et al., 2007; Deforce, 2006, 2010; van den Brink, 1988, 1989; Van Haaster, 2008). The *Vitis* pollen identified might result from the consumption of grapes, raisins or wine, as all these can contain considerable amounts of pollen (Greig, 1982; Rösch, 2005).

3.2. Intestinal parasites

Eggs of three different taxa of intestinal parasites, *Ascaris*, *Trichuris* and cf. *Capillaria*, have been identified. It is not always possible to differentiate between species within these three genera as some have an identical egg morphology (Jones, 1982). However, since these parasite eggs have been recovered from human burials, it is most likely that the eggs can be attributed to the species that prefer humans as a host: *Trichuris trichiura* (whipworm), *Ascaris lumbricoides* (roundworm) and *Capillaria hepatica* (hairworm). Still, the presence of other species cannot be completely excluded. Humans can also get infected by species of intestinal parasites that have other mammals as preferred host and in some rare cases such infections have been reported from archaeological contexts (e.g. Le Bailly et al., 2014).

Trichuris occurs in 8 samples, *Ascaris* in 4 samples and cf. *Capillaria* has only been found in a single sample. Most intestinal parasite eggs have been recovered from pelvic samples but *Trichuris* eggs have also been found in two control samples, i.e. in a sample from the shoulder area of grave F113 and in a sample taken next to the skull in grave F154. Parasite egg concentrations vary between 0–223 eggs/g for *Ascaris*, 0–3122 eggs/g for *Trichuris* and 0–331 eggs/g for cf. *Capillaria*. Some of the samples with insufficient pollen preservation also proved to be positive for *Ascaris* or *Trichuris* indicating a high resistance of these parasite eggs to corrosion. Samples with no pollen at all were also negative for parasite eggs.

4. Interpretation and discussion

High percentages of Cerealia pollen and associated weeds are a common feature of pollen assemblages from medieval coprolites, cesspits and other contexts containing human faecal remains. This is generally explained to result from the consumption of cereal-based food such as bread or porridge (Deforce, 2010; Greig, 1981; Jankovská and Kratochvílová, 1988; Troubleyn et al., 2009). The pollen spectra observed from the pelvic gridle might thus reflect the contents of the digestive tract, representing the last meals of the buried individuals. This would be in accordance with Berg (1997, 2002) and Reinhard et al. (1992) who consider the pelvic basin as a natural bowl, collecting the abdominal contents during the decomposition of the body. However, as samples from other areas within the graves, i.e. from the area next to the skull, arm or leg bones, show equally high percentages of pollen from Cerealia, Poaceae and associated weeds as the samples from the pelvic area, possible other origins for these pollen types must equally be taken into account.

4.1. Straw and hay

The most obvious explanation for the equally high percentages of pollen from Cerealia, Poaceae and associated weeds in samples from different locations within the graves would be the use of straw or hay (i.e. the dried stalks and leaves of cereals and wild grasses respectively) as 'bedding' material inside the coffins or graves. As most cereals are self-pollinating, a large number of pollen remains in the hulls after flowering. Additionally, high numbers of cereal pollen stick to the ears and stems. Straw thus contains large numbers of cereal pollen as demonstrated by analyses of the different parts of cereal plants (Jankovská and Kratochvílová, 1988; Joosten and van den Brink, 1992; Robinson and Hubbard, 1977). These analyses also demonstrated that next to the high amounts of cereal pollen, straw can also contain high numbers of pollen from the surrounding vegetation, especially arable weeds. Although most wild grasses are wind-pollinated, hay similarly contains a large number of pollen from both the hay producing plants (i.e. grasses and associated weeds) and the surrounding vegetation (Greig, 1982; Macphail et al., 2004; Schepers and Van Haaster, 2015).

There are several historical, folkloristic and iconographic documents which indicate that straw was commonly used in medieval and post

Table 2
Results of the pollen analyses of the burials from Nivelles.

Grave	F10	F10	F14	F14	F19	F19	F51	F119	F154	F154	F164
Sample location	P	P	RL	P	S	P	P	RA	P	S	P
Trees and shrubs											
Acer						0.2				0.3	
Alnus	1.0	0.9	1.8	0.5	0.6		0.5	0.2	0.9	1.2	1.6
Betula			0.1		0.2	0.4	0.3			0.3	1.0
Carpinus betulus			0.6		0.2					0.3	0.5
Castanea sativa				0.5			0.3				0.3
Corylus avellana	0.8	2.0	1.3	1.4	1.5	3.4	2.6	0.2	0.9	3.0	2.6
Fagus sylvatica	0.7	0.5	0.9	0.9	0.2	0.5	0.8	0.1	0.4	0.3	0.3
Frangula alnus	0.2										
Fraxinus excelsior		0.2		0.2	0.2						
Hedera helix	0.2	0.2					0.3				
Ilex aquifolium									0.2		
Juglans regia								0.1			
Pinus sylvestris		0.2		0.2			0.3		0.2	0.6	
Prunus						0.2					
Quercus	1.3	1.4	1.0	1.2	1.4	0.7	1.3	0.5	0.2	1.2	0.5
Salix		0.4	0.3	0.2	0.2	0.4		0.1		0.3	0.3
Sambucus nigra type			0.3	3.2			0.3	0.1			
Sorbus type								0.1			
Tilia		0.2	0.1	0.2		0.2	0.8				
Arboreal pollen	4.2	5.9	6.5	8.6	4.3	6.0	7.1	1.5	2.7	7.4	7.0
Herbs											
Agrostemma githago		0.4			0.3	0.2					
Anthriscus cerefolium							0.3				
Apiaceae	0.8	0.7	1.2	1.2	1.2	1.4	2.0	0.6	0.2	0.6	1.3
Artemisia	0.2		0.4	0.2	0.5	0.2		0.4		0.6	0.8
Astragalus type	0.5			0.2							
Asteraceae-Liguliflorae	13.1	14.9	18.5	4.4	6.9	4.2	11.7	2.2	3.5	15.7	11.4
Brassicaceae	1.2	1.1	1.5	0.9	0.8	2.4	1.3	0.5	0.2	1.8	2.6
Calluna vulgaris	2.3	1.4	0.6	1.2	0.8	0.7	1.0	0.1	0.2	0.6	0.3
Caltha type									0.2		
Cannabinaceae		0.4			0.2			0.1			0.3
Caryophyllaceae	0.8	0.4	0.3	0.2	0.2	0.9	0.3	0.5			0.3
Centaurea cyanus	1.2	0.4	0.1	0.5	1.4	0.9	1.3	0.2		1.5	1.0
Centaurea jacea type	0.8	0.4	0.6	0.2	0.2	0.4	1.0	0.5			
Cerealia undiff.	20.8	18.3	14.4	16.0	18.5	26.4	9.2	23.6	24.2	12.2	8.3
Secale cereale	0.5	0.5		0.2	0.3	1.1		0.4	0.2	0.3	0.3
Cerealia total	21.3	18.9	14.4	16.2	18.8	27.5	9.2	23.9	24.4	12.5	8.6
Cirsium type	0.3		0.4				0.8	0.1		0.3	
Chenopodiaceae	0.5	0.7	0.6	1.2	0.6	0.4	2.3	0.1			0.3
Convulvulus arvensis type					0.2						
Cyperaceae	1.5	1.3	0.9	1.2	0.5	0.7	0.5	1.3	1.8	0.9	1.8
Dipsacus	0.3										
Ericaceae undiff.		0.2									
Fallopia											
Filipendula	0.5		0.3	0.5	0.5		0.3		0.2		0.3
Jasione montana type		0.4			0.2				0.2		
Linum usitatissimum type	0.2				0.2				0.2		
Lotus type	0.3		0.1		0.2			0.1	0.2	0.3	0.3
Matricaria type	4.7	5.2	3.6	3.9	2.9	1.6	0.8	1.3	1.2	2.1	1.8
Mentha type							0.3	0.1	0.2	0.3	
Orlaya grandiflora	0.3	0.7	0.1	0.5	0.2	0.2	1.0			0.3	0.5
Papaver rhoeas type	0.2										
Persicaria maculosa type								0.1			
Plantago lanceolata	3.7	4.1	2.7	11.3	1.4	3.8	1.3	8.7	4.1	3.0	1.3
Plantago major/media type	0.2	0.4			0.2					0.3	0.3
Poaceae	32.6	36.1	35.1	33.3	51.2	39.9	50.8	50.8	54.6	41.2	44.7
Polygonum aviculare type	0.5	0.2	3.1	0.2	0.5	0.4	0.5			5.0	6.0
Potentilla type	0.3	0.2	0.7	1.2	0.2	0.9	0.3	0.2			0.8
Ranunculus acris type	0.7	0.5	0.3	2.5	0.3	1.3	0.8	1.5	0.7	0.6	1.3
Ranunculus arvensis type	1.0	0.2	0.1	0.7		0.2			1.1		
Rosaceae undiff.				0.9		0.4				0.6	0.3
Rubiaceae			0.1						0.2	0.6	0.3
Rumex acetosa type	2.8	2.5	3.6	5.8	2.3	2.5	1.5	1.3	1.2	2.4	5.2
Sanguisorba minor type									0.2		
Senecio type			0.1	0.2		0.4			0.4		
Spergula arvensis		0.2		0.2							
Succisa pratensis	0.2	0.2	0.1					0.1	0.2		
Trifolium pratense type	0.8	0.5	1.2		0.8	1.1	1.3	1.5	1.2	0.3	0.8
Trifolium repens type	1.8	1.4	2.4	1.9	1.5	1.6	2.0	1.8	0.7	0.6	0.5
Urtica dioica type		0.2			0.9					0.3	0.3
Verbena officinalis									0.2		

Table 2 (*continued*)

Grave	F10	F10	F14	F14	F19	F19	F51	F119	F154	F154	F164
Sample location	P	P	RL	P	S	P	P	RA	P	S	P
Vicia type	0.2	0.2	0.1	0.7	0.2			0.2		0.3	
Vitis vinifera							0.5				
Sparganium emersum type									0.2		
Sparganium erectum type								0.1			
Non-arboreal pollen	95.8	94.1	93.5	91.4	95.7	94.0	92.9	98.5	97.3	92.6	93.0
Pollensum	601	557	675	432	649	552	392	849	566	337	385
Concentration (pollen per gramme)	16,070	11,041	15,720	32,113	70,532	17,763	2269.4	219,136	187,831	29,823	8093.7
Spore plants											
Anthoceros punctatus type	0.2		0.3	0.2			0.3				0.3
Equisetum		0.5			0.5	0.4			0.2		0.3
Filicales	0.8	0.4	0.9	0.2	0.3	0.2	3.3	0.1		0.3	1.3
Polypodium vulgare	0.2	0.4									0.3
Pteridium aquilinum	0.2	0.4	0.3		0.3	0.4	1.0	0.1			1.0
Riccia type	0.2	0.2					0.3				
Sphagnum	0.2										
Intestinal parasites											
Ascaris (eggs/g)		20		223		64	6				
Trichuris (eggs/g)	134			3122		129			664	796	84
cf. *Capillaria* (eggs/g)									332		
indeterminata	1.2	2.0	3.0	3.9	0.8	2.2	3.1	0.6	1.1	3.9	2.9

P: pelvic area; RL: right leg; S: scull; RA: right upper arm.

medieval funerary rituals, as bedding material for the body of the deceased, before and during the transport to the graveyard, and finally the grave (e.g. Aries, 1983; De Cleene and Lejeune, 2003; Gilchrist and Sloane, 2005; Oomen, 1885; Vovelle, 1983; Figs. 3 and 4). In contrast, only few archaeological records of the use of straw and hay in burials exist but this could be the consequence of poor preservation possibilities of uncharred botanical remains in burial contexts. From Belgium, examples are known from late and post medieval burials inside the Cathedral of Our lady and the St.-Pauls Church in Antwerp. At both sites, straw was found in a number of coffins, either used as a pillow beneath the head of the deceased or spread out over the entire bottom of the coffin, sometimes together with charcoal and ashes (Steel, 2007; Veeckman, 1997). In the main church of Breda, The Netherlands, members of the royal family were buried between 1475 and 1526 AD, with a layer of straw in their coffins, (Van Den Eynde and De Roode, 1996). In Germany, king Wilhelm Heinrich von Nassau-Saarbrücken and his son Ludwig von Nassau-Saarbrücken were buried on a bed and pillow filled with straw and other plant materials (Van Haaster and Vermeeren, 1999). The presence of a pillow made of plant material was also observed during the excavation of a late 13th-century grave in the cathedral of Quimper, in France (Dietrich and Gallien, 2012). From England, graves that were lined with vegetation, dating between the 12th and 16th century, were reported by Gilchrist and Sloane (2005), and Hodder (1991). In some of these graves, straw was used, but mostly in combination with mosses, hay and sometimes arable weeds (Gilchrist and Sloane, 2005). In an early medieval grave from Georgia, the deceased was laid down on a bed of plant material (Kvavadze et al., 2008).

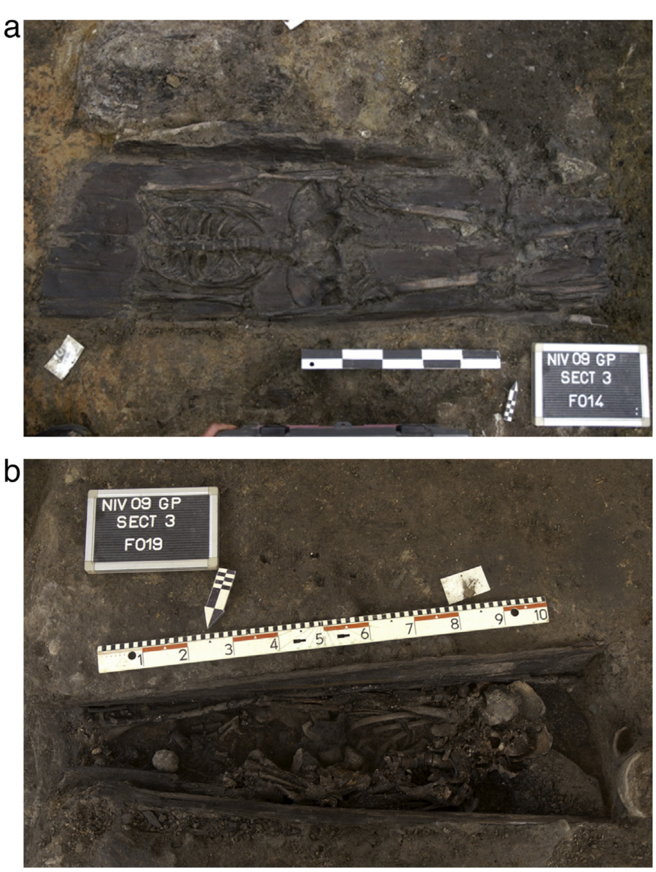

Fig. 2. Two of the burials studied (F14 and F19).

Fig. 3. Detail from the painting 'The triumph of the death' by Pieter Breughel the Elder (1562 AD), Museo del Prado Madrid.

Fig. 4. 18th century painting of the Cemetery Chapel at Saint John's Hospital (Bruges, Belgium), with a body completely wrapped in straw, in preparation of its burial. Anonymous - St. Janshospitaal museum Brugge - ©Image: Lukas - Art in Flanders vzw.

The practice of using straw or other plant material as a pillow or cover for the corpse, within the coffin or simply within the burial pit, might have its origin in early Christian church history. Innocentius I, pope from 401 to 417 AD, dictated that the dying should be removed from their bed and placed on a bed of ash and straw before receiving the last rites, as a sign of humility and penance. This tradition was later adapted to the custom of placing ash and straw or other plant material in the coffin (Veeckman, 1997). Next to religious regulations, practical motivations, e.g. the absorption of body fluids, might also have played a role.

Most of the archaeological finds of straw, hay and other plant materials, used as bedding material in the grave listed above seem to derive from high status or elite burials. However, this does not necessarily mean that it was a custom reserved for the highest social classes. A contextual, taphonomic bias must be taken into account. Archaeological records of burials with straw or other plant materials are all known from the study of sarcophagi, crypts and other dry or sealed environments, which are favourable for the conservation of organic material but typically represent the burials of the upper classes of society. In the more common grave types, i.e. plain burials in the soil, characteristic for the common people within medieval society, there is hardly any chance for uncharred botanical remains to be preserved. As a consequence, the use of straw, hay and other plant materials as bedding material remains invisible in the archaeological record of such contexts.

At Nivelles, preservation conditions for organic material are far better compared to most other, NW-European medieval burial sites, due to the high humidity level of the soil. The high percentages, in the pollen assemblages from the graves, of cereals, grasses and associated weeds from arable fields and grasslands are therefore interpreted to result from the use of straw and hay in the burial ritual, inevitably biasing the sampled contents from the pelvic area.

Still, there are indications that part of the pollen assemblage from the pelvic area originates from the digestive tract of the buried individuals. Except for the Cerealia, pollen from food plants like *V. vinifera* and *A. cerefolium* exclusively occur in the pelvic samples. Also, eggs of intestinal parasite eggs occur far more frequent in the pelvic samples compared to the control samples.

4.2. Intestinal parasites

All samples from the pelvic area produced eggs belonging to one or more taxa of intestinal parasites, indicating that the infection rate was high in the medieval population of Nivelles. This observation is in accordance with the fact that eggs of *Trichuris* and *Ascaris* have previously been identified from coprolites recovered from three of the excavated burials from Nivelles, one of these showing exceptionally high concentrations of *Trichuris* eggs (Rácz et al., 2015).

Trichuris and *Ascaris* must have been very common infections during medieval and postmedieval times, as eggs from these intestinal parasites have been found in numerous archaeological contexts dating to this period, e.g. at archaeological sites from Belgium (e.g. Appelt et al., 2014; De Clercq et al., 2007; Deforce, 2010; Fernandes et al., 2005; Rocha et al., 2006; Troubleyn et al., 2009) and other areas in NW-Europe (e.g. Brinkkemper and van Haaster, 2012; Bouchet et al., 2003b). Today these parasites are still common in so-called developing countries (Bethony et al., 2006).

Capillariid eggs have also been found in archaeological sites in NW-Europe (e.g. Bouchet, 1997; Dittmar and Teegen, 2003; Mowlavi et al., 2014), including Belgium (Rocha et al., 2006; Fernandes et al., 2005), although these finds are far less numerous compared to these of *Trichuris* and *Ascaris* (Bouchet et al., 2003b). The presence of Capilariid eggs in one of the graves from Nivelles might result from spurious or from hepatic infection. Spurious infection occurs when the liver of an infected animal is consumed, resulting in the ingestion of unembryonated eggs that pass through the digestive tract and which are shed in the faeces (Galvão, 1981). Hepatic infection, or true infection, results from the ingestion of embryonated eggs, after which the larvae hatch and penetrate through the intestinal wall, migrate into the hepatic portal system, develop into adults and finally release eggs in the liver parenchyma (Farhang-Azad, 1977). If this was the case, the eggs must originate from the decomposed liver of the buried individual. Finally, as several Capillaridae have rodents, including rats, as a preferred host, the eggs in the grave might result from the decomposition of an infected animal in the grave, but as no animal bones have been found in this grave, this is unlikely.

5. Conclusions

Historic documents and archaeological records document the use of straw and other plant materials as bedding in medieval burials. The larger part of the archaeological records for these burial customs seems to originate from high status or elite burials, which are located inside churches, sometimes in sarcophagi and crypts. This interpretation is most likely to be taphonomically biased as the preservation of plant remains is generally much better in these sealed environments. Pollen analyses of burials from the medieval cemetery at Nivelles, which show exceptional good preservation for organic material due to the high humidity of the soil, now indicates that this practice was probably far more common.

At the same time, the results obtained have consequences for the interpretation of pollen assemblages from medieval burials. Liquidification of the soft body parts, and mixing with the contents of the grave may have resulted in the dispersion of pollen, also into the pelvic area, from plant material used during the burial rites. When sampling is restricted to the pelvic area, this might lead to the conclusion that the pollen types found reflect the contents of the digestive tract and thus the last meals of the buried person. Therefore, the present study provides an extra argument for the rigid analysis of control samples, next to those from the pelvic area, as already argued by Berg (2002) and Reinhard et al. (1992).

Acknowledgements

We wish to thank, Stefan Deconinck, Anton Ervynck, Jan Moens, Karl Reinhard and Frank Vanhyfte for providing historical information and useful comments on an earlier version of the manuscript.

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