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Detailed recording of tooth wear (Grant, 1982) as an evaluation of the seasonal slaughtering of pigs? Examples from Medieval sites in Belgium

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ABSTRACT: In theory, the detailed recording of tooth eruption and wear, following Grant (1975, 1982), can reveal whether pigs were slaughtered throughout the year or only during a limited season. This statement is tested in four case-studies, involving medieval sites of high status from Belgium that are all heavily depending on pig breeding for their meat supply. The oldest site (Wellin) was occupied by the Carolingian elite, while the others were property of the feudal nobility. It is demonstrated that a slaughtering season in winter can be attested in all four sites by the presence of peaks in the age distributions of the pigs. However, an alternative explanation based upon the unequal duration of the wear stages, although unlikely, cannot be ruled out completely. Several important sources of variation must also be taken into account, involving multiple birth seasons within a year cycle, variations in the timing of birth and slaughtering, and differences in tooth eruption and wear, due to food abundance, genetic variation or weather conditions.

KEYWORDS: *SUS SCROFA* F. DOMESTICA, SEASONALITY, KILL-OFF PATTERNS, TOOTH WEAR, MIDDLE AGES, BELGIUM

RESUMEN: En principio, el registro meticuloso de la erupción y el desgaste dentario, de acuerdo con los criterios de Grant (1975, 1982), puede evidenciar si los animales, en este caso cerdos, fueron sacrificados a lo largo del año o sólo en épocas muy concretas del mismo. Tal aseveración ha sido aquí sometida a análisis a través de cuatro muestras procedentes de asentamientos medievales belgas de alta extracción social, todos ellos fuertemente dependientes de la cría de porcino para su aprovisionamiento cárnico. El asentamiento más antiguo (Wellin) fué habitado por la aristocracia carolingia mientras que los restantes fueron feudos de la nobleza. Podemos evidenciar que una época de matanza coincidente con el invierno se detecta en los cuatro lugares en virtud de la aparición de máximos en las frecuencias de determinadas edades de los animales. A pesar de ello, no resulta posible invalidar totalmente hipótesis alternativas referidas a la desigual duración de las diferentes etapas de desgaste dentario. Otras importantes fuentes de variación deben asimismo ser tenidas en cuenta. Es el caso de la existencia de múltiples épocas de parto a lo largo del año, variaciones en la sincronización entre el nacimiento y el sacrificio así como variaciones en los patrones de emergencia y desgaste dentarios causados por diferentes abundancias de alimento en diferentes épocas, así como variabilidad genética y climatológica.

PALABRAS CLAVE: *SUS SCROFA* F. DOMESTICA, ESTACIONALIDAD, PATRONES DE SACRIFICIO, DESGASTE DENTARIO, EDAD MEDIA, BÉLGICA

INTRODUCTION

It is common knowledge that during the Middle Ages pigs (*Sus scrofa* f. domestica) were generally slaughtered at the end of the year. This pattern is explained by the economics of pig husbandry. At the end of autumn, the animals attain maximum meat and fat weight, after a period of foraging in the woods, feeding on the then abundant acorns, beech-mast and other plant products. However, when winter comes, the animals lose weight, due to the scarcity of food during that season. This loss of biomass can only be prevented by extra feeding (which is an uneconomical option) or by slaughtering the animals and preserving the meat, by smoking, salting or drying.

Iconographic sources, i.e. medieval calendars, illustrate the seasonal kill-off pattern in pig husbandry. The illustrations accompanying the months of October or November traditionally show pig herds foraging in the woods. Medieval or early post-medieval representations depicting winter scenes often show the animals being slaughtered and the meat being processed (Ten Cate, 1972; Laurans, 1975). According to written sources from France, the herding of pigs in the forests (Fr.: *la glandée*) generally took place from the beginning of October to the end of November, although some regional or chronological variations occurred. Considering the timing of slaughtering, historical information confirms that this happened mainly at the end of the year (Laurans, 1975).

Although the seasonal slaughtering of pigs is thus commonly accepted as part of Medieval husbandry in North-Western Europe, this pattern has, as far as is known, not yet conclusively been attested in archaeozoological material from that period and region. In this study, pig remains from four medieval sites from Belgium are analyzed for seasonal slaughtering patterns, using a cheap and easy method of observation. The paper starts with a discussion of the theory and methodology of assessing seasonal kill-off patterns from archaeological pig remains.

THEORY

Unlike some species living in the wild, domestic animals are present near human dwelling places during the whole year. This excludes the use of phenomena such as seasonal migrations as indicators for the seasonal exploitation of domestic animal resources by man. Moreover, pigs do not seasonally develop easily observable morphological characteristics, such as the antlers in the Cervidae. Pigs show increments in their tooth cementum, that differ seasonally (Landon, 1993), but this phenomenon will not be discussed here (see below).

A characteristic of many mammal species is the seasonal nature of reproduction. This is also true for the wild boar (*Sus scrofa*), the wild living conspecific (and forefather) of the domestic pig (*Sus scrofa* f. domestica). The animals mate in a certain season (near the end of the year) and after a gestation period of constant length (4 months) the young are born in a certain time period within the year (spring) (Mohr, 1960). It will be discussed below whether this general scenario is always valid for wild boar and whether it is also true for domestic pigs. However, accepting the assumption of one constant and limited birth season a year, creates the possibility to see in which season an animal was killed by assessing its age.

If detailed age estimations can be obtained from a bone collection from a site where pigs were only killed during a specific part of the year on a site, seasonality will reveal itself by a discontinuous age distribution curve (Figure 1). Only the age classes that the animals go through during the slaughtering season will be present. In the case where animals are killed throughout the year, but preferentially in a certain season, the distribution curve will be continuous, but will show peaks caused by an over-representation of the age classes attained by the animals during the slaughtering season.

Observations on bone material, allowing an estimation of the age at which an animal was killed, include epiphysial fusion, tooth eruption and wear, and tooth cementum increment analysis. Epiphysial fusion data can only be used with caution for aging pig bones (Bull & Payne, 1982) and have the disadvantage of frequently only yielding upper or lower estimation limits. Moreover, at almost all sites, pig bones are severely fragmented, which further hampers the applicability of this method. The observation of tooth eruption and wear has proved to be a fairly reliable method for age estimation (Hillson, 1986) and is certainly more often applicable than epiphysial fusion data. Tooth cementum increment analysis has recently been applied on pig remains and proves to be a promising method (Landon, 1993). However, this technique will not be discussed here, since it consumes more time and money, and entails more technical support, than the simple morphological observation of tooth eruption and wear. Therefore, it could be possible that it is less suitable for some researchers in the field. In this study, it is the recording of tooth eruption and wear that will be further explored, i.e. the methodology developed by Grant (1975, 1982).

DETAILED RECORDING OF TOOTH ERUPTION AND WEAR: GRANT'S METHOD

There is no need to discuss here at length the method of recording the eruption and wear of mandibular teeth in pigs, as developed by Grant (1975, 1982). In summary, the eruption stage and wear of each individual permanent molar in the mandible is coded by comparison to a figurative scheme (Grant, 1982: 94). These codes (19 different ones for M_1 and M_2, and 16 for M_3) are subsequently given a numerical value and these are added for the complete molar row. This sum (MWS: mandibular wear stage) is an evaluation of the wear of the molar dentition in the lower jaw. Since tooth eruption and wear gradually develop through time, the wear stages also represent age classes, although there is no straightforward way to calculate one from another for each MWS. Thus far, no correlation study has been undertaken on a large collection of domestic pig mandibles derived from animals of known age. Higham (1967) gives age estimations for wear stages of the M3 but these cannot directly be correlated with Grant's scheme. Further complicating factors of Grant's method are the fact that the individual MWS represent unequal time lengths and that the real age corresponding with a certain MWS may differ between pig populations (see below). However, observations on the bone material allow some MWS to be related to real ages, a possibility that will be explored further.

Despite the uncertainties about real ages, Grant's method is powerful, especially because of the great detail in observation. In the case of pigs, it enables one to recognize 52 MWS (from 0 to 51), which is a considerable number, compared to the limited descriptive set of wear stages used by other authors (e.g. 7 in Becker, 1980; 6 in O'Connor, 1989). Another advantage of Grant's method is the relatively easy and quick way in which it can be used, compared to other more complicated techniques put forward to describe tooth wear (e.g., as in Prummel, 1983).

UNEQUAL LENGTH OF MWS

Following Grant's method, the assessment of seasonal kill-off patterns within a population of domestic animals will be based upon the recognition of peaks or discontinuity in a MWS distribution. However, a factor complicating the recognition of patterns in these distribution curves is the fact that the MWS, as has been mentioned above, have different (and unknown) duration. As long as these variations do not follow a trend, this should

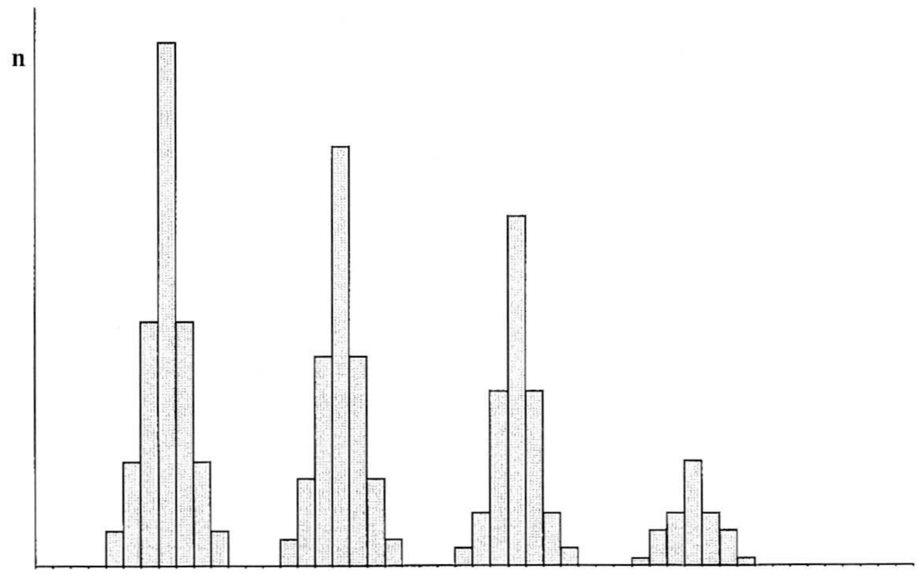

FIGURE 1

Example of a theoretical distribution of age classes, derived from a population of animals born in the same season and all slaughtered in a limited period within the year. The peaks represent animals killed during their first, second, third and fourth year.

not severely hamper the recognition of patterns. However, one must expect that an animal probably goes more quickly through the stages during which a molar erupts, an event that occurs three times in the life of a pig. Consequently, a MWS distribution curve from a population characterised by a non-seasonal slaughtering pattern could still show peaks and troughs, the latter comprising the stages with active tooth eruption. Since the relationship between Grant's MWS and real age is not studied, the effect of this unequal duration of the MWS upon the distribution curves cannot be evaluated. Moreover, little is known about the actual time it takes for a tooth to erupt (and come into wear) and to what degree this differs between the molars. It is the author's impression that the eruption process takes considerably less time for M_1 and M_2 compared to M_3, although objective time estimations cannot be put forward.

The possibility that MWS including eruption events will always be scarcely represented, cannot be ruled out, but is, on the other hand, also not proven. It could, for example, be possible that, for an individual molar, certain wear stages take less time to go through than certain eruption stages. Certainly, only observational work on recent populations can shed more light upon these methodological problems. The possible impact of the unequal lengths of the MWS upon the analysis of seasonal slaughtering will further be discussed when dealing with the results of the case-studies.

IDENTIFICATION OF THE SLAUGHTERING SEASON

Assuming that the unequal lengths of the MWS do not significantly influence the pattern of peaks in the distribution curves, it can be concluded (as described above) that, if a distribution curve of MWS is discontinuous or shows peaks, a seasonal kill-off pattern was in effect. However, once such a pattern has been established, it is still not known during which season the slaughtering took place. This knowledge comes from connecting real ages to (some of) the MWS, and from knowing precisely in what season the animals are born.

As a first approach, it will be assumed that the timing of birth of primitive breeds of domestic pig did not differ significantly from that of wild boar. The birth season of *Sus scrofa* in Belgium extends from February to April (Frechkop, 1958), and in the Netherlands and Germany from March to April (Mohr, 1960; Eygenraam, 1973 *fide* Lauwerier, 1983). That these periods could also be valid for primitive domestic pigs is suggested by late-medieval written sources from France, which state that domestic pigs were generally born during the months of February, March and April (Laurans, 1975). From these birth data, the ages of animals killed during their first, second and third winter can be derived (Table 1).

Months of the year (average)	Age range (average)
Spring farrowing:	
February - April (March)	birth
first year's December	7-11 (8-10)
second year's December	19-23 (20-22)
third year's December	31-35 (32-34)
Autumn farrowing:	
August - October (September)	birth
first year's December	1-5 (2-4)
second year's December	13-17 (14-16)
third year's December	25-29 (26-28)

TABLE 1

Expected ages (in months) of pigs killed in their first, second and third winter (explanation see text).

In order to see which season the peaks in the distribution curves of MWS really represent, the only step that still needs to be taken is finding some real age marking points along the MWS scale. Some of the MWS can indeed be related to a real age of death, i.e. those where tooth eruption is occurring (Grant, 1982). All sources in the literature give the same eruption sequence for the lower teeth of wild boar and pig, except some 18th century data listed by Silver (1969) that are now regarded as unreliable (Bull & Payne, 1982). The estimations for the timing of the eruption of the individual molars differ between authors. Some of the more important examples are given in Table 2, but more references can be found in Bull & Payne (1982). In what follows, the averages given by Matschke (1967) will be used, based on the assumption that primitive, medieval pig breeds showed an eruption timing comparable to wild boar. The identification of the MWS where tooth are erupting can best be done in each bone collection separately, thus correcting for inter-population variation.

	wild boar[1] Briedermann 1972	wild boar[2] Mohr 1960	wild boar[3] Matschke 1967	pig[4] Habermehl 1975	pig[5] Silver 1969
M1	5 - 10	5 - 6	5 - 6 (6)	4 - 6- 8	4 - 6
M2	12 - 14	12 - 18	12 - 14 (13)	7 - 10 - 13	7 - 13
M3	21 - 24	21 - 24	-	16 - 18 - 20	17 - 22
M_3	-	-	23 - 26 (25)	-	-
M^3	-	-	26 - 33 (29)	-	-

TABLE 2

Ages at eruption (in months) of permanent molars in wild boar and domestic pig, according to the main literature sources. Only Matschke (1967) gives data that distinguish between upper and lower third molars.Given are: [1], [2], [5]: range; [3]: range and average (between brackets); [4]: average for early, middle and late breeds.

ONE FARROWING A YEAR, OR MORE?

Before dealing with the case-studies, one further consideration has to be made. It has so far been assumed that pigs were born only once a year, but this may not be a valid statement for all pig populations. Lauwerier (1983) highlighted the fact that, when food is abundant, wild boar populations can have two farrowings a year, i.e. one in spring and one at the end of summer or in early autumn. That this pattern also occurred in primitive domestic pig populations, is proven by written sources from classical Rome and from late medieval and early post-medieval England (Lauwerier, 1983). The statement is also confirmed by medieval written sources from France, mentioning that pigs were also born outside the main period of February to April and that it is possible for a sow to have two farrowings a year (Laurans, 1975). However, this requires that the domestic pig population was kept with an abundant food supply, that the farmer had the necessary know-how, and that it was an economically profitable strategy to have more than one farrowing a year (Lauwerier, 1983).

Assuming a spring and autumn farrowing, a traditional slaughtering period in winter will produce a double number of peaks in the MWS distribution curve (Figure 2), representing a larger variety of age ranges (Table 1). However, this will not obstruct the evaluation of seasonal kill-off patterns. Only when more than two farrowings a year have to be accepted or when they appear irregularly from year to year, could peaks in the distribution curve be difficult to recognize.

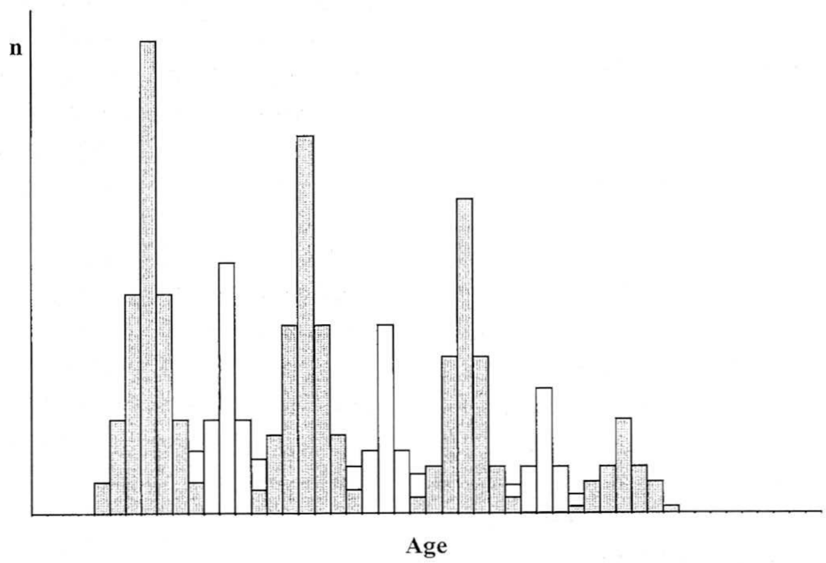

FIGURE 2

Example of a theoretical distribution of age classes, derived from a population of animals born in two seasons (shaded and white) and all slaughtered in a limited period within the year. Compare to Figure 1.

CASE-STUDIES

As test cases for the explained theoretical considerations and for the applicability of Grant's method, four sites from Belgium are presented. They are all habitations of the feudal nobility or its predecessor, the Carolingian elite. The reason for this choice is that pigs played an important role in the food supply of these noble sites, not only in terms of biomass but also in terms of status and economical independence (Ervynck *et al.,* 1994, Ervynck & De Meulemeester, 1996). Pig bones are always found in large numbers on these noble sites, which increases the possibility of finding a large collection of mandibles, thus ensuring a firm basis for analysing the distribution of the MWS.

In this study, only mandibles (for which Grant's method initially was designed for) were used, while maxillae were excluded. It has been noted for wild boar that the timing of eruption is different for upper and lower tooth rows, i.e. M^3 erupts significantly later than M_3 (Matschke, 1967, Bull & Payne, 1982). Most probably, this statement is also true for domestic pigs although it is not described in the literature (Bull & Payne, 1982). In the sites studied, mandibles were always more frequently (and more completely) preserved than maxillae. It should be noted that no distinction was made between right and left mandibles. The theoretical possibility of including in the analysis two mandibles of the same individual was not considered to have any consequence for the interpretations.

Only complete rows of lower molars or fragments of mandibles with only one tooth missing were included in the analysis. The wear code of a missing tooth was reconstructed in the way described by Grant (1982), i.e. on the basis of the most frequent combinations of individual tooth wear stages within each MWS. In three of the four sites, the proportion of 'reconstructed' MWS was fairly high. However, comparison of the MWS distribution curves with or without the reconstructed specimens yielded no difference at all. All distribution curves presented (Figures 3 to 6) give the running mean of the number of finds per MWS, implying that the frequency of each class was replaced by the mean of the class frequency, the frequency of the foregoing and of the following class. In this way, the curves were smoothed, reducing the impact of random fluctuations and possible observer bias.

For the interpretation per site, the possible impact on the distribution curves of the unequal lengths of the MWS will first be ignored. This phenomenon will, however, be taken into account in the final discussion.

Londerzeel

During late medieval times, a polygonal brick castle was erected on an artificial hill at Londerzeel (province of Brabant) (Dewilde *et al.,* 1994). From a refuse layer on the western slope, 2667 identifiable animal remains were handcollected, dating from the end of the 13th to the third quarter of the 14th century. Amongst the 892 pig bones, 82 mandibles could be used for an MWS estimation (Ervynck *et al.,* 1994). Only 12 reconstructed specimens (15%) are included in the sample. Within the group of larger domestic mammals slaughtered at the site (cattle, pig and sheep), 64% of the remains belonged to pig.

The MWS distribution curve clearly shows two peaks (Figure 3), labeled as W2 (around MWS 18) and W3 (around MWS 29). Considering the correlation of MWS with real age classes, it could be noted from the bone collection that mandibles with an erupting M_2 (of animals around 13 months old, see Table 2) have an MWS around 12. Mandibles with erupting M_3 (around 25 months old) could be found between MWS 22 and 28. It follows that peak W2 represents animals between 13 and 25 months, and could thus be the result of the slaughtering of individuals born in spring, during their second winter (and thus 20 to 22 months old, see Table 1). Peak W3 could represent animals born in spring and killed during their third winter, at the age of 32 to 34 months. Generally, the distribution does not contradict a pattern of preferred winter slaughtering, while there is no indication of more than one farrowing a year for Londerzeel's pig population.

Animals born in spring and killed during their first year, at the age of 8 to 10 months, were clearly absent from the bone collection. An explanation could be that the context at Londerzeel was taphonomically identified as kitchen refuse, while table leftovers were certainly not present amongst the animal remains (Ervynck *et al.,* 1994). The pig bones consisted almost exclusively of cranial fragments and could thus represent parts of the heads of older animals, discarded during some process of food preparation. The head bones of younger individuals could well have been served on the dish, together with the meat parts, for example when complete animals were prepared.

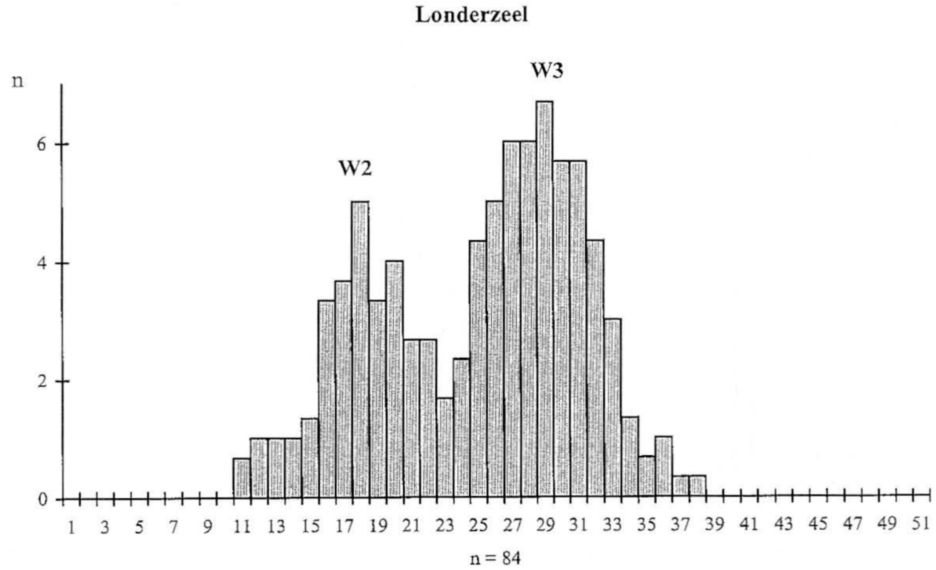

FIGURE 3
MWS distribution for Londerzeel (n: running mean of the number of specimens, other codes: see text).

Vilvoorde

The excavations of the medieval fortified site 'Notelarenberg' at Vilvoorde (province of Brabant) were only published in a short note (Borremans, 1979). However, a report exists on the handcollected animal remains, dealing with consumption refuse dating from the 11th and 12th century (Gautier, *s.d.*). The number of identifiable bones was 3222, with 2289 pig remains. Within the collection 137 mandibles could be used for age estimation. The number of reconstructed MWS is 58 (42%). Within the group of cattle, pig and sheep, 73% of the remains belonged to pig.

The MWS distribution curve (Figure 4) shows several peaks, labeled B, W1, W2 and W3, respectively around MWS 1-2, 8, 16-17 and 26-28. Observations on the bones revealed that M_1 erupted around MWS 4, M_2 around MWS 12 to 13, and M_3 between MWS 24 to 27. Peak W1 thus represents animals between 6 and 13 months old, most probably born in spring and slaughtered during their first winter. Following the same deductions, peak W2 would indicate the winter killing of second year animals that were born in spring, while W3 could represent third year animals born in spring and killed in winter. Finally, peak B clearly represents piglets that were killed at very young ages ('suckling pigs') or animals that died at birth. As at Londerzeel, a seasonal slaughtering pattern seems to be present, while there is no indication of a birth period in autumn.

Wellin

At Wellin (province of Luxemburg), a refuse pit was excavated, belonging to a Carolingian site from the 8th century A.D. Due to the restricted area investigated, the nature of the habitation is not totally clear, but the cultural artifacts point to a household of high status, most probably the center of power of a Carolingian domain (Evrard, 1993). In the refuse pit, 6275 identifiable animal remains were handcollected, yielding 3843 pig bones. Amongst these, 182 mandibles could be found that were suitable for age estimation. 85 MWS (47%), were based on glued jaws. Pig constituted 88% of the major domestic mammals (cattle, pig and sheep) (Wattiez, 1984).

The MWS distribution curve (Figure 5) shows a comparable pattern of peaks to that of Vilvoorde (fig. 5). Following a similar line of deduction, the observed eruption timing in MWS 3-5 (M_1), 11-13 (M_2) and 20-24 (M_3) points to the winter slaughtering of animals born in spring (peaks W1, W2 and W3). Noticeable is the large amount of piglets that were killed or that died shortly after birth (peak B). The observations on the material from Wellin can be seen as a further corroboration of the conclusions drawn from the previous case-studies.

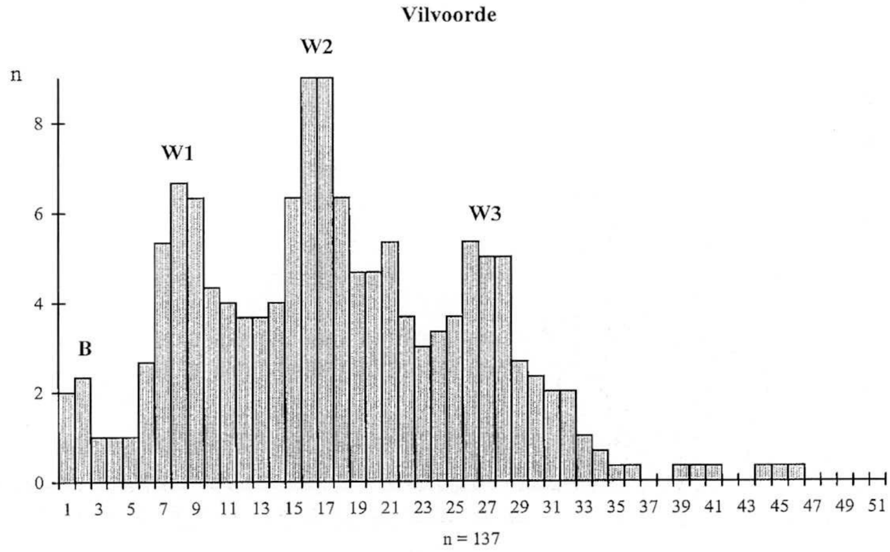

FIGURE 4
MWS distribution for Vilvoorde (n: running mean of the number of specimens, other codes: see text).

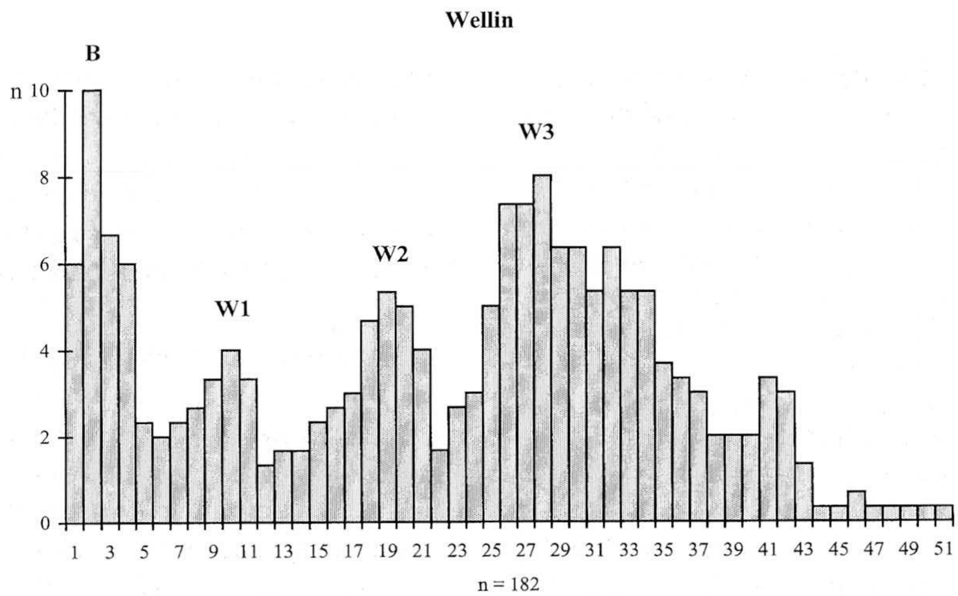

FIGURE 5
MWS distribution for Wellin (n: running mean of the number of specimens, other codes: see text).

Sugny

A fortification was erected and inhabited during Carolingian times (ca. 750-850 A.D.) on the top of a rock at Sugny (province of Namur). During a later phase of occupation (end of the 10th century to around 1100 A.D.), a castle was built on the site, serving as an exploitation center in a sparsely inhabited and heavily forested region (Matthys, 1991). Nearly 3000 identifiable bones were recovered from waste deposits at the foot of the rock, all dating from the 11th century occupation phase. Pig is the dominant mammal amongst the consumption remains (Ervynck,1992 and unpublished data). However, only 49 pig mandibles could be used for age estimation, due to a significant degree of fragmentation of all animal remains. Due to the same reason, 21 (43%) of the MWS needed to be reconstructed.

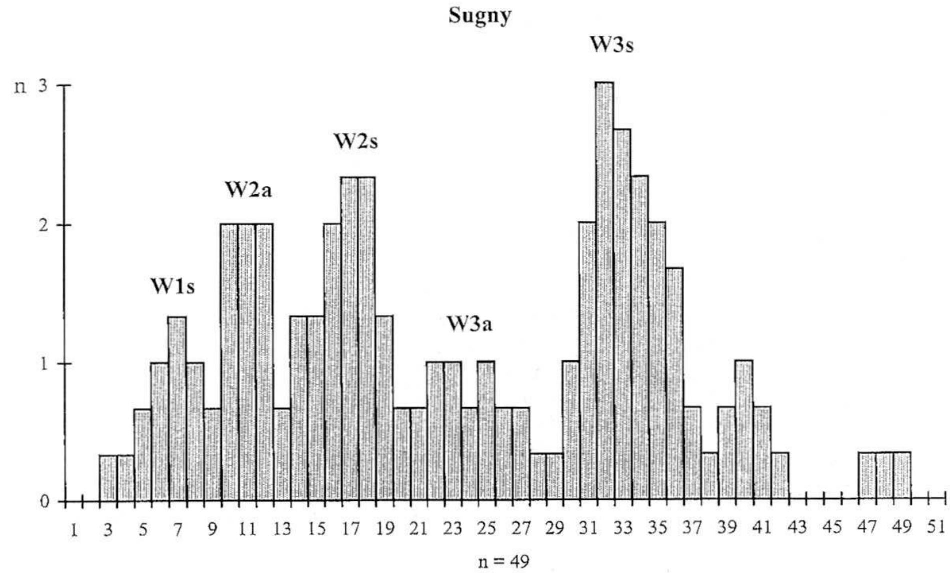

FIGURE 6
MWS distribution for Sugny (n: running mean of the number of specimens, other codes: see text).

The MWS distribution curve of this site (Figure 6) also shows peaks but is not comparable to the other curves because there are more peaks present. Assuming that the peaks do not represent random fluctuations of a slaughtering pattern that was continuous throughout the year, the data can still be interpreted in terms of a winter killing pattern, if we accept two farrowings a year for the Sugny pig population. It could be observed that the eruption of the individual molars was situated in MWS 4-6, 11-13 and around 26, which corresponds with the ages of (on average) 6, 13 and 25 months. In that way, peak W1s could represent animals of 8 to 10 months that were born in spring and killed during their first winter (hence the label W1s). Peak W2a could be formed by pigs born in the second half of the year that were killed during their second winter. However, to make this interpretation fit with the distribution curve and the noted eruption timing, it is necessary to assume that these animals were born at the end of the autumn birth season and thus only attained an age of around 13 months. Peak W2s could represent animals of 20-22 months, born in spring and killed during their second winter, while peak W3a could indicate pigs born in autumn and killed during their third winter. Again assuming that the autumn pigs were born at the end of the birth season, these animals would have been slaughtered at the age of around 25 months. Finally, peak W3s could represent the pigs born in spring and killed during their third winter. Apparently, pigs that were born in autumn were not killed during their first winter. This makes sense since these animals are only 2 to 4 months old at that moment. It can finally be noted that no death around birth could be attested for the Sugny population.

Following the interpretations presented above, the Sugny material could be derived from a pig population with two birth seasons a year on which winter slaughtering was practiced. However, this interpretation must be presented with caution, since the data set upon which it was based was restricted (49 specimens). For the same reason, the presence of two farrowings a year must still be regarded as a hypothesis. However, if two birth seasons a year are a sign of food abundance, this could fit with the location of Sugny in the Ardennes, at that time a densely forested region. Two of the other sites investigated (Vilvoorde and Londerzeel) were certainly situated in regions with less wood and higher human population density. A reason for the single yearly birth season at Wellin is harder to find, since the site was also situated in a wooded area. However, it could be that for some economical reason the pig farmers at Wellin only wanted one farrowing a year, or did not have the know-how to achieve two birth seasons.

Generally, the four sites studied do not corroborate the view of Lauwerier (1983) that the possibility of having a multiple birth season in pig populations will definitely obstruct a reconstruction of the season of slaughtering. Apparently, this possibility should have revealed itself directly in the MWS distributions, but did not play a role in three of the four sites studied.

DISCUSSION

The results from the case-studies illustrate the use of a detailed method of recording tooth eruption and wear. The patterns observed seem to corroborate the hypothesis that slaughtering of pigs took place mainly in winter. An explanation for the pattern of peaks as resulting from random variations in death rate in relation to age seems more unlikely and is contradicted by the constancy of the position of the peaks and the fact that they can be explained by a demographic model of former pig husbandry that makes sense in economic terms.

Theoretically, it is still possible that the MWS located between the observed peaks only represent stages the animals go through quickly because tooth eruption takes place. This possibility can not yet be excluded, especially since the eruption of all three molars takes place during the period within the year that slaughtering activity is low, according to the model of seasonal slaughtering during winter. In theory, it could thus be possible that at Londerzeel, Vilvoorde and Wellin pigs were killed throughout the year and that the patterns observed in the distribution curves are intrinsic to Grant's method and not related to seasonality. The unlikeness of this explanation in terms of medieval pig husbandry cannot be accepted as an argument against it, because this would result in circular reasoning. However, the patterns observed at Sugny cannot be explained by non-seasonal slaughtering and unequal time length of the MWS since, for example, the W2a peak coincides with the MWS comprising the eruption of M_2. Detailed observation of the distribution curve from Londerzeel also shows that the MWS characterised by the eruption of M3 (MWS 22 to 28: Figure 3) do not completely coincide with the trough between W2 and W3, but are partly included in peak W3. Unpublished MWS distribution curves from the ancient town of Sagalassos (Anatolia, Turkey) show peaks that coincide with MWS characterised by eruption stages (De Cupere, pers. comm.). In conclusion, these observations make it unlikely that the patterns observed in the four Medieval sites studied are only the result of unequal time lengths of the MWS. However, the effect of this phenomenon on the distribution curve remains to be taken into account and must be further studied by observations on recent populations.

As a working hypothesis, it can be put forward that the patterns observed are not only the result of random events or unequal time lengths of the MWS, but must be linked to seasonal variations in slaughtering frequencies. Although the results thus point to a preferred winter slaughtering of pigs in Medieval noble sites from Belgium, they do not completely exclude the killing of pigs outside winter. The distribution curves are never discontinuous, except within the range of the very old animals (MWS 35 and beyond). The continuity of the distribution curve could indeed be caused by some slaughtering outside winter or because animals died by accident throughout the year. However, it is likely that, even if there was only winter slaughtering, the observed peaks will always be very broad, due to different causes of variation. First, variation in timing of birth or slaughtering will always have occurred. Secondly, since the calculation of MWS is based on the observation of two phenomena, i.e. eruption timing and tooth wear, two sources of variation influence the MWS. The partial independence of eruption and wear can be seen in wild boar populations where the M3, although fully erupted, sometimes stays (partly) covered with flesh (Briedermann, 1972). Individual differences in tooth eruption can be caused by genetic variation or may even be sex related (although no research has yet revealed differences between males and females in tooth eruption in pigs). Of course, pathology and environmental factors will further add to the variation. Grant (1978) points to delay in tooth eruption due to a low nutritional plane. Also, weaklings may have later eruption ages than stronger individuals in the same litter. From this it may be inferred that interference between individuals (competition within the population), causing subdominant animals to feed on inferior food products, might induce a delay in development and consequently in tooth eruption ages. These individual differences in feeding behaviour may also cause variation in tooth wear. Finally, the eruption and wear of a tooth can differ between the left and right half of the lower jaw (Grant, 1978), a variation that can easily attain two MWS (Rolett & Chiu, 1994). Another complicating factor, responsible for the broad peaks in the distributions, is the fact that the curves are the result of multiple year cycles and will thus be influenced by yearly variation in mating and birth season, food quality and abundance and slaughtering time, for example due to year-to-year differences in weather or husbandry practices.

All sources of variation combined will make it nearly impossible to discriminate, on the basis of a MWS curve, between a site where pigs were killed exclusively in winter and sites where pigs were mainly slaughtered in that period. The variation will also make it more difficult to see whether a pig population studied had one or two farrowings a year, especially when the autumn birth season produced relatively few young. Evolution of domestic pig breeds, differences in husbandry techniques or food availability, ecological factors and genetic variation will also explain why MWS distribution curves will not always be easy to compare between sites, particularly when these are significantly separated in time or space.

CONCLUSION

Although important sources of variation act upon the MWS distribution curves, the impression remains that a seasonal pattern of pig slaughtering was revealed at the four sites studied. In the future, it will be interesting to see whether, within north-western Europe, this seasonal pattern also occurs in medieval urban contexts, or in sites from other periods, such as the late Roman *castra* that also depended heavily on pig consumption. On the other hand, the detailed recording of tooth eruption and wear will not only reveal patterns of seasonality, it will also illuminate other aspects of pig husbandry. It must, for example, be possible in large collections with sufficient complete mandibles to discriminate between the slaughtering patterns for sows and boars. The MWS distribution curves can also easily be converted to survival curves (Figure 7) that produce information about the proportion of animals killed in their first, second or third year, or as old individuals. This will certainly produce a better understanding of former pig husbandry techniques.

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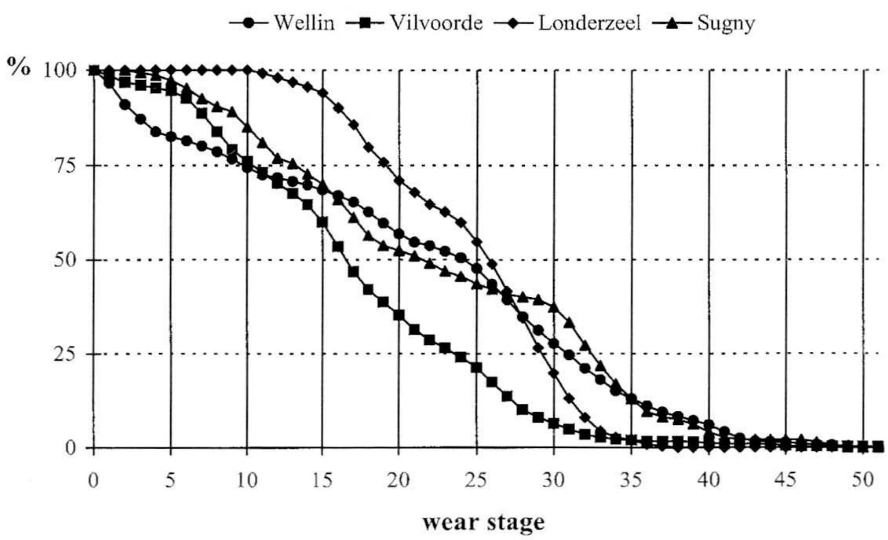

FIGURE 7

Survival curve of the pig populations from the four sites studied. Presented are the negative cumulative distribution curves, with '%' indicating the percentage of the originally born population that is still present at each MWS.

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