

Biometric variation of domestic animals in Rome from the Orientalizing/Archaic period to the Middle Ages

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ABSTRACT

A large number of assemblages of animal remains have come to light in the modern city of Rome and have been studied over the past forty years, providing a large amount of information on animal consumption and exploitation from the Early Iron Age (9th c. BC) to the Late Middle Ages (13th c. AD). This long chronological period witnesses the succession of important historical events that have profoundly influenced all aspects, among them the urban landscape, the demography, but also the diet and all economic activities involving animals. Some papers devoted to the discussion of faunal data from single context or on particular topics and some overviews on animal consumption and management in ancient Rome have been already published, but a detailed analysis of biometric data has not yet completely carried out. Biometry is an important tool used in zooarchaeological studies that provides data on size variation in animal populations, contributing to our understanding of husbandry practices, focusing on breeding control and improvement in ancient time. This paper is devoted to the discussion of the results of the biometric analyses carried out with the LSI (Logarithm Size Index) method, in order to investigate on the variation of domestic animals in Rome from the Orientalizing/Archaic period to the Late Middle Ages.

1. Introduction

Forty years of studies of animal remains found in numerous archaeological contexts that have been investigated in the urban area of Rome (Italy) offer the possibility to delineate a reliable picture of diet and exploitation of animals by people that lived in the city and to verify all change that happened in a long and continuous temporal sequence, from the early Iron Age (9th c. BC) to the Late Middle Ages (13th c. AD) (De Grossi Mazzorin, 2016; De Grossi Mazzorin and Minniti, 2009, 2017).

This long chronological period witnesses the succession of important historical events that have profoundly influenced all aspects of ancient life. The several small villages that had arisen on some hills (Palatine, Capitolium, Velia), with the necropolises arranged in the valley, in the Early Iron Age, were afterwards unified in a single proto-urban settlement, whereas the necropolises were displaced on other hills (Esquiline, Quirinal) (Carandini, 1997, 2007, 2011; De Santis, 2009; De Santis et al., 2010a, 2010b; Ampolo, 2013; Carafa, 2014). When flourished the Roman rule, Rome progressively became a large urban centre that reached its maximum expansion in the first centuries AD (Cresci

Marrone et al., 2020). The Roman Empire ended in the 4th c. AD and the city progressively went into a crisis as documented by the Germanic peoples invasions that occurred in the Late Antiquity (5th–6th c. AD). The city became at that time the site of numerous sacks, plagues and famines, which followed one another up, until the succession of Lombard and Byzantine dominations, and, then, the Holy Roman Empire (9th c. AD). The following history of Rome is widely affected by the policy of the Papal State and the contrasts between the papacy and the emperors (Gatto, 2000).

Aware of the difficulty of summarizing in a few lines the history of Rome, in this paper we want to deal only with change that affected all economic activities that involved animals through time. Previous studies carried out on animal remains have in fact highlighted some important change in diet and animal exploitation during the transitional periods. For the Iron Age/Roman period transition have been already evidenced the increasing in pork consumption at the expense of a previous economy based on livestock, the development of breeds and varieties for domestic animals, and the introduction of exotic animals (Mackinnon, 2004; De Grossi Mazzorin et al., 2005; De Grossi Mazzorin and Minniti, 2017). The high incidence of pork consumption in Rome in the first

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centuries of Imperial period is indeed widely known, as well as its decline from the Late Antiquity. A significant change in pig management with larger animals kept locally, probably due to a drastic reduction of market supplying and change of urban demography and landscape in the Late Antiquity/Middle Ages transition has been also already suggested (De Grossi Mazzorin, 2016; De Grossi Mazzorin and Minniti, 2001; Minniti, 2016; Albarella et al., 2019).

Different varieties of domestic animals seem to be also emerged from the Roman period onwards, although to various degrees. Preliminary studies have in fact, observed changes in pig and caprine size suggesting that Romans may have improved animals by introducing and developing different forms (De Grossi Mazzorin and Minniti, 2017). A similar process has also been seen in other domestic animals, such as dogs. Changes in the morphology and size of dog bones from Roman contexts clearly reflect an emergence of different canine breeds and varieties (De Grossi Mazzorin and Tagliacozzo, 2000).

Despite these results, a biometric analysis on archaeological material from Rome finalised to verify all process of size increase, which might be occurred in domestic animal populations through time, has not yet properly investigated.

This paper aims to use the biometric analyses carried out with the LSI (Logarithm Size Index) method, in order to investigate on the variation of domestic animals in Rome and to what extent change in biometry reflect change in political and economic organisation on animal husbandry through time.

Biometry has long been recognized as an important tool that allows to investigate on husbandry practices, and breeding control and their change through time. The validity of LSI method in investigating on size difference in animal populations, and consequently in contributing to our understanding of husbandry practices and breeding control and improvement in ancient times has been long demonstrated. It can overcome the presence of small samples permitting to merge different measurements of the same species on the same scale, so that, through their combination, they can provide larger samples (Albarella, 2002, with reference therein).

The data used in this paper largely derive from the faunal studies carried out by Jacopo De Grossi Mazzorin and Claudia Minniti, many of these still not fully edited in detail, made possible by the long work carried out until 2001 by De Grossi Mazzorin within the Archaeological Superintendence of Rome (currently Special Superintendence of Rome, Archaeology, Fine Arts and Landscape, Ministry of Culture).

2. Material and methods

The biometric data used in this paper come from a large number of contexts of urban Rome from which measurements are available. The biometrical analysis is here performed using a broad chronological spectrum. Five chronological macro-periods regroup the data; they are listed in Table 1. The Orientalizing/Archaic period includes the centuries from the 8th to the 6th BC; the Republican period spans from the 5th to the 2nd c. BC; the Roman Empire developed between the 1st c. BC to 4th c. AD; the Late Antiquity refers to the 5th-6th c. AD; the Early Middle Ages spans from the 7th to the 10th c. AD; the Late Middle Ages refers to data dated from the 11th c. to the 14th c. AD. These macro-periods include a different number of contexts and biometrical data; some periods are better represented than others, as usually happens for a city with a long continuous historical and stratigraphic sequence, which generally can involve the removal of the oldest strata by more recent activities.

The biometric analysis is carried out using the “Zoolog” package created by Valenzuela et al. (in this volume) and has been performed in RStudio.

The following standard references have been used: the mean of the cattle measurements from the Period II (dated to the 1st BC - 1st c. AD) documented at Elms Farm, Heybridge (Johnstone and Albarella, 2002), the mean established in a group of unimproved Shetland ewes (Davis,

Table 1

Rome: list of the archaeological contexts used in this paper, with relative chronology and references.

Context	chronology	macro period	reference
Acqua Marcia	1st BC - 1st c. AD 1st - 2nd c. AD 2nd - 3rd c. AD	Empire Empire Empire	De Grossi Mazzorin (1996)
Arco Costantino	1st c. AD 2nd c. AD	Empire Empire	De Grossi Mazzorin and Minniti (2012, 2017)
Argileto	8th-11th c. AD	Early Middle Ages	De Grossi Mazzorin (1989)
Centocelle	4th-3rd c. BC	Republic	
Colosseo ambiente XXXVI	11th-13th c. AD	Late Middle Ages	Bedini (2002)
Colosseo arco LXVIII	3rd c. AD 11th-13th c. AD	Empire Late Middle Ages	Minniti, in study
Colosseo collettori	2nd-3rd c. AD 2nd-5th c. AD 3rd-5th c. AD 4th-5th c. AD	Empire Late Antiquity Late Antiquity Late Antiquity	Minniti, in study
Colosseo Passaggio di Commodo	1st c. AD 2nd c. AD 3rd c. AD 4th c. AD 7th c. AD 9th c. AD 8th-9th c. AD 13th c. AD	Empire Empire Empire Empire Early Middle Ages Early Middle Ages Early Middle Ages Late Middle Ages	Minniti, in study
Colosseo cuneo XXXIII	3rd c. AD	Empire	Delfino and Minniti (2005)
Colosseo ipogei	1st c. AD 1st-2nd c. AD 2nd c. AD	Empire Empire Empire	
Colosseo piazzale	11th c. AD	Late Middle Ages	Minniti (2008)
Crypta Balbi esedra	7th c. AD 8th c. AD 9th c. AD 10th c. AD	Early Middle Ages Early Middle Ages Early Middle Ages Early Middle Ages	De Grossi Mazzorin and Minniti, 2001; Minniti, 2005, 2009
Crypta Balbi mitreo	5th c. AD	Late Antiquity	De Grossi Mazzorin (2004)
Foro di Cesare cisterna a tholos	1st c. BC 1st BC - 1st c. AD	Empire Empire	Minniti (2014)
Foro di Cesare edificio 1 pozzo B	6th-5th c. BC	Republic	De Grossi Mazzorin (2014)
Foro di Cesare pozzo A389	12th-14th c. AD	Late Middle Ages	De Grossi Mazzorin (1989)
Foro di Cesare settore B dolio 286	8th c. BC	Orientalizing/Archaic	De Santis et al. (2010a)
Foro di Cesare settore B fornace	8th - 7th c. BC	Orientalizing/Archaic	De Santis et al. (2010a)
Foro di Cesare settore B pozzo	6th c. BC	Orientalizing/Archaic	De Santis et al. (2010b)
Foro di Cesare settore D fornace in taberna X	1st BC - 1st c. AD 5th c. AD 5th c. BC	Empire Late Antiquity Republic	Minniti et al. (2012b), Minniti (2014)

(continued on next page)

Table 1 (continued)

Context	chronology	macro period	reference
Foro Romano Basilica Iulia	4th c. BC 2nd c. BC 1st c. BC 1st BC - 1st c. AD	Republic Republic Empire Empire	
Foro Romano Domus Regia	8th c. BC	Orientalizing/ Archaic	Minniti (2012a)
Foro Romano Lapis Niger	6th c. BC	Orientalizing/ Archaic	De Grossi Mazzorin and Minniti (2012, 2013)
Foro Transitorio	1st c. AD	Empire	De Grossi Mazzorin (1989)
Meta Sudans UUSS 3180 - 3641	5th-6th c. AD	Late Antiquity	De Grossi Mazzorin (1995)
Meta Sudans US 1361	1st c. AD	Empire	De Grossi Mazzorin and Minniti (2012)
Meta Sudans US 3399	1st c. AD	Empire	De Grossi Mazzorin and Minniti (1995, 2012)
Palatino Germalo scavi Puglisi	8th-7th c. BC 5th-4th c. BC 3rd c. BC	Orientalizing/ Archaic Republic Republic	De Grossi Mazzorin (1989); Minniti (2012)
Palatino scavi Boni pozzo primitivo	8th-5th c. BC	Orientalizing/ Archaic	Van Kampen et al. (2005)
Palatino scavi Boni sepolcreto	8th-5th c. BC	Orientalizing/ Archaic	Van Kampen et al. (2005)
Palatino Terme di Elagabalo butti 1- 2	2nd c. AD 12th-13th c. AD	Empire Late Middle Ages	De Grossi Mazzorin (2019)
Palatino pendici N-E US 4194	2nd c. AD	Empire	De Grossi Mazzorin, in study
Palatino pendici N-E teche A-B	6th-5th c. BC 5th c. BC 4th c. BC 3rd c. BC	Republic Republic Republic Republic	De Grossi Mazzorin and Garganese (2017)
Palatino temenos	4th-3rd c. BC	Republic	Minniti, in study
Palatino Porta Mugonia	3rd c. BC	Republic	Bedini (2017)
Terme di Diocleziano Quirinale	1st c. AD	Empire	De Grossi Mazzorin (1998)
S Cecilia in Trastevere	12th-13th c. AD	Late Middle Ages	De Grossi Mazzorin and Minniti (2004); Minniti (2005, 2009)
Terme Traiano	2nd c. AD 6th c. AD 7th c. AD	Empire Late Antiquity Early Middle Ages	De Grossi Mazzorin, Minniti, Mezzina, in study
Velia pozzo B	7th-6th c. BC	Orientalizing/ Archaic	De Grossi Mazzorin and Minniti (2009), Minniti (2012a)
Via Gela pozzo	7th-6th c. BC	Orientalizing/ Archaic	Minniti, in study
Via Sacchi	1st c. AD 2nd c. AD	Empire Empire	De Grossi Mazzorin and Coppola (2008)

1996) and the mean of the Late Neolithic pig measurements from Durrington Walls (Albarella and Payne, 2005).

Only some post-cranial measurements of bones with epiphyses fully fused were employed in this study; measures were kept separate according to the axes of length and width, since a correlation between measurements that are taken along the same axis has been ascertained (Davis, 1996). All employed measurements were taken in accordance with the methodologies proposed by von den Driesch (1976) and Davis (1992, 1996). The choice of using only fused epiphyseal parts is made in order to reduce age bias as much as possible, as size increase in most cases cease before or at the time of fusion. However, to completely avoid this bias, we decided to use only the age-independent dimensions, which are so defined by Davis (2000). The measurements taken along the long axis of bones include the following, in order of priority: GL (greatest length) for the limb-bones, GLl (greatest length of the lateral half) or GLm (greatest length of the medial half) for astragalus, HTC (vertical

diameter of the trochlea at its central constriction) for humerus. The measurements taken along the width axis of bones include Bd (greatest width of the distal end) for tibia and metapodials.

The results of biometric analysis may be impacted the sexual dimorphism which is a more difficult influence factor to control since individual bones cannot be sexed with confidence. For this reason, the data from the specific analyses performed for identifying the presence of different sexual groups will be discussed together with those from biometric analyses.

Statistical differences in LSI values between periods were analysed using the Wilcoxon rank sum test.

3. Results

3.1. Cattle

The small quantity of cattle remains recovered in the contexts of Rome listed in Table 1 provided a small assemblage of biometric data (Table 2). This because cattle are generally the least represented category of domestic animals used as food. In addition, the length measurements are less than the width measurements since the remains are generally highly fragmented.

The scarcity of biometric data, then, allows us only with prudence to note difference in cattle size per periods. LSI length values show an increase between the Orientalizing/Archaic-Republic and Imperial periods that is not highly significant ($p > 0.05$) and a decrease after the Empire that becomes very significant between the Late Antiquity and the Middle Ages ($p < 0.05$ between Late Antiquity and Early Middle Ages; $p < 0.01$ between Early and Late Middle Ages) (Fig. 1).

LSI width values seem to confirm all trends demonstrated by LSI length values but without a confirmation of significance by statistical analysis (Fig. 2).

The difference in size cattle may depend on sexual dimorphism. Biometric distinctions between the bones from three sex groups, bulls, cows and steers, can be carried out plotting the measurements of metacarpal that provides the maximum amount of distinction (Albarella, 1997). Unfortunately a dataset of measurements of cattle metacarpals is available only for the Early Middle Ages group (Fig. 3) that confirms the presence of the three sex groups of cattle, though castrates are predominant than females and males. However, looking at the group of castrates, it is possible to notice a discrete variability in size with the greatest length varying between 180 and 207 cm.

3.2. Sheep/goats

More data are available for sheep and goats although the fragmentation state due to butchery and consumption processes must have conditioned their quantity as for cattle (Table 3). All of the data refer to samples that are composed by the different genera of sheep and goat. The majority of bones from archaeological samples are usually identified as belonging to the category of caprine, because sheep and goat bones have similar skeletons and it is difficult to distinguish between them using the traditional morphological approach (Boessneck et al., 1964; Zeder and Lapham, 2010). However, most zooarchaeological studies of

Table 2

Rome: total number of cattle specimens from which measurements have been taken, means of both LSI length and width values per period.

	cattle		
	n.	mean length	mean width
Orient./Archaic	15	0.000	0.009
Republic	15	0.014	0.022
Empire	23	0.085	0.055
Late Antiquity	26	0.067	0.047
Early Middle Ages	183	0.042	0.040
Late Middle Ages	21	0.002	0.052

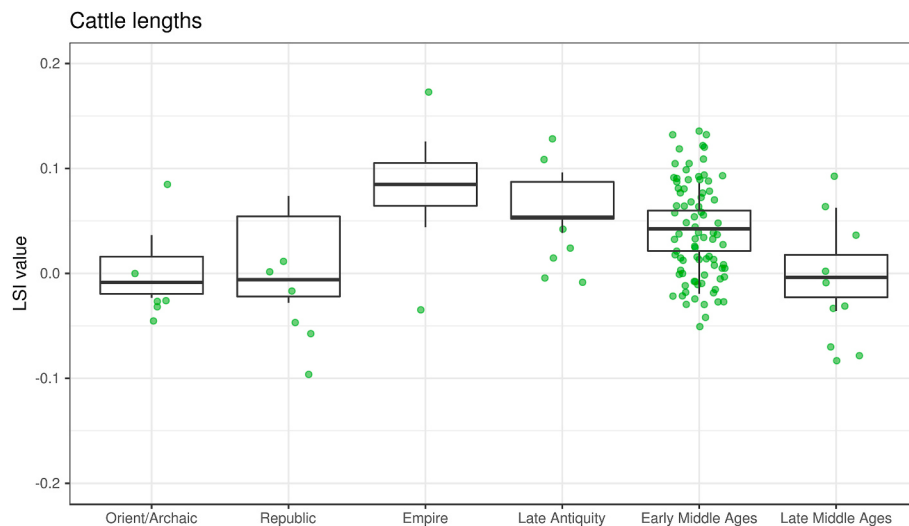


Fig. 1. Rome: cattle LSI length values per period.

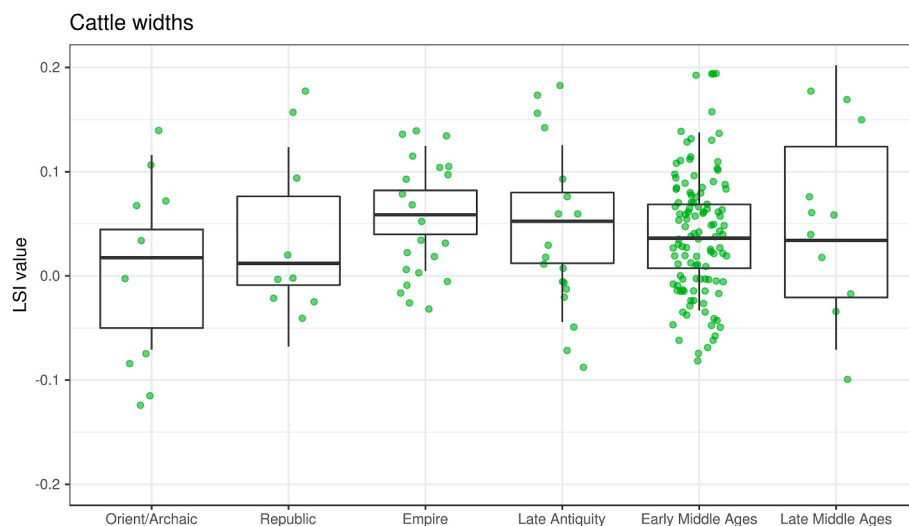


Fig. 2. Rome: cattle LSI width values per period.

Italian animal remains indicate that sheep were overwhelmingly more common (De Grossi Mazzorin and Minniti, 2009).

The data also may refer to different sex groups, as for cattle, as shown by plotting the indices obtained from the ratio between the maximum length (GL) and the minimum width of the diaphysis (SD) of numerous metacarpals dated to different periods and comparing them with those obtained both for females, males and castrated by the modern group of Shetland sheep (Davis, 1996, 2000) (Fig. 4).

Despite these limitations, biometric data give significant results. LSI length values show a progressive increase in caprine size from the Republican period to Empire ($p < 0.01$) and the Late Antiquity ($p < 0.001$) (Fig. 5).

The size of sheep and goats instead decreases from the Late Antiquity onwards and significantly in the transition between the Early and the Late Middle Ages ($p < 0.001$). LSI width values of sheep and goats (Fig. 6) show the same trends, with a progressive increase from the Orientalizing/Archaic period onwards and throughout the Roman period until the Late Antiquity, then a decrease during the Middle Ages. Significant differences in width values were found between Orientalizing/Archaic period and Empire ($p < 0.01$), as well as between Empire and Late Antiquity ($p < 0.05$); between Late Antiquity and the Late Middle Ages ($p < 0.05$), as well as between Early and Late Middle Ages

($p < 0.001$).

3.3. Pigs

Despite pigs is the major domestic species represented in the samples, few biometric data are available (Table 4). This is due to the fact that pigs were usually slaughtered in young and subadult ages and this prevented to collect fused bones which allow taking measurements. However, according to the available data, we can note a fluctuation that consist in a very light increase between the Iron Age and the Roman period, a clear increase in pig size in the transition between the Late Antiquity and the Early Middle Ages and, finally, a decrease in the Late Middle Ages (Fig. 7). Only LSI length values between Late Antiquity and Early Middle Ages have significant variation ($p < 0.001$). LSI width values confirm this increase in pig size during the Middle Ages and particularly in the Late Middle Ages ($p < 0.001$), but also show that pigs remained slender between the 1st to the 6th centuries AD (Fig. 8).

As for other species, we cannot exclude the influencing of sexual factor in the variation of pig size: the study of the shape and size of the lower canines and their alveoli shows that the two sexes are roughly equally represented (Fig. 9).

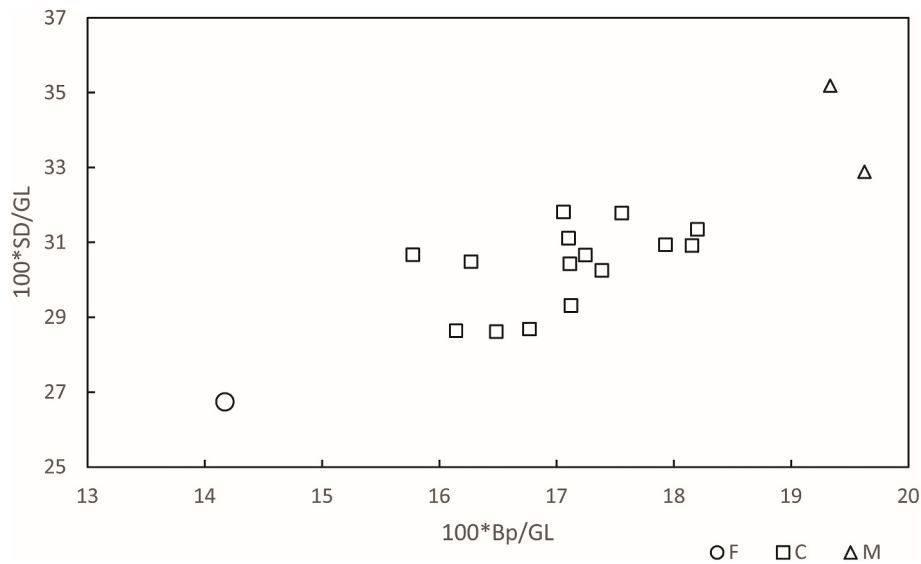


Fig. 3. Rome: shape of cattle metacarpals in the Early Middle Ages by sex group (F = female; C = castrate; M = male).

Table 3
Rome: total number of caprine specimens from which measurements have been taken, means of both LSI length and width values per period.

caprine			
	n.	mean length	mean width
Orient./Archaic	204	0.019	−0.005
Republic	41	0.010	0.024
Empire	52	0.045	0.038
Late Antiquity	56	0.060	0.055
Early Middle Ages	569	0.057	0.041
Late Middle Ages	189	0.022	0.019

4. Discussion

The results of the biometrical analysis carried out on the remains of the three main domestic animal categories used as food that were found

in different contexts of the urban area of Rome allow us to draw some discussion points.

Cattle and caprine measurements show similar trends in size variation, though only those of caprine result statistically significant. A size increase from the Iron Age or Republican period to Late Antiquity is documented, with a more pronounced intensity between Republican and Imperial periods. In the same way, a similar trend of decrease is documented for both categories of livestock from Late Antiquity to Late Middle Ages. This decrease is particularly significant for both animals between Early and Middle Ages.

Pig measurements show different trends that record the presence of small animals throughout the Roman period and a size increase in the transition between Late Antiquity and Early Middle Ages, and again a strong reduction in the Late Middle Ages.

In cattle, lengths generally show more change than widths that instead remains more stable. This can mean that less muscular and perhaps less powerful cattle varieties which were less advantageous for

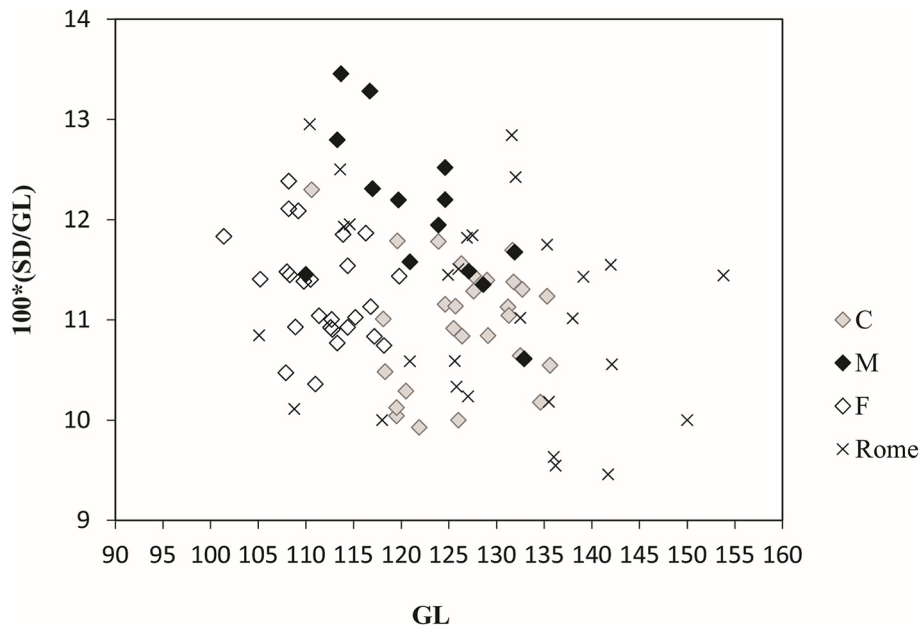


Fig. 4. Rome: shape of caprine metacarpals of different period and comparison with those of female, male and castrate metacarpal of modern Shetland sheep (Number of samples: Orient./Archaic = 2; Republic = 2; Empire = 3; Late Antiquity = 2; Early Middle Ages = 20).

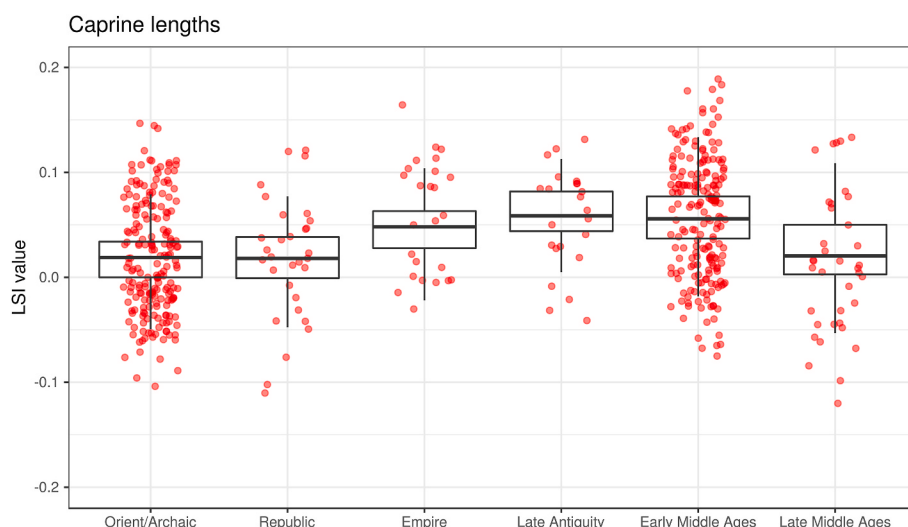


Fig. 5. Rome: caprine LSI length values per period.

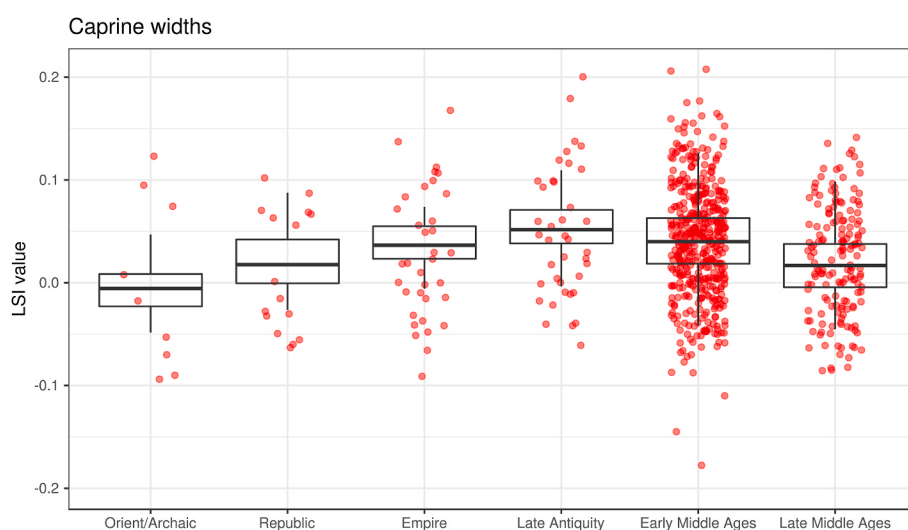


Fig. 6. Rome: caprine LSI width values per period.

Table 4

Rome: total number of pig specimens from which measurements have been taken, means of both LSI length and width values per period.

Pig			
	n.	mean length	mean width
Orient./Archaic	19	−0.029	−0.126
Republic	28	−0.039	−0.027
Empire	113	−0.021	−0.033
Late Antiquity	63	−0.026	−0.022
Early Middle Ages	607	−0.004	−0.001
Late Middle Ages	50	−0.009	−0.038

work purposes, or animals at the end of their production lifecycle, were sold to urban meat market.

The general scenario of size increase in cattle consumed at Rome finds support in the wider biometric analysis carried out by [MacKinnon \(2010\)](#) on Roman Italy: it shows a general consistently improvement, that should have involved the majority of Italian provinces, even if at different regional levels.

Written and epigraphical sources also testify from Roman period onwards a great increase in morphological variability of all domestic

species and that Rome should have been the point of arrival of animals and animal products coming from several regions and countries.

Ancient writers cite the regions of Etruria, Latium and Campania; the latter still supplied the Rome market with beef in the 6th century AD. According to written sources, from Campania came cattle that were small but sufficiently strong for light crops (Colvm. 6, 1, 1–3). Two varieties are documented as coming from Umbria, a wide and white type and a small and red one. The region of Etruria and Latium was famous for heavy and strong cattle, while on the Apennines were kept cattle that were strong but not of beautiful appearance (Colvm. 6, 24, 5). Pliny (nat. 8, 70, 179) also states that Alpine cows were not beautiful because they were short in stature, even if they provided a lot of milk. Varro (res rusticae 2, 5, 10) writes that from Liguria came small cattle. Strabo (5, 3, 1) lodes the region of Sabina for its cattle. Lucilius (6, 262–263) speaks of the strong bulls raised in the Lucanian mountains.

In relation to more distant countries, Pliny (nat. 8, 70, 176) mentions the oxen of India and Epirus for their extraordinary size, the latter also praised by Varro (res rusticae 2, 5, 10). Pliny (nat. 8, 70, 179) remembers the gibbous oxen of Caria as excellent working animals. Strabo (3, 2, 4) mentions the cattle coming from the Iberian peninsula, in particular from the area corresponding to present-day Andalusia.

From the epigraphic sources it appears that several provinces were

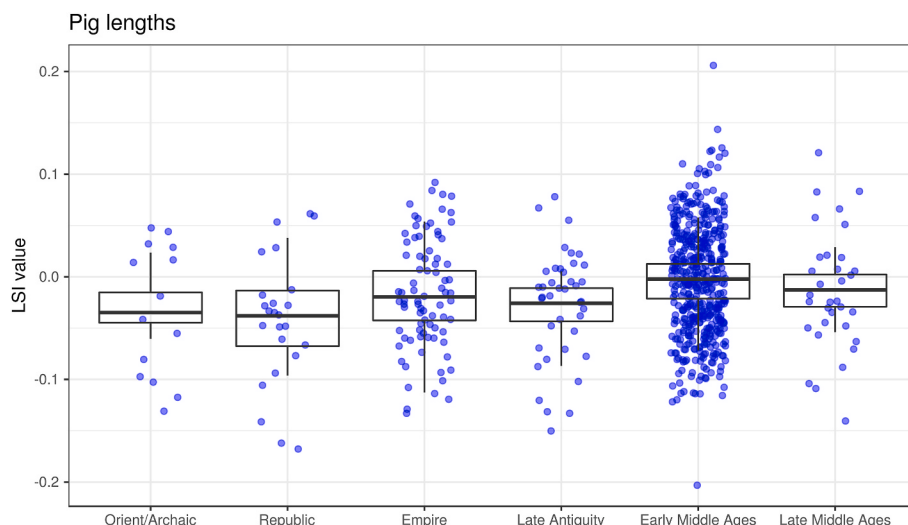


Fig. 7. Rome: pig LSI length values per period.

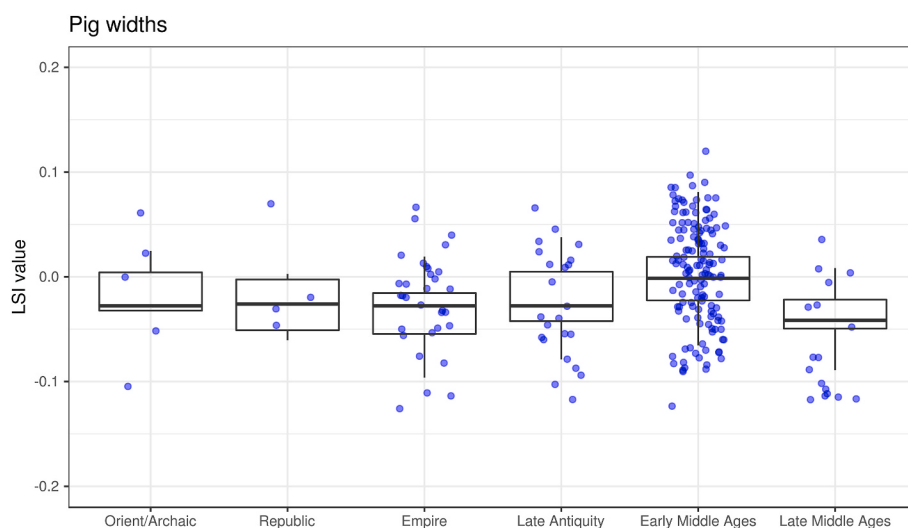


Fig. 8. Rome: pig LSI width values per period.

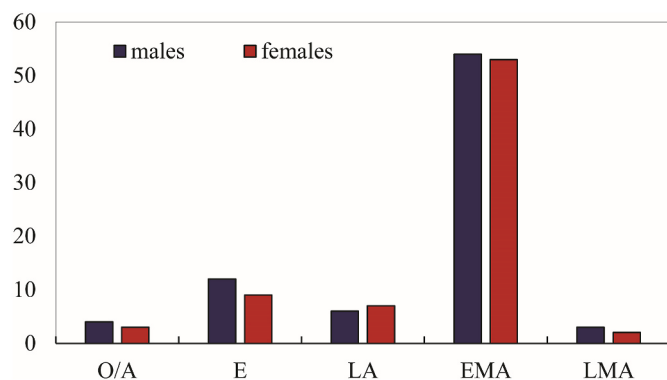


Fig. 9. Rome: percentages of sexed pig lower canines (in mandibles) and their alveoli by period.

devoted to cattle raising, such as the southern provinces of Italy, among them the area of Venosa, but also the northern provinces, such as Sabina, southern Etruria and the alpine and pre-alpine northernmost provinces (Chioffi, 1999). An epigraph of the *mercator bovarius* Q. Brutius found in

Rome refers to Samnium, while from Campania came the cattle that *M. Antonius Teres* sold in Rome; other cattle merchants (*boarii*) attested in Rome came from Gallia Transpadana.

In caprines the general trends of size change seem to involve both length and width measures, this means that taller and more robust sheep/goats were destined to the urban market in Roman time probably as a consequence of a general breed improvement that should have involved all territories under Roman influence or control.

The diffusion of different varieties of sheep in Roman time is testified by written sources at least starting from the 1st century AD onwards. However, they explicitly refer to the production of wool (Morel, 1978). Columella (VII, 2) considers the Calabrian, Apulian and Milesian varieties particularly esteemed and defines the Taranto variety as the best ever. The most popular sheep were those of Gallia, in particular those of Altino, but also those that populated the Campi Macri between Parma and Modena. Martial (epigr., CLV) argues that the region of Apulia was particularly famous for white wool.

Nevertheless, if much attention was given to producing breeds that resulted in high-quality wool, sheep/goat must also have been intentionally produced to improve their quality as meat, even though these details are not preserved in the written record.

Pig measurements suggest that their remains from the urban contexts

dated to the Roman period belonged to individuals that were taller than those from Iron Age features. Although the Iron Age/Roman transition see this increase, during all the Roman period and the following Late Antiquity, the pigs documented at Rome remains of stable size on both length and width measurements. Small pigs were likely to be kept more easily for being slaughtered and sold at the urban market; they could be correspond to small and glabrous pigs depicted by iconographical sources (MacKinnon, 2001).

The particular preference of the inhabitants of Rome for pork is well known and well documented by faunal data (De Grossi Mazzorin and Minniti, 2009, 2017) and written sources, that also documents the city supply from the territory of many regions and provinces subject to the Roman rule (Belli Pasqua, 1995; Chioffi, 1998, 1999). The sources mention the northern regions as the main areas for pig husbandry and for the export of dried pork in the Republican period; in particular, are mentioned the Gallia Transalpina, Narbonense and especially Cisalpina. The city of Aquileia is the largest supplier, famous among other things for the preparation of salted meat (*succidia*), but also for raising very fat and large pigs (Str. 4, 4, 3; 5, 1, 12; Varro, *res rusticae* 2, 4, 10–11; Plb. 2, 15–16). Starting from the 2nd century AD, the importation of fresh and salted pork is well documented from Sardinia (Cassiod., var. 9, 39; Novell. Valent. 36) and from the southern regions, such as Campania, Samnium, and Bruttium and Lucania, from which originates the so-called *lucanica*, still widespread today (Donati, 2003). The import of lard from the southern provinces would seem documented by sources only in the 4th century (Belli Pasqua, 1995). Also famous for the export of pigs were the Lusitania (Varro, *res rusticae* 2, 4, 11), the region of the Pyrenees located in the eastern part, between present-day Spain and France, but in general the whole Iberian peninsula (Plb. 4, 8, 8; Str. 3, 4, 11). During the reign of Diocletian (284–305 AD) the origin of pigs from the southern municipia is well documented: one of the taxes established by the emperor for these provinces provided for the payment in pigs, which were collected by the guild of pig merchants (*suarii*) and that thus went to supply the market of Rome and the free distributions (*caro porcina*) to the plebs.

Other important changes in domestic size are recorded at the end of Late Antiquity and the passage to the Middle Ages. They may be strictly linked to the profound transformation of the city with the development of locally husbandry strategies. Historical sources let us know that with the end of the Roman Empire and especially from the second half of the 5th century, after the Germanic invasions, the economic crisis hit the provinces supplying the urban market. For example, during the reign of Theodoric the pork canon paid by the southern regions was reduced due to the inability of taxpayers to provide the requested quantity, a provision that did not, however, prevent a rebellion. From the 7th c. AD, the *annonaria* services previously provided to supply people with free grain, wine, oil and meat, completely stopped to exist.

In the Middle Ages Rome had a new urban planning, which must have had nothing to do with the sumptuous city of the early centuries of the Empire that housed almost a million of inhabitants. It underwent a gradual process of depopulation and ruralisation, which had to manifest itself in the abandonment of large residential areas, in the transformation of many ancient monuments that were adapted to new functions and the consequent landscape of ruins, uncultivated spaces, gardens and vineyards in which animals were left to graze. Under all these condition, Rome had stopped being only a consumer site but had become also a self-producer site.

The changes caused the development of a rural management system of husbandry are well documented by kill-off patterns of pigs and caprines (De Grossi Mazzorin and Minniti, 2004; Minniti, 2016). Mortality data suggest that in the Roman period there was a preference for the slaughter of young and sub-adult pigs, slaughtered in the first year and between the second and third years of life. In the early medieval centuries there is a greater frequency of adult pigs, slaughtered after the third and fourth year of life, given that it could be indicative of animals raised in the wild, which fed mainly on acorns, a low protein food that

could slow down their growth and therefore make them reach sexual maturity relatively late (Albarella et al., 2019). Also as regards caprines, in the Roman period most of them were killed between the second and third year of life for meat consumption. In the Middle Ages, on the other hand, the number of animals killed beyond the third year of life increased, perhaps due to a growth in interest in the exploitation of secondary products (mainly wool).

In the Middle Ages the development of different husbandry strategies have been favoured and affected the shape and size of animals, with the appearance of small ad slender cattle, small but robust caprines and taller and larger pigs.

5. Conclusion

The biometric analyses carried out on the animal remains coming from archaeological contexts show their usefulness in investigating some aspects of economic activities of ancient people. The analysis of the three main domestic species used as meat source and found in the urban area of Rome highlights that some interesting change and fluctuation in animal size occurred through time. They provide further information to our understanding of ancient life, when they are combined with those obtained from other aspects of the zooarchaeological analysis (i.e. mortality, representation of sexual groups) and from other resources (written, iconographic, epigraphic) and archaeological and historical evidence.

Important changes in the management of animals followed the social, political and demographic transformations of the city. The increase in the size of domestic animals that is documented in the passage from the Iron Age to the Roman period is evident but not particularly pronounced and could be rather the continuation of an improvement process already started during the Iron Age, in Rome earlier than in other contemporary settlements of central Italy. Major transformations are evident and significant during the Roman period, and go hand in hand with the growth of the city and the small and long-scale trades development and commercial liveliness of Empire. Other important transformation seem to occur at the end of Late Antiquity when Rome gradually depopulated and developed a self-productive economy with the on-site husbandry of domestic animals. The process seems to converge in the appearance of small varieties of domestics in the Late Middle Ages.

Author contributions

The authors have contributed to the paper in equal parts.

Data availability

Most of data refer to yet unpublished contexts. Part of the biometric data is available in De Grossi Mazzorin, Minniti (2017), at <https://doi.org/10.1093/oxfordhb/9780199686476.013.11>.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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