PIG HUSBANDRY STRATEGIES IN AN EMERGENT COMPLEX SOCIETY IN CENTRAL CHINA

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ABSTRACT

This paper is concerned with animal husbandry strategies based on age profiles of pigs from a large middle Yangshao site at Xipo in Lingbao county, western Henan province, China. The age structures for pigs show a wide range of age distribution, suggesting that a self-sufficient subsistence economy may have taken place at the site. It is likely that specialized animal production and consumption did not occur in such an emergent complex society. It seems reasonable to suggest that changes in animal husbandry from self-sufficiency towards more specialized production took place in central China in more complex societies.

Studies of settlement archaeology suggest that the earliest complex societies emerged in Lingbao, western Henan province, central China, during the middle Yangshao period (4000-3500 BC) (Figure 1) (Liu in preparation; Ma 2003). Excavations carried out at the middle Yangshao site of Xipo (40 ha), one of the largest sites in the region, recovered some extremely large and elaborate buildings, indicating that the site may have functioned as a central place (Ma 2003). This paper attempts to explore pig husbandry strategies based on age profiles of pigs from Xipo.

EXPECTATIONS FOR PIG HUSBANDRY STRATEGIES

Age structures of domestic pigs are closely related to husbandry strategies. If meat production is the main strategy, an age profile dominated by young individuals or individuals just prior to maturity is expected, because body growth and weight gain both slow significantly at maturity. Ideal harvest profiles for meat production from pigs are 80% or more of immature individuals, while only a small number of adults should be maintained as breeding stock (Greenfield 1991).

Where meat production is not the only reason, an alternative age profile might be expected. For example, in Malekula (Vanuatu) a wealthy man is one who possesses many boars with finely curved tusks, so that an important goal of rearing pigs is to produce boar tusks, which can be obtained from carefully tending older animals more than five years old (Deacon 1934:196). To enhance the role of pigs in competitive exchange, the Chimbu of Siniasina in New Guinea purposefully control pig breeding to achieve the size and sex configuration of herds geared to the periodicity of their ceremonial cycles (Feil 1985). These cases are not concerned with the optimisation of meat yield, which usually means culling pigs at a relatively young age. On the contrary, mature individuals are valued for their size and thus an older age profile is expected in such circumstances.

Age classes of domestic animals can indicate whether the species was produced and consumed at a site, brought into the site, or largely raised for slaughter and consumption elsewhere (Landon 1997; Reitz and Wing 1999:179; Zeder 1991:40). If domestic pigs were reared and eaten on site, they would have been slaughtered over a wide range of ages (Grant 2002:19). The presence of neonate remains should be an important indicator of breeding sows kept and bred within the site. When a site largely relied on imported pork for consumption, a restricted age class, normally young pigs, might be expected. In contrast, if pig rearing at a site was primarily for sale, we might expect the prime age animals to be missing. In urban-rural food supply and distribution systems, urban-rural differences can be apparently identified through the age patterns of domestic animals, with urban assemblages procuring a more focused range of animals and rural ones showing a more varied pattern related to alternative uses of animals (Landon 1997; Zeder 1991:141).

These are obviously simple models and the real picture at any site is likely to be far more complex. A variety of possible factors may affect kill-off patterns profoundly and hence confuse the interpretation of archaeological harvest

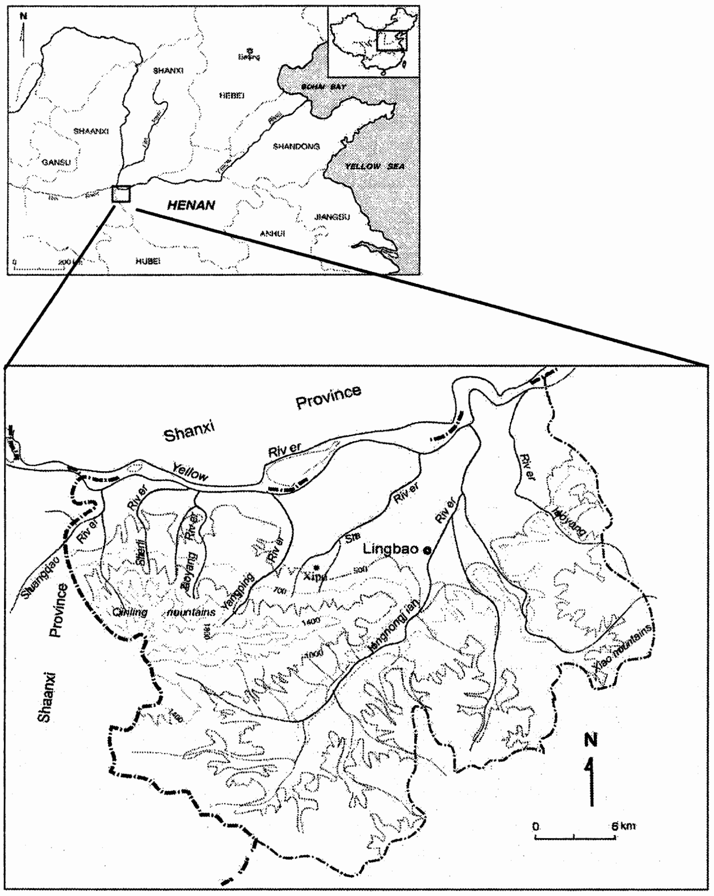

Figure 1: The location of Lingbao in Henan, China.

profiles. For instance, although we know meat production is the sole purpose of pig husbandry in many cases, it is difficult to predict harvest preference for either fat and/or lean meat (Lauwerier 1983). When fat is pursued, older pigs are probably kept since they make more effective use of fodder than do younger animals, converting a larger proportion of nutrients into fat than into muscle (English et al. 1988:30, Figure 3.3; Loon 1978:2, 84). It is not known, in fact, at what age primitive domestic pigs reached their full size, though some researchers consider six months as a prime age for meat return (English et al. 1988:332, Figure 13.1; Redding 1991; Zeder 1991:41). In addition, a number of variables of cultural context, disposal strategies, recovery procedures and analytical methods may tend to confuse patterning. These models, therefore, are idealised and cannot be expected to replicate precisely the age structures of herds from which the animals were drawn (Cribb 1987). However, if an age distribution from a site conforms clearly to one of the above patterns, then the appropriate model is the most likely explanation for the composition of the assemblage (Greenfield 1991).

METHODS AND DATA

Faunal remains were carefully recovered from two seasonal excavations at Xipo and twenty-four species were identified. Among the faunal remains, domestic pig bones accounted for 84% of bones recovered (Ma 2003:138). The rich pig remains, especially the large numbers of teeth, provide a unique opportunity to study age profiles of pigs.

Age structures for pigs were investigated based on measurements of tooth eruption and wear (Grant 1982; Payne and Bull 1988) and the state of epiphyseal fusion of post-cranial elements (Bökönyi 1972; Bull and Payne 1982; Silver 1969).

Dental eruption and wear

The eruption and wear stages of pig teeth from Xipo are recorded using the method presented by Grant (1982), which is based on patterns of dentine and enamel exposure on the occlusal surface of the tooth. Tooth wear stages designed by Grant were used to record dental attrition on isolated mandibular and maxillary molars, as well as on those in complete and incomplete molar rows. Wear of the deciduous fourth premolar (m4) and molar germs (unerupted or partially erupted molars with unformed roots) in complete and incomplete mandibles and maxillas were also recorded. Formed but unworn teeth were recorded as C, V, 1/2, E and U following Grant's definition (1982).

Grant (1982) presents an effective method for estimating the ages of pigs through the analysis of dental eruption sequences and molar wear patterns. Following Grant (1982), Rolett and Chiu (1994) simplify her method for observing the range of variation between eruption and wear stages of associated molars from separate demi-mandibles. They verify the validity of using Grant's method in non-European regions.

This method was used at Xipo to examine the most frequently occurring combinations, as well as the widest observed range of variation between eruption and wear stages of associated molars from separate demi-mandibles. Sixty demi-mandibles with at least two attached molars (M1 and M2, M2 and M3, or M1, M2 and M3) were recovered from the middle Yangshao deposits at Xipo and are used to document associations between molar eruption and wear stages (Table 1).

Table 1 shows that the associations between molar eruption and wear stages for the Xipo mandibles generally fall into the corresponding range of the British data documented by Grant (1982), but there are some differences between the two regional data sets. One possible explanation

Table 1: Numbers of associated pig molars from separate demi-mandibles observed in various eruptions and wear stage combinations

	Second molar (M_2)													
	C	V	E	1 2	U	a	b	c	d	e	f	g	h	j
First molar (M_1)														
E	3	1												
1 2	2													
U	5													
a	10*	10**												
b	7	15***	7*		1									
c	2*	5*****	3	1*	1	6	1							
d	1	*	2	*	*	3***	11*	4****						
e	1	*	2	2	1	6**	12**	4***						
f		1	1				7	3	2**					
g						1	8	16	10**	4	1			
h							7	7	4	1*	2*			
j							1	12	5	12	1**	2	1	
k								5	4	5	9	4	1	*
l								1	3	3	3	5	2	

	Third molar (M_3)+										
	C	V	E	1 2	U	a	b	c	d	e	f
Second molar (M_2)											
V	6										
E	8	1									
1 2	3										
U	3										
a	3	12	1								
b	5	21	9	5	4	3					
c	1	4	8	11	17	8	3				
d		1*	5**	2		8	12				
e				1*	1	11**	13****				
f					2	5	11***	3***	1**	*	
g			1			2	9	6	2		
h							3	4			1
j									5		*
k							1		2	2	
l									1	2	

Based on (a) data from British archaeological sites (Grant 1982: table 4), listed by number; (b) observations on demi-mandibles recovered from Xipo shown by *. Eruption stages: C, alveolar perforation of crypt visible; V, tooth visible in crypt but below alveolar rim; E, tooth protruding through bone; 1/2, tooth half erupted; U, tooth almost at full height but unworn. Wear stages (lower case letters) are shown following Grant (1982).

is that the attrition of the second molars among Xipo pigs was slightly faster in the moderate wear stages (stages c, d, e, f). An alternative assumption is that first molars among Xipo pigs were relatively durable and the eruption of the third molars was comparatively slow. These variations were taken as a basic reference for using European reference standards (e.g., Higham 1967; Hillson 1986; Matschke 1967) to estimate the age profiles of Xipo pigs.

Estimated age ranges for Xipo pigs, based on the data in Tables 2 to 4, as well as the established correspondences between eruption and wear stages for different teeth (Table 1), are divided into seven classes (Table 5). Such age ranges represent the dental maturation of the molar teeth, ranging from the unerupted first molar to heavy wear on the third molar. Classes II (4-6 months), III (6-12 months) and V (18-24 months) are defined on the basis of the eruption of the first, second and third molars, as the keys for marking the onsets of these age classes. Class I represents the period before the eruption of the first molar (before 4 months). Classes IV (12-18 months), VI (24-36 months) and VII (over 36 months) are defined on wear stages and hence the boundaries between stages are less clear.

By using the scheme (Table 5) for grouping age classes, a mandible or a maxilla associated with two or three molars tends to be ascribed to representing a contiguous range of ages, unlike isolated teeth which can be simply ascribed to a single age class. For example, while a first molar belongs to Class II, the associated second molar falls into Class III. Under these ambiguous conditions, a fraction is applied to each possible age class depending on the number of teeth in the mandible or maxilla that might belong to that age class, or on the higher frequency of association between molars, as shown in Table 1.

Constructing the age profile using eruption/wear stages of teeth is based on mandibles that had one or more molars attached, rather than on isolated molars. There are several reasons for using this method. First, the large sample size of mandibles with attached molar(s) from the assemblage allows statistical analysis (Table 6). Second, the number of isolated molars that were identified to side and eruption/wear stage and mandibles with no molars, is small. Third, the problem of specimen interdependence exists when isolated molars are used to represent an individual, since the tooth-per-individual ratio is greater for older animals (Rolett and Chiu 1994). Individuals in older groups, for instance, bear first, second and sometimes third molars in overlapping stages of eruption and attrition, while younger pigs bear only the first molars. When using isolated molars to construct age profiles, older individuals are very likely counted more than once. Using a large sample of mandibles can minimise the problem of overrepresentation.

Table 2: Stages of pig dental development and estimated ages

Stage	Dental development	Estimated age in in months
1	Deciduous premolars unerupted	foetal
2	Deciduous PM2-3-4 in primary eruption	birth-one week
3	Deciduous PM2-3-4 in secondary eruption	1-4 weeks
4	Deciduous PM2-3-4 in tertiary eruption	4-7 weeks
5	Deciduous PM2-3-4 in primary wear M1 unerupted	2-4
6	M1 in primary eruption	4-5
7	M1 in secondary eruption	5-6
8	M1 in tertiary eruption	6-7
9	M1 in primary wear, M2 unerupted	7-8
10	M1 in secondary wear, M2 unerupted	8-9
11	M2 in primary eruption	9-10
12	M2 in secondary eruption	10-11
13	M2 in tertiary eruption	11-12
14	PM2-4 in primary eruption	12-14
15	PM2-4 in secondary eruption	14-15
16	PM2-4 in tertiary eruption	15-16
17	PM2-4 in primary wear, M3 unerupted	16-17
18	M3 in primary eruption	17-19
19	M3 in secondary eruption	19-21
20	M3 in tertiary eruption, cusp one in primary wear	21-23
21	M3 cusp one in secondary wear	23-25
22	M3 cusp two in secondary wear	25-27
23	M3 cusp three in secondary wear	27-29
24	M3 all cusps in late secondary wear	30+
25	M3 all cusps in early tertiary wear	adult
26	M3 all cusps in late tertiary wear	late maturity
27	M3 all cusps in quaternary wear	old

After Higham (1967: appendix B).

It is important to note that the same bias occurs when relating mandibles to the actual age at death. For example, when the whole number of tooth-attached-mandibles is taken as the basis of establishing an age profile, it is very likely that the left/right mandible and its matched right/left one are counted together and thus the two demi-mandibles from the same individual are counted more than once. Very often, the more mandibles there are, the greater the overestimation of individuals. To control for this, the left and right sides of mandibles were separately computed first for comparison and then counted in total. Age distributions are summarised in Table 7.

Maxillae were used to establish age structures for comparison, based on the record of eruption and wear stages, although there is a slight difference in timing of eruption (Matschke 1967: table 1) and dental attrition (Rolett and Chiu 1994) between mandibular and maxillary molars. The left and right sides of maxillae were also separately counted, like mandibles. Age distributions are summarised in Table 8.

The eruption and wear of mandibular teeth is affected to varying degrees by a number of factors, many of which are impossible to evaluate in an archaeological assemblage. Environment, diet, breeding habits and gender may all potentially interact to alter timing of eruption of teeth and rate of wear (Grant 1978, 1982:105). Differences in timing of emergence between early and late maturing domestic pigs, for example, account for variations as great as 6 months in some teeth (Bull and Payne 1982: table 1; Hillson 1986: table 3.11). There are many different opinions among scholars

Table 3: Ages (in months) for gingival molar emergence among European wild hogs

Tooth	Age range for emergence
M^1	5.3-6.4
M^2	12-14
M^3	26-33
M_1	5.3-6
M_2	12-13.8
M_3	23-26

Based on Matschke (1967: table 1)

Table 4: Ages (in months) for gingival molar emergence among domestic pigs

	Maturing			
Tooth*	Early	Middle	Late	Overall range
M1	4	6	8	4-8
M2	7	10	13	7-13
M3	16	8	20	16-20

Modified from Hillson (1986: table 3.11).
* Upper and lower molars included together.

Table 5: Age criteria for Xipo pigs, arranged by the eruption/wear stages of mandibular teeth

Age class	Age in months	m4	M1	M2	M3
I	0-4	a, b, c			
II M1 erupting	4-6	d, e	erupting, a		
III M2 erupting	6-12	f, g, h, j, k	b, c	erupting	
IV	12-18		d, e	a, b, c	
V M3 erupting	18-24		f, g, h	d, e, f	erupting, a, b
VI	24-36		j, k	g, h	c, d, e
VII	36-		l, m, n	j, k	f, g

M: Molar; a, b, c...m, n: wear stages shown in Figure 2.

Table 6: The numbers of mandibles, maxillae and isolated molars recovered from Xipo

	Tooth-attached		Non-tooth-attached		Isolated tooth	
	left	right	left	right	left	right
Mandible	125	114	39	42	5	1
Maxilla	65	61	19	18	4	2

regarding the timing of tooth eruption in wild and domestic, as well as in modern and ancient pig populations (e.g., Bull and Payne 1982; Higham 1967; Matschke 1967). Also, the patterns of tooth wear for pigs exhibit a high degree of inter-observer variation compared with herbivores (Grant 1982; O'Connor 2000:84). These problems, however, do not affect the results of analysis significantly, as long as relative age stages, rather than absolute ages, are used as the primary units of analysis (Hongo 1996:124; Reitz and Wing

Table 7: Age distributions based on eruption stages and wear of mandibular teeth from Xipo

Age class	Left		Right		Total	
(in months)	%	No.	%	No.	%	No.
I (0-4)	20.0	25	23.7	27	21.8	52
II (4-6)	16.9	21	21.9	25	19.3	46
III (6-12)	26.4	33	19.3	22	23.0	55
IV (12-18)	17.6	22	18.4	21	18.0	43
V (18-24)	12.7	16	10.5	12	11.6	38
VI (24-36)	4.8	6	5.3	6	5.0	12
VII (36-)	1.6	2	0.9	1	1.3	3
Total	100	125	100	114	100	239

1999:185). An awareness of the influence of both extrinsic and intrinsic factors over dental development may aid in the recognition of potential biases and limitations of the data.

Epiphyseal Fusion

The harvest profiles presented here are based on post-cranial parts examined according to the sequence of fusion presented by Silver (1969), Bökönyi (1972) and Bull and Payne (1982). Post-cranial elements are grouped into three age categories: early-fusing, middle-fusing and late-fusing (Table 9). In general, the epiphyses of the early-fusing category join before 12 months, corresponding to infantiles/juveniles; the middle-fusing category at about 24 months, equating with subadults; and the late-fusing category at about 42 months, representing adults. A bone with a fused epiphysis indicates that the animal survived the beginning of the next growth stage, but it does not indicate how long the animal continued to live afterwards.

Epiphyses were classified as 'fused', 'fusing' or 'unfused'. A bone was recorded as "fused" when the epiphyseal line was no longer visible on bone surface by visual inspection. When an epiphysis was completely separated from the diaphysis, the bone was labelled 'unfused'. When an epiphysis was no longer separated from the shaft but the epiphyseal line was still visible, the bone was labelled 'fusing'. In this study, both epiphyses and diaphyses were counted, after attempting to match unfused epiphyses and their associated diaphyses. Where matches could be achieved, the specimens were counted as a single unfused specimen. Unfused epiphyses and diaphyses that could not be matched were counted as separate specimens. The data on epiphyseal fusion are presented in Table 10 and summarised in Table 11.

Table 8: Age distributions based on eruption stages and wear of maxillary teeth from Xipo

Age class (in months)	Left %	Left No.	Right %	Right No.	Total %	Total No.
I (0-4)	15.4	10	8.2	5	11.9	15
II (4-6)	18.5	12	34.4	21	26.2	33
III (6-12)	23.1	15	21.3	13	22.2	28
IV (12-18)	21.5	14	19.7	12	20.6	26
V (18-24)	13.8	9	11.5	7	12.7	16
VI (24-36)	3.1	2	4.9	3	4.0	5
VII (36-)	4.6	3	-	-	2.3	3
Total	100	65	100	61	100	126

- = No bones available in this category.

Age determination based on epiphyseal fusion is influenced by factors that may have contributed to variability in the timing of epiphyseal closure. Variations may exist between nutritional level, sex and the state of domestication of the species and the environment (Moran and O'Conner 1994; Noddle 1974; Wilson 1978). For example, good nutrition and shelter tend to accelerate epiphyseal fusion (Silver 1969). Analysis of epiphyseal fusion is affected by differential preservation and recovery procedures (Maltby 1982; Payne 1973). Unfused epiphyses are less dense than fused epiphyses and thus fused elements have a greater chance of survival and a high frequency of recovery in hand-collected samples (Meadow 1975; Payne 1972, 1975).

Each ageing method has strengths and weaknesses. Tooth eruption and wear patterns clearly have more age categories, compared with the fusion-based method, which only identifies three age categories. Since mandibles and maxillae are relatively meat-poor elements, they are often less damaged than other bones and more frequently recovered. Age data based on post-cranial bones can use more elements. More importantly, relying upon more types of elements as indicators of age can highlight differential processing and disposal and thus give more information about cultural behaviour.

It should be remembered that the results of ageing based on epiphyseal fusion and on tooth eruption and attrition are not directly comparable, because calibration and methodological problems make it difficult to combine fusion and wear patterns. Fusion scores represent the percentage of individuals surviving beyond an age category counted on the basis of elements related to each specific age category. Age classes based on mandibles represent a percentile of individuals living beyond an age class counted on the basis of the total population of mandibles (Zeder 1991:94).

Table 9: Age criteria for pigs based on epiphyseal fusion*

Category (age of fusion)	Element
Early-fusing specimens: (*c*. 12 months)	Scapula (d), Humerus (d), Radius (p), Pelvis (acetabulum)
Middle-fusing specimens: (*c*. 24 months)	Metapodial (d), Tibia (d), Calcaneum
Late-fusing specimens: (*c*. 42 months)	Humerus (p), Radius (d), Ulna (p&d) Femur (p&d), Tibia (p)

p = proximal, d = distal

*After Silver (1969), Bökönyi (1972) and Bull & Payne (1982)

Table 10: The state of 'unfused', 'fusing' and 'fused' bones of pigs from Xipo.

Category	Element	Fused	Fusing	Unfused	Total	% Fused + Fusing	% Unfused
Early-fusing	Scapula (d)	5	2	10	17	41	59
	Humerus (d)	18	7	51	76	33	67
	Radius (p)	16	6	20	42	53	47
	Pelvis (acetabulum)	6	4	13	23	44	56
	Subtotal	45	19	94	158	41	59
Middle-fusing	Metapodial (d)	5	2	23	30	23	77
	Tibia (d)	10	3	44	57	23	77
	Calcaneum	1	0	20	21	5	95
	Subtotal	16	5	87	108	19	81
Late-fusing	Humerus (p)	2	1	14	17	12	88
	Radius (d)	4	1	5	10	50	50
	Ulna (p and d)	7	4	50	61	18	82
	Femur (p and d)	11	5	59	75	21	79
	Tibia (p)	3	1	9	13	31	69
	Subtotal	27	12	137	176	22	78

p = proximal, d = distal

Table 11: Percentage survival for Xipo pigs before the given age

Age class	% Survival
< 12 months	59
< 24 months	81
< 42 months	78

RESULTS AND ANALYSIS

Harvest profiles for pigs based on mandibles (left 125, right 114, total 239) are shown in Figure 2 (based on data in Table 7). The total mandibular data show that pigs were primarily slaughtered before they reached one and half years of age. The proportion of pigs slaughtered is around 20% for the first four classes (Classes I, II, III and IV) and then markedly drops in Class V. The proportion of older pigs of Classes VI and VII is very low.

The age at death suggested by a total number of 126 maxillae (left 65, right 61) shows an emphasis on animals younger than two years of age (Figure 3, based on data in Table 8), roughly similar to the pattern suggested by mandibles. However, the proportion of the Class I for maxillae is comparatively low, pointing to a smaller number of infant animals killed. The difference is probably caused by the fact that maxillae, especially young ones, are more fragile and break up readily, so that they are less likely to be recovered. For this reason, the evidence of age at death from mandibles is generally more reliable, as suggested by Albarella and Serjeantson (2002:36).

Age distributions based on the left (125 samples) and right (114 samples) sides of mandibles exhibit a similar pattern, though the left mandibles show an emphasis on Class III and the right ones comparatively on Class I (Figure 2). Age distributions based on left (65 samples) and right (61 samples) sides of the maxillae show a similar pattern, with the right maxillae having predominately Class II wear (Figure 3). This finding indicates that there is no symmetry bias on mandibles or maxillae and thus age construction can be generally investigated using the combination of both left and right sides.

The fusion evidence suggests that 59% of the pigs were killed before the early fusing epiphyses fused (before about 12 months), 81% before the middle fusing epiphyses fused (before about 24 months) and 78% before the late fusing epiphyses fused (before about 42 months) (Tables 10 and 11).

It is clear that there is contradiction between the middle and late fusing categories - a higher proportion (81%) of elements fused before 24 months and a lower (78%) before 42 months. This is caused primarily by comparatively greater numbers of fused distal radii and proximal tibiae (Table 10) and may have been the result of differential survival and recovery of bone elements. Bones of lower density break up and disintegrate at a quicker rate than those from the denser elements of the skeleton. Inadequate screening is likely to recover higher proportions of larger elements. As a consequence, the age distribution may be biased to older age classes.

Although the age distributions based on tooth eruption and attrition data and the epiphyseal fusion data are not directly comparable, the results obtained from the two analytical techniques have significant similarities. Both data assemblages indicate an emphasis on animals less than one year old - 64.1% as based on mandibles and 59% as based on post-cranial parts. Most animals were slaughtered before two years of age - 93.7% using mandibular data and about 81% by post-cranial elements. A marked inconsistency is that the fusion data suggest a relatively high proportion (22%) of animals killed after three and half years, while the corresponding figure from mandibular data is only 1.3%.

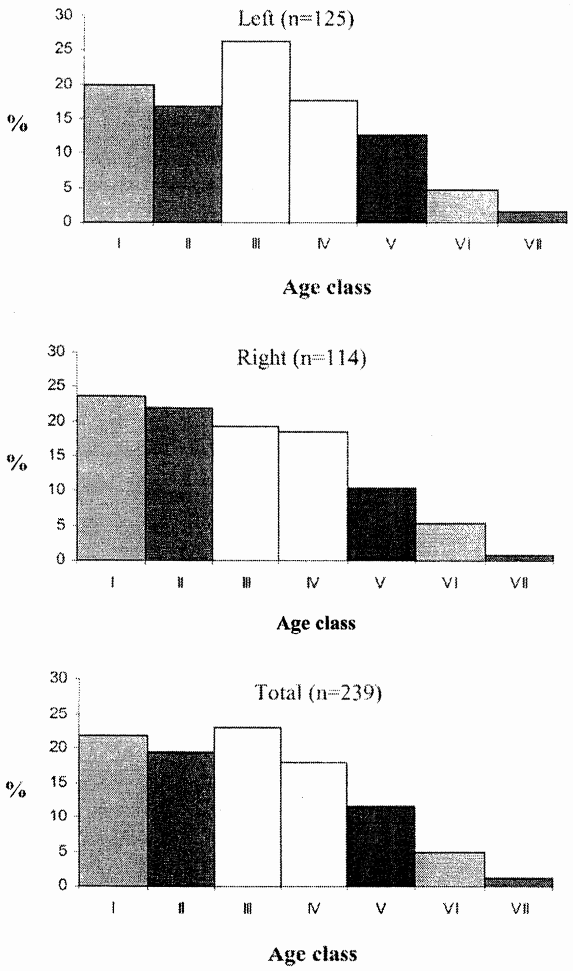

Figure 2: Kill-off patterns for pigs from Xipo based on tooth eruption/wear of mandibles. Left and right sides and total demi-mandibles are expressed by percentage respectively.

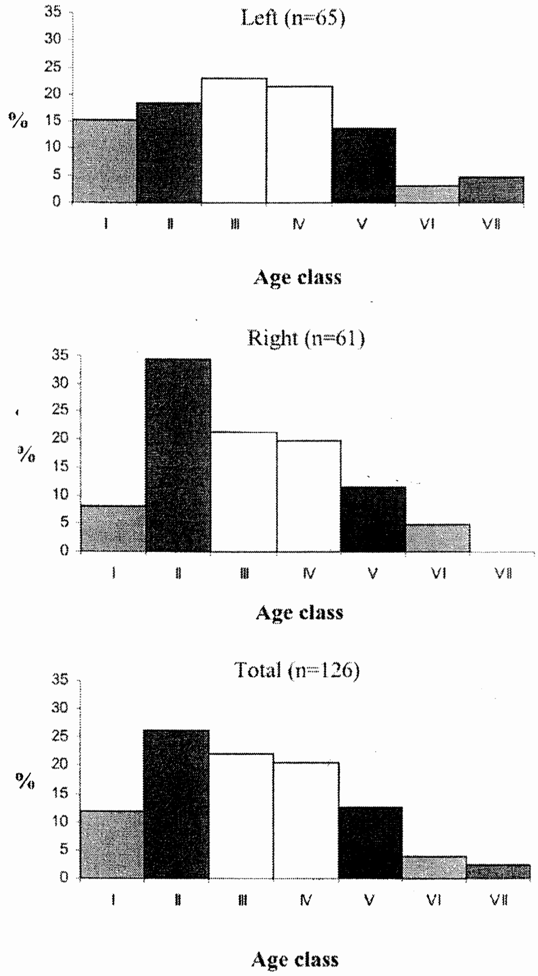

Figure 3: Kill-off patterns for pigs from Xipo based on tooth eruption/wear of maxillas. Left and right sides and total demi-maxillas are expressed by percentage respectively.

It is useful to compare the results of ageing based on different data sets, which can provide more lines of evidence about the nature of an assemblage. For the assemblage from Xipo, for example, when comparing the kill-off patterns based on a large samples of mandibles and maxillae, the inconsistency between them suggests that various factors readily bias maxillae and that ages at death derived from mandibles are more reliable.

AGE-BASED SPATIAL DISTRIBUTION OF PIGS

If there were some differences in slaughtering strategy among different groups at a site, differences in age distribution of the animals would be expected. An effective avenue to obtaining this information is to examine the age-based spatial distribution of such animals in different parts of the site from contexts with a large number of bones, in which age profiles can reflect the consumption behaviour over short periods of time.

Age distributions of pigs from the south and north excavation areas of the Xipo site are compared in Figure 4. Pits H22 and H110 are selected for their large sample size (F is an abbreviation for *fangzi*, meaning house foundation; H for *huikeng*, meaning pit; T for *tanfang*, meaning grid; and G for *gou*, meaning cistern). They represent the south and north parts of the site respectively. The age-at-death profile for pigs from the two pits based on tooth eruption/wear of mandibles is presented in Figure 5.

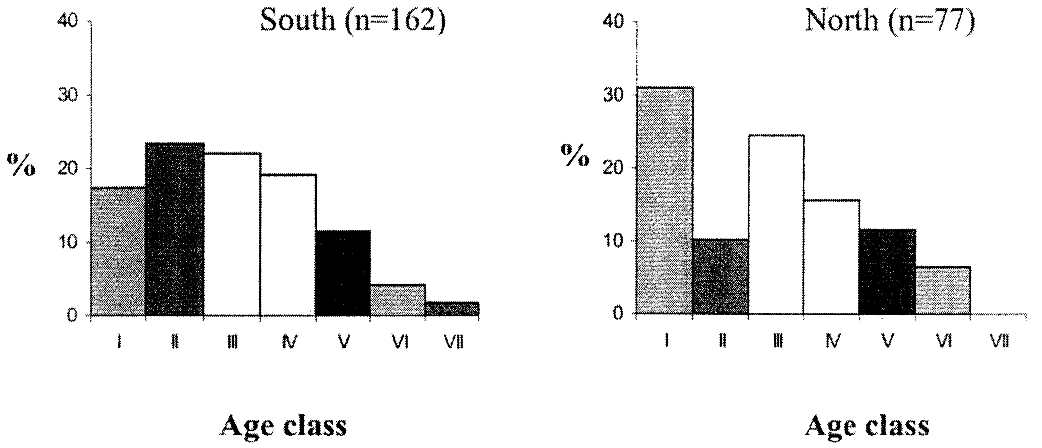

Figure 4: Age distributions for pigs in south and north excavation areas based on tooth eruption/wear of mandibles.

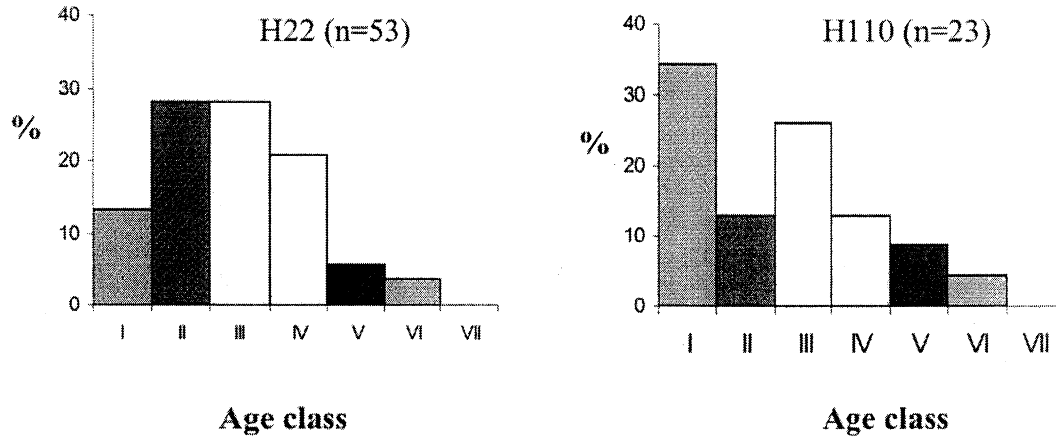

Figure 5: Age distributions for pigs in pits H22 and H110 based on tooth eruption/wear of mandibles.

Figure 4 shows a similar pattern of age distribution, with the north area emphasising Class I and the south area Class II. A similar situation is evident in the comparison of pits H22 and H110 (Figure 5). The slight differences between two areas and between their specific features might be caused by recovery bias. Sieving was conducted in the north area of the site and faunal remains were much more carefully collected in the north than in the south part. The careful recovery procedure makes it likely that smaller mandibles were also recovered. The other explanation is that there could have been real differences in slaughtering strategy in the two areas of the site. However, the differences are not significant.

Although there is a difference in age distribution between pits H22 and H110, a wide range of ages is observed in both contexts (Figure 5). If collecting bias can be ruled out, the pattern may suggest that people who lived near these pits ate pork from pigs of different age and that the pigs consumed were probably reared by the consumers themselves. It is possible, therefore, that the Xipo inhabitants may have practised a self-sufficient economy.

DISCUSSION

Both tooth and post-cranial data from Xipo demonstrate that the majority of pigs were slaughtered before reaching two years of age and only a very few individuals reached adult or old age. This selective kill-off profile is consistent with a pattern where 80% or more immature pigs are killed for meat, with a small adult breeding population kept alive, consisting mostly of sows (Greenfield 1991; Redding 1991).

The mandibular data demonstrate that the pigs were killed at Xipo on a regular basis throughout the first three years of life (Table 7, Figure 2). This is an optimal kill-off pattern, in which younger animals were consumed for their good-quality meat, others were grown to produce a substantial amount of meat and a small number of adults were kept for breeding. This suggests that Xipo was a production and consumption site and a self-sufficient community. This interpretation is supported by the recovery of several nearly complete pig embryos and neonates. According to the age distributions, there is no evidence that the pigs were brought from elsewhere into the site for consumption, or raised at the site for slaughter and export. This is consistent with evidence from the body part distributions (Ma 2003).

It is useful here to compare the kill-off pattern in pigs at Xipo with that from a much younger site that exemplifies a direct consumption system. Several decades of excavations indicate that the urban site of Xinzheng in central Henan, capital of the Zheng and Han states in the Eastern Zhou period (770-221 BC), was occupied by elites and various professional craftsmen (HPICRA 1994:231). In the city, meat was probably obtained from outside the village by direct provisioning or by purchase. There is little evidence of animal husbandry within the city. This model is strongly supported by the age-at-death distribution derived from a sample of 59 mandibles (Figure 6). It is important to note here that the faunal remains were hand-collected carefully, although sieving was not conducted. These mandibles were measured and analysed by me. As Figure 6 clearly shows, the pigs of Xinzheng belonged almost exclusively to Classes IV, V and VI, representing animals that died in the one to three year range. About 70% were killed between one and two years of age.

This pattern is probably linked to rural-urban provisioning and may reflect a rational culling pattern associated with a tactic of maximising meat supply for urban consumption, although faunal data from rural sites are needed to reveal alternative kill-off patterns. Such age structures suggest an optimal age for slaughter, as part of an intensive meat-producing system. However, this optimal age for culling is inconsistent with the so-called 'optimal age' for meat return (e.g., English *et al.* 1988:380; Redding 1991). Could it be suggested that there were some problems with pig husbandry in urban provisioning systems? To address this question, we need to understand what the husbanding strategy was for pig herders in such systems.

In market-oriented economic systems, the optimal choice for producers is to balance the relationship between the rate of meat return and the value of fodder. The profit produced will be an important concern. When the profit from meat is higher than the cost of fodder, producers will prefer to rear pigs than sell fodder, though the efficiency of conversion of fodder into meat is lower in older animals than in younger ones (Loon 1978:2, 84). When profit from meat declines, producers will lose interest in the raising of animals. Although the labour required in rearing pigs sometimes is a concern, it was probably not a significant factor affecting pig rearing (as, for instance, in current undeveloped regions of China). Therefore, optimal pig husbandry strategies must take into account the value of meat versus fodder, the availability of fodder and associated social systems.

Compared with the kill-off patterns in rural-city provisioning systems, the culling ages of pigs at Xipo was relatively young. Did pig rearing at Xipo conform to a particular optimal strategy? To answer this question, we need to understand another basic issue: the reproduction of pigs.

Reproduction is a seasonal phenomenon in both wild and domestic pig populations (Dardaillon 1988; Dobney and Ervynck 2000; Lauwerier 1983). Wild pigs in France reproduce only once a year, mainly in April (Dardaillon 1988), in March and April in Belgium and Denmark (Frechkop 1958; Mohl 1978) and in April and May in Turkey and China (Bull and Payne 1982; Lu 1962). The frequency of births for domestic pigs varies, due to rearing practices, food supply, climate and economic variables (Lauwerier 1983). Domestic pigs farrow twice a year in the tropics and births may be scattered throughout the year (Williamson and Payne 1978), but in Europe they give birth twice, peaking in March and September (Lauwerier 1983). However, based on a British Neolithic site and four Belgian medieval sites, Dobney and Ervynck (2000) found that, by analysing the occurrence of linear enamel hypoplasia (LEH), the vast majority of all pigs in five sites were born during spring and that double farrowing was absent or uncommon.

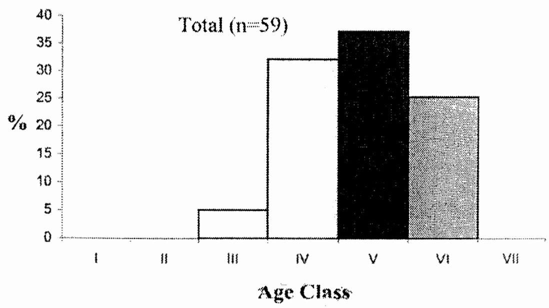

Figure 6: Kill-off patterns for pigs from Xinzheng based on tooth eruption and wear of mandibles.

Food supply and climate are important factors affecting farrowing frequency (Lauwerier 1983). Winter is a particularly challenging season in terms of food availability, nutritional quality and energy requirements. At the end of autumn, animals usually reach maximum meat and fat weight owing to abundant fodder. However, in winter the insufficiency of food is often responsible for weight loss and undernutrition of animals (Dobney and Ervynck 2000; McCance et al. 1961). For instance, Dobney and Ervynck's (2000) analysis of linear enamel hyoplasia (LEH) shows a clear pattern, where developmental stress is observed on the second and third molars during their crown development in winter. This is interpreted as due to undernutrition. Primarily for this reason, a large number of domestic pigs were traditionally slaughtered before winter (Ervynck 1997).

It is difficult to judge whether each sow at Xipo farrowed once or twice a year, in April, or in both April and October. If all Xipo pigs were born in April, they would have undergone a food challenge in their first winter and early spring when they reached six (October) or seven (November) months of age. If the pigs were not killed during the first winter, but killed before the second, they would have lived to be one and a half years old. If the pigs lived until the third winter they would have reached two and a half years of age. If all or most Xipo pigs farrowed once a year, in April, then 82.1% (Classes I, II, III, IV) did not survive until their second winter. 41.1% (Classes I and II) were slaughtered before the first winter and only 17.9% (Classes V, VI, VII) entered or survived their second winter (Figure 2).

Alternatively, if all Xipo pigs were born in October, they would have experienced the first winter and early spring, after weaning in December or January. If the pigs were killed before the second winter, they would have attained one year of age. If killed before the third winter, they would have been two years old. If the pigs passed the third winter and were killed before the fourth winter, they might have reached three years of age. If all or most Xipo pigs farrowed once a year in October, then based on the kill-off patterns of Xipo, 64.1% (Classes I, II, III) were slaughtered before the second winter. 29.6% (Classes IV and V) survived the second winter but were killed before the third and only 6.3% (Classes VI and VII) passed the third winter (Figure 2).

Overall, no matter how many times (once or twice) each sow farrowed during the year at Xipo, the kill-off patterns suggest that the majority of the pigs were slaughtered before the second winter, when they reached 12 or 18 months old. A small number of pigs were probably kept for breeding or later culling. It is clear that, unlike rural-urban provisioning systems, there was no strong demand to keep pigs to adult size at Xipo.

CONCLUSION

The kill-off patterns for pigs indicate that most pigs from Xipo were slaughtered before they reached two years of age. A wide range of age distribution suggests that they were reared on site, as part of a self-sufficient subsistence economy. Thus, the specialized animal production and consumption patterns that characterise complex societies had not yet developed at the time of Xipo. They must have occurred later, related to the increasing development of political, economic and social complexity.

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