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Integration of Linearbandkeramik cattle husbandry in the forested landscape of the mid-Holocene climate optimum: Seasonal-scale investigations in Bohemia

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ABSTRACT

Domestic animals and plants were introduced to Europe from the Near East and subsequently spread across Europe, entailing adaptations to different environments with consequences for the biology of organisms, agro-pastoral technical systems and socio-economic organisation. Agriculture was introduced to Central Europe by Linearbandkeramik (LBK) societies between 5600 and 4900 cal. BC, in predominantly forested environments. LBK farming systems involved intensive permanent field cultivation in natural openings. Milking was practiced as evidenced from cattle mortality profiles and lipid residues in ceramics. Questions arise as to what extent LBK cattle husbandry relied on woodland, and as to whether the seasonal scarcity of fodder conditioned cattle reproduction cycles, with consequences on milk availability. Results from the $\delta^{13}C$ and $\delta^{18}O$ analysis of cattle tooth enamel at Chotěbudice and Černý Vůl (Bohemia, Czech Republic) suggest a limited use of dense forest for cattle herding, even on a seasonal scale: cattle were kept in the open component of the forest/steppe mosaic landscape. Winter forest browsing/provision of leafy fodder was evidenced in one specimen. At Chotěbudice, cattle births mainly occurred over a two to three-month period, suggesting environmental constraints on cattle fertility cycles, and possibly seasonal fodder scarcity. A direct consequence of this would be a shorter period of milk availability throughout the year.

1. Introduction

The primary centres of domestication of European cattle, caprines and pigs are located in the Near East and date to the 9th millennium cal BC. These animals were then introduced to Europe at the turn of the 7th millennium with domestic plants and husbandry practices. They spread westward along the Mediterranean margins, on one hand, and following the continental Danubian route, on the other hand, to reach western Iberian coasts during the second half of the 6th millennium and European northwestern coasts at the turn of the 5th millennium. The British Isles were eventually colonized several centuries later (Tresset and Vigne, 2011). During this expansion across Europe, animals and husbandry practices had to adapt to diverse environmental conditions, which differed from those in the Near East (Vigne, 2008). New selection pressures linked to the climate, landscape, dietary resources and pathogens led to the development of new physiological abilities/technical practices regarding reproduction, feeding behaviour, metabolism, animal products and resistance to diseases (Balasse and Tresset, 2007, 2009, 2017; Flori and Gautier, 2013). In this sense, the spread of domesticates across Europe represents some of the earliest deliberate acclimatisation of domestic animals by human societies. More specifically, environmental factors determine livestock feeding resources and reproductive behaviours, which in turn greatly impact the rhythms of pastoral systems on a seasonal scale. Investigating the extent to which environmental constraints affected agropastoral systems, and the solutions adopted to cope with these constraints, is paramount for a better understanding of how Neolithic economies successfully spread across the diverse climatic zones of Europe.

In Central Europe, agriculture was first introduced by the Linearbandkeramik (LBK) societies. The LBK developed between 5600 and 4900 cal. BC (Price, 2000; Banffy, 2004; Dolukhanov et al., 2005; Pavlů, 2005; Jakucs et al., 2016) over a period of winter warming, summer cooling and increased precipitation (Sanchez Goni et al., 2016). The mid-Holocene climatic optimum led to the retreat of the Pleistocene steppe in Central Europe in favour of the spread of deciduous forests. The degree of openness of these forests has been debated, and a steppe component has also been brought to light in the landscape, the extent of which may have varied considerably in accordance with

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regional macroclimatic differences (Kreuz, 2008; Bogucki et al., 2012; Marinova et al., 2012/2013; Salavert et al., 2014; Pokorný et al., 2015). LBK communities developed farming systems with the following main features. Natural openings were exploited for the intensive permanent field cultivation (Bogaard, 2005; Saqalli et al., 2014) of crops dominated by hulled wheat (einkorn and emmer; Colledge et al., 2005; Jacomet, 2007; Dreslerová and Kočár, 2013). Soil fertility may have been maintained using manure from livestock (Bogaard, 2005; Bogaard et al., 2013). Cattle (*Bos taurus*) were raised as an important component of the animal economy (Bogucki, 1982; Kovačiková et al., 2012; Arbogast and Jeunesse, 2013), even though regional variability has been observed in the relative proportion of cattle among domestic stock, as well as in the role of hunting (Tresset and Vigne, 2001). The analysis of 19 cattle mortality profiles from LBK contexts concluded that milk exploitation was a widespread, although non-intensive, practice across Europe (Gillis et al., 2017). Milk exploitation and transformation were presumed to have been practised in the LBK of Central Europe due to the occurrence of perforated vessels similar to sieves in typology (Bogucki, 1984). Their actual use for cheese making was confirmed by the identification of dairy fat residues in ceramic sieves from the classic to late phases of the LBK (5200–4900 cal. BC) in the region of Kuyavia, Poland (Salque et al., 2012) and at Brodau (LBK classic phase) in Germany (Salque et al., 2013). Dairy fat residues were also retrieved in some instances from non-perforated bowls in the Kuyavia LBK (Salque et al., 2012). Meanwhile, no milk residues were detected in ceramic assemblages from other LBK sites in Saxony and Bavaria in Germany (Salque et al., 2013), or in Bohemia (Mátlová et al., 2017), although the absence of evidence of the use of ceramic vessels for milk collection or processing does not preclude milk exploitation.

These combined elements raise questions concerning the extent to which LBK cattle husbandry developed in the woodland component of the landscape. How was the availability of open grasslands managed throughout the year to feed these large domestic, predominantly grazing herbivores, especially if open lands were cultivated? Palynological evidence indicates pasturing in the floodplains of the river valleys (Kreuz, 2008). The use of forest resources, including woodland grazing and the production of fodder from coppicing and pollarding is often assumed (Kreuz, 2008; Saqalli et al., 2014), building on direct evidence in more recent contexts (lakeside and wetland settlements from the last third of the 5th millennium cal BC onwards; summary in Kühn et al., 2013). It has also been argued that the reconfiguration of caprine husbandry by early Neolithic farmers in southeastern Europe, into a cattle pastoral system in the LBK was a consequence of adaptation to a forested landscape, based on the assumption that cattle cope relatively well with forest browsing (Rowley-Conwy and Legge, 2016). However, beyond the environmental perspective, social factors including forms of property have been put forward as the main driving factor for the high representation of cattle in LBK sites (Shennan, 2011; Manning et al., 2013). The use of the forest to feed cattle has actually only been directly tested to a small extent in LBK contexts (see below). The question of subsistence strategies is also paramount, firstly, for a better understanding of how crop cultivation, animal husbandry and forest exploitation were functionally interconnected in LBK economic systems, and secondly, because the management of the cattle diet would have directly influenced animal production. Seasonally-reduced forage availability, especially in wintertime, when meadows are covered with snow and forests do not produce much fodder, could have conditioned cattle reproduction cycles, for which food resources are the main restricting factor (Santos et al., 2006; Burthe et al., 2011). In turn, cattle birth distribution would have partly determined the organization of pastoral tasks throughout the year, but also the availability of milk on a seasonal scale: both elements are key parameters for approaching the socioeconomic modalities of these agropastoral systems.

These aspects of LBK cattle husbandry can be investigated using stable isotope analyses of skeletal remains. Previous stable isotope studies of LBK faunal assemblages consisted in the analysis of bone collagen stable carbon (δ^{13}C) and nitrogen (δ^{15}N) isotope compositions in order to define the environmental settings. In particular, δ^{13}C values can be used to evaluate the degree of habitat closure: in closed forests, the reduction of light intensity influences photosynthesis efficiency, leading to lower δ^{13}C values in plants (the canopy effect; van der Merwe and Medina, 1991). These values are then passed along the food chain (Drucker et al., 2008). They may therefore be used to test for cattle feeding on forest resources. In this article, we first present a summary of previously published δ^{13}C values in cattle bone collagen in LBK contexts; we show that even though the evidence points to cattle feeding on forest resources in a few sites in the western margin of the LBK extension area, the question remains open in other regions of Central Europe. We then provide two additional δ^{13}C datasets for cattle remains from the LBK sites of Chotěbudice and Černý Vůl in northwestern Czech Republic. Feeding on forest resources was additionally investigated on a seasonal scale, through the sequential analysis of stable carbon and oxygen isotope ratios in tooth enamel. Our hypothesis is that stable isotope values measured in bone collagen are less suitable for detecting the seasonal contribution of forest resources to cattle diet than the enamel record. Meanwhile, stable oxygen isotope ratios provide a tool for investigating cattle birth seasonality. Although this parameter has been investigated in other European prehistoric contexts, no data are currently available for the LBK. Studies conducted in the Romanian early Neolithic and Chalcolithic (early 6th and 5th millennium BC; Balasse et al., 2013, 2014), and in the Middle Neolithic in France (early 4th millennium BC; Balasse et al., 2012a), point to restricted birth seasons, compared to year-round breeding in present-day European husbandry where the nutritional status of cattle is maintained to a high level throughout the annual cycle. Although a restricted calving period is also expected for the LBK, this parameter must be directly determined on faunal remains before it can be confidently introduced into models aiming to describing the sustainability of LBK farming systems (for example, Saqalli et al., 2014).

2. Previously published δ^{13}C datasets from LBK bovine bone collagen

Available datasets of bone collagen stable isotope composition measured on LBK assemblages are summarized in Fig. 1A. Values specifically referred to as “aurochs” in the given publications are not included. However, it must be noted that the “cattle” datasets from the studies in Bickle and Whittle (2013) often potentially include aurochs as a minor component. This is important given that the Holocene aurochs is commonly referred to as a forest animal. The mean δ^{13}C values within each site range from −22.9 to −19.8‰ but variability within each dataset may be important. In modern ecosystems, the great majority of δ^{13}C values in C_3 plants (which dominated Neolithic Europe) range from −29 to −25‰ (−26.5‰ on average) when growing in open areas (Kohn, 2010). These would lead to δ^{13}C values of −27.5 to −23.5‰ (−25‰ on average) in plants from pre-industrial ecosystems (once corrected by +1.5‰ for the fossil fuel effect: Freyer and Belacy, 1983), and δ^{13}C values ranging from −22.5 to 18.5‰ (mean −20‰ on average) in collagen (when applying a 5‰ spacing between diet and collagen δ^{13}C; Ambrose and Norr, 1993). In contrast, late Boreal/early Atlantic aurochs feeding in the dense Atlantic forest in Scandinavia yielded δ^{13}C values ranging from −24.2 to −22.4‰ (Noe-Nygaard et al., 2005a, 2005b). Considering this, we use the −22.5‰ value in collagen as a threshold for a major forest component in the diet.

Among the collected datasets for Central Europe, the δ^{13}C values appear to follow a geographical pattern, along a longitudinal gradient (Fig. 1B). The highest δ^{13}C values were measured in the eastern margin of Hungary (settlements of Füzesabony-Gubakút, Polgár-Ferenci-hát and Balatonszárszó; Whittle et al., 2013a), indicating cattle grazing in open areas. The lowest δ^{13}C values were measured in the western margin of southwestern Germany (Vaihingen; Fraser et al., 2013) and in