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RESEARCH

Experimental Protocol for Cooking Rabbits and its Archaeological Implications

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Abstract

Small prey such as rabbits are present in Middle Paleolithic and are abundant in the diet of Upper Paleolithic human groups in southwestern Europe, especially in the Iberian Peninsula. Several archaeological and experimental studies have attempted to relate anthropogenic modifications, in this case cut marks, to different processing and consumption activities. However, the data do not always give similar results, as the presence and quantity of cut marks is variable across time, geography, and anatomical elements. Therefore, the lack of clear answers forces us to hypothesize if these variations could be indicative of the choice of particular cooking, processing, and consumption patterns, including the aim of preserving the meat by drying or smoking. The first objective is to present an empirical methodology to resolve uncertainties about the processing and consumption patterns adopted by human groups in different temporal and geographical contexts. The second objective is to characterize the cut marks found on the bones and relate them to a cooking method. To achieve these objectives, the paper presents a complete experimental protocol. This protocol included three cooking methods (drying, smoking, roasting) that could have been used by Paleolithic human groups when processing rabbits. The results of these experiments are then analyzed in terms of time, weight loss, and the condition of the meat and marrow. Following this, the first results of the taphonomic study focusing on the cut marks identified on the experimental bones are reported. In addition, we critically review other experimental studies focusing on rabbits and compare their results with our own in order to present a comprehensive framework and discuss their archaeological implications.

Keywords Paleolithic · Zooarchaeology · Taphonomy · Leporids · Experimental archaeology · Prehistoric cooking

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Introduction

The human groups that inhabited Eurasia during the Paleolithic had a diversified diet in which medium and large ungulates played a predominant role (Gaudzinski, 2006; Rendu, 2022; Romandini *et al.*, 2020; Salazar-García *et al.*, 2013; Stiner, 2013). However, in southwestern Europe, smaller species, such as leporids (mainly rabbits), also acquired a relevance in human subsistence, mainly from the Upper Paleolithic period onwards (*e.g.*, Aura *et al.*, 2002; Fa *et al.*, 2013; Jones, 2004; Morin *et al.*, 2019; Pérez Ripoll & Villaverde, 2015; Real, 2020; Starkovich, 2012). The presence of leporids is well documented in archaeological assemblages of this region from the Early Middle Paleolithic to Mesolithic (*e.g.*, Aura *et al.*, 2002; Blasco & Fernández-Peris, 2012a, 2012b; Cochard et al., 2012; Carvalho et al., 2018; Hockett & Haws, 2002; Morales Pérez, 2015; Morin *et al.*, 2019; Pérez Ripoll & Villaverde, 2015; Real *et al.*, 2024; Rosado-Méndez et al., 2018; Sanchis, 2012; Sanchis & Fernández Peris, 2008; Sanchis *et al.*, 2016; Stiner, 2009; Villaverde *et al.*, 1996; Yravedra, 2008), although their importance has varied temporally and geographically.

From the Aurignacian, rabbit emerged as the main prey documented in archaeological sites in the Mediterranean part of Iberia, with the number of remains significantly increasing. However, the depositional agents of the assemblages may include both human and carnivores, such as mammalian and avian predators. In this regard, there are sites with a main anthropic character, as evidenced in some sites from northeastern Iberia such as Catalan sites Cova de L'Arbreda (Lloveras *et al.*, 2016) and Cova Foradada (Morales *et al.*, 2019); however, a minor human origin is also evidenced in some contexts such as Cova de les Malladetes (Sanchis *et al.*, 2016). In all contexts, its importance in relation to human exploitation is consolidated by the Gravettian (Lloveras *et al.*, 2011b; Pérez Ripoll, 2004; Sanchis *et al.*, 2016).

The rabbit presence continues in the Solutrean and, during the Magdalenian, rabbit percentages peaked in the Iberian Peninsula, both in the Atlantic and Mediterranean regions (Gordón Baeza, 2016; Haws & Valente, 2006; Hockett & Bicho, 2000; Hockett & Haws, 2002; Kaufmann *et al.*, 2024; Lloveras *et al.*, 2011b; Martínez-Polanco *et al.*, 2017; Real, 2020; Rodríguez-Hidalgo *et al.*, 2011; Yravedra *et al.*, 2019). This trend continued until the Mesolithic, when a significant decline of this taxon was documented in the central part of the eastern Iberian Peninsula (Morales Pérez, 2015; Real *et al.*, 2024), in contrast to what was observed on other sites in the northeast (Rosado-Méndez *et al.*, 2018).

The constant presence and high percentage of rabbits in the faunal record of this area reflect the crucial role that this species played in the diet of Paleolithic human groups in the Iberian Mediterranean area, Portugal, and Southern France (see, Aura *et al.*, 2002; Bicho *et al.*, 2006; Cochard, 2004; Cochard & Brugal, 2004; Haws & Valente, 2006; Jones, 2004, 2006; Manne & Bicho, 2009; Pérez Ripoll, 2004; Rufà *et al.*, 2018; Villaverde *et al.*, 2012).

Studies on this prey, under the category of"small game"or"small prey,"have been steadily increasing in the international scientific literature since the twentieth century (Blasco *et al.*, 2022; Lupo & Schmitt, 2002; Stiner, 2009; Stiner *et al.*, 2000). The development of taphonomic research, the implementation of experimental programs, and more in-depth and systematic analyses of leporid assemblages – including rabbits and hares – have confirmed the hunting and consumption of these species by both Neanderthals and Anatomically Modern Humans (AMH) (Alonso *et al.*, 2024; Blasco & Fernández-Peris, 2012a, 2012b; Carvalho *et al.*, 2018; Lloveras *et al.*, 2009, 2016; Morin *et al.*, 2019; Sanchis, 2012; Sanchis & Fernández Peris, 2008; Sanchis *et al.*, 2016; Speth, 2000), even in other parts of the world such as North America (*e.g.*, Fisher & Johnson, 2014; Lubinski, 2003; Ugan, 2010). However, there are still notable gaps in the knowledge of how these societies processed and managed the resources derived from rabbits.

Regarding the current state of research, studies on small prey are mainly focused on leporids in the Iberian Mediterranean area. Researchers have been able to establish a set of basic inferences from the evidence analyzed, identifying a series of fundamental traits/patterns: (1) leporids are an abundant and constant potential prey available in Iberian Mediterranean environments; (2) they are prey for both human groups and other predators; (3) zooarchaeological assemblages are usually composed of 60–95% leporids; (4) due to their full consumption and quantity, it is possible to suggest that they constitute an important resource within the human diet; (5) their processing for the consumption of meat and marrow by humans does not require specialized equipment and is carried out using lithic tools and/or manual/dental action. Despite these observations, many questions remain unanswered regarding the methods employed during the manipulation and preservation of leporids.

Several archaeological and experimental studies have attempted to relate anthropogenic modifications, in this case cut marks, to different processing and consumption activities (Lloveras *et al.*, 2009, 2011a; Pérez Ripoll, 1992, 2001, 2004, 2005; Rosado-Méndez *et al.*, 2016). However, the data do not always yield similar results, which forces us to propose two starting and correlated hypotheses for our work. On the one hand, the cut marks identified in the archaeological remains vary considerably between sites, presenting differences in terms of location, morphology, and quantity. In this sense, cut marks are not always reflected in the archaeological record despite their observation and verification in some experimental works (*e.g.*, Lloveras *et al.*, 2009). This can be due to disarticulation by using simple hand movements, which does not usually leave marks and masks human activity. Consequently, the presence and quantity of cut marks is variable across chronology, sites, and anatomical elements. Therefore, it is hypothesized that these variations are indicative of the choice of particular processing and consumption patterns, or even a reflection of the skill of the person performing the actions.

On the other hand, it has been suggested that leporids were processed with the aim of preserving the meat by drying or smoking. This could be related to more stable and prolonged occupations in the place of habitation (Pérez Ripoll, 2002, 2004). This hypothesis has ethnographic parallels in some indigenous populations in North America, where meat would be preserved for later consumption (Spier, 1978). As the Rosado-Méndez *et al.* (2016) experimental results show, this practice could leave a greater number of cut marks on certain bones of the postcranial skeleton, such as the scapula and humerus, as a result of defleshing the meat after it has been dried, as it remains more attached to the bones and is more difficult to separate. However, at present, there is an absence of conclusive evidence to support the practice of meat preservation by human groups. Furthermore, the method by which bone marrow from smoked rabbits would be ingested is not yet fully elucidated.

This paper has two main objectives: first, to present an empirical methodology, focusing on a comprehensive experimental program with rabbit carcasses; and second, to characterize the cut marks identified on the bones and relate them to a cooking method. This approach will help resolve uncertainties about the processing and consumption patterns adopted by human groups in various temporal and geographical contexts. The results obtained provide a framework for the execution of analogous experiments on other small taxa, such as marmots, birds, or even certain small carnivores. Additionally, a comparison of the taphonomic data from the experiment with those from archaeological assemblages can facilitate the identification of cooking and processing methods present in each site.

To achieve this goal, the current paper presents the full experimental protocol we followed, which involved three cooking methods (drying, smoking, roasting) that could have been used by Paleolithic human groups when processing small prey such as rabbits. The results of this experimentation are then analyzed in terms of time, weight loss, and the condition of the meat and marrow. Following this, the first results of the taphonomic study, focusing on the cut marks identified on the experimental bones, are reported. Finally, we also critically review other experimental studies works focusing on rabbits and compare their findings with our own in order to present a comprehensive framework for future replication studies and discuss their archaeological implications.

Neotaphonomic Framework

In order to gain insight into human behavior and the dynamics of interaction with other predators, such as carnivores and raptors, it is imperative to conduct experimental and neotaphonomic research. This is an essential component for better understanding and interpreting the results of zooarchaeological studies applied to Paleolithic assemblages. Experimental studies have been conducted primarily to understand the exploitation of large/medium-sized prey through the analysis of butchery processing such as cut marks (*e.g.*, Egeland *et al.*, 2014; Galán & Domínguez-Rodrigo, 2013; Soulier & Costamagno, 2017; Vigne, 2005), modifications to fractures on specific bones (*e.g.*, Blasco *et al.*, 2014; Galán *et al.*, 2009; Jin & Mills, 2011; Outram, 2002; Pickering & Egeland, 2006; Vettese *et al.*, 2020), or even their consumption with the use of teeth (Romero *et al.*, 2016; Saladié *et al.*, 2013;). Experiments have also been applied to other specific species concerning the use of certain resources, such as carnivore skins (Cueto *et al.*, 2016; Fairnell, 2008; Mallye, 2011; Pérez-Ripoll & Morales Pérez, 2008; Val & Mallye, 2011) or bird feathers and talons (Romandini *et al.*, 2014, 2016).

In the twenty-first century, there has been a growing interest in this approach for interpreting accumulations of small prey, such as leporids. The main focus of these approaches has been to understand the origins of these accumulations among various agents. This is because the exploitation of these prey can be attributed not only to human activity, but also to other terrestrial and avian predators (see compilation by Lloveras & Nadal, 2015 and Sanchis, 2012). Nevertheless, most of these studies focus on observing the behavior of animals rather than humans. Specifically, they analyze the habits of terrestrial carnivores such as foxes and lynxes (*e.g.*, Cochard, 2004; Hockett & Haws, 2002; Lloveras *et al.*, 2008a, 2012a; Mallye *et al.*, 2008; Mondini, 2000; Rodríguez-Hidalgo *et al.*, 2013, 2015; Sanchis, 2000; Sanchis & Pascual, 2011), as well as a wide range of birds of prey (*e.g.*, Cochard, 2004; Cruz-Uribe & Klein, 1998; Guennouni, 2001; Guillem & Martínez Valle, 1991; Hockett, 1995, 1996; Sanchis, 2000; Lloveras *et al.*, 2008b, 2009, 2012b; Yravedra, 2004, 2006).

Conversely, the number of studies focusing on the controlled reproduction of past human actions is smaller. As far as we know, there are 11 studies on human actions versus 30 on non-human actions; both are equally crucial. This is significant because the number of leporid remains typically represents a considerable proportion of the total skeletal remains in Paleolithic sites in southern Europe (*e.g.*, Martínez Valle, 1996; Hockett & Bicho, 2000; Hockett & Haws, 2002; Pérez Ripoll, 2004; Pérez Ripoll & Villaverde, 2015; Lloveras *et al.*, 2010; Blasco *et al.*, 2013; Morin *et al.*, 2019; Rufí *et al.*, 2020). The percentages reach as high as 90% in the Late Upper Paleolithic and Epipaleolithic periods (*e.g.* Aura *et al.*, 2002; Morales Pérez, 2015; Rosado-Méndez *et al.*, 2018; Rufà *et al.*, 2018; Real, 2020; Villaverde *et al.*, 2012). Furthermore, as pointed out in the"Introduction"section, numerous issues remain unresolved. Despite extensive research, little is known about the procurement, processing, and meat preservation techniques that ancient human groups might have used and any traces that may have manifested on bone. This lack of knowledge is partly due to a lack of systematic methodology, and partly because no experiments have been conducted on the subject that can be correlated with the presence or absence of certain elements in the bone assemblages. A review of the experimental work focused on human modifications in rabbits reveals a total of 11 publications. However, these publications correspond to only seven experiments with highly disparate characteristics (Table 1).

The earliest experimental work on rabbits dates to the beginning of the twenty-first century (Fernández-Peris *et al.*, 2007; García-Argüelles *et al.*, 2004; Pérez Ripoll, 2005). These studies focused on specific archaeological assemblages from the Middle and Upper Paleolithic and the Epipaleolithic periods (Table 1). In the light of the challenges encountered in the various assemblages, the authors have referred to the experimental activities they conducted. While these studies were pioneering in the field of small-prey research, they are not regarded as standalone methodologies. It is therefore not possible to outline the specific procedures used or provide quantitative data.

A second set of experimental works published includes studies published between 2009 and 2012 (Table 1). These comprise Lloveras *et al.*, (2009, 2011a), which pertain to the same experimentation; and Sanchis *et al.* (2011) and Sanchis (2012), the same. These papers are presented as fully experimental works, with a dual focus on the cut marks produced during the processing and consumption of the carcasses, and

Table 1 The seven experiments cited in the text and their main characteristics

Reference	Objectives	Modifications	Methods	MNI	Process tools	Archaeological comparison
Alonso, G., *et al.* 2024	To determine distinctive taphonomic patterns that can be attributed to the intentional use of fire	Thermal alterations	13 combustion structures into two experimental series: seven for roasting the rabbits and six for cleaning the waste from the first series	8	–	–
Pérez, L., *et al.* 2017	To investigate ways in which we can identify the diagenetic phase in which a given bone is burned	Thermal alterations	Eight open hearths (2–8 h). Rabbits (in different stage of fresh and dry) were buried: 96 bones in the substrate, 23 in the hearth base, 20 in the flames, and 5 in the embers. Excavated after 24 h in two facies. Bones were cleaned with distilled water	6 (148 NISP)	–	El Salt (Spain), Middle Paleolithic
Rosado-Méndez, N., *et al.* 2016	To describe and analyze traces left on appendicular bones during the stages of defleshing and scraping meat out of the bone in various levels of meat preservation (fresh and dried)	Cut marks	Rabbits were skinned, eviscerated, and disarticulated in raw. Only forelimb, hindlimb, scapula, and innominate were used. Three rounds of processing/consuming: (1) fresh; (2) fresh and dried (with salts); (3) dried (with salt), roasted, and rehydrated. Three types of activities to see the marks: defleshing, scraping off meat, and Achilles tendon removal. Then, the bones were boiled	8 (29 limbs)	12 unretouched flint flakes	Cova de la Guineu, Font Voltada and Balma del Gai (Spain), Epipaleolithic

Table 1 (Continued)

Reference	Objectives	Modifications	Methods	MNI	Process tools	Archaeological comparison
Sanchis, A. 2012	To identify the fracture patterns and the tooth marks made by humans	Cut marks, fractures, and tooth marks	Rabbits were skinned, dismembered, and defleshed. Long bones (humerus, femur, and tibia) were fractured and cleaned by manual and dental actions	5	Several unretouched flint flakes	Cova del Bolomor (Spain), Middle Paleolithic
Lloveras, Ll., *et al.* 2009	To identify traces left by each operation (butchery, cooking, and consumption)	Cut marks (butchery), thermal alterations (roasting), and tooth marks (consuming)	Rabbits (5 already eviscerated) were skinned, disarticulated, defleshed, and roasted (whole and in parts). Three rabbits were consumed by 10 people	9	14 flint and quartzite flakes	–
Fernández Peris, J. *et al.* 2007	To test the effect of fire on rabbit bones during the cooking of meat packages	Thermal alterations	Two forelimbs and two hindlimbs were roasted into direct fire	2	–	Cova del Bolomor (Spain), Middle Paleolithic
Pérez Ripoll, M. 2005	To define the anthropogenic fractures, their characterization, and their typologies	Fractures, tooth marks	Rabbits were skinned and defleshed. Then, long bones (humerus, femur, and tibia) were fractured (in raw and after roasting) and consumed by manual and dental action	Several	Several unretouched flint flakes	Cova de les Cendres (Spain), Gravettian

on the tooth marks left during consumption of the meat. A shift in methodology is evident in all these studies, as the articles themselves are focused exclusively on the experimentation itself. In both cases, quantitative data pertaining to the experimentation is presented.

The abovementioned studies from the second set provide a significant theoretical and methodological foundation, indicating the establishment of this novel taphonomic approach as a new method for studying the exploitation of small prey by human groups across different periods. Furthermore, they have become a point of reference in the study of archaeological assemblages of Leporidae from the Mediterranean area of the Iberian Peninsula (*e.g.*, Lloveras *et al.*, 2016; Real, 2020; Rufà *et al.*, 2018). However, despite their utility, the methodological approaches employed are not entirely systematic, as each experimental action is not performed on a consistent number of individuals or anatomical groups. Consequently, although the results are valid, they lack statistical representativeness.

In a final group of experimental works, we may include the most recent studies (Table 1) by Pérez (2015), Rosado-Méndez *et al.* (2016), Pérez *et al.* (2017), and Alonso *et al.* (2024). Pérez *et al.* (2017) present data that had not been previously considered for leporids, including post-depositional thermal alterations. In a similar vein, Alonso *et al.* (2024) also focus on the study of thermal alterations to diagnose taphonomic patterns attributed to deliberate utilization of fire. This work, in addition to presenting the alterations to the bones of the roasted rabbits, also includes the use of fire as a means of cleaning the discarded remains. Rosado-Méndez *et al.* (2016) offer a comprehensive experimental program to describe and analyze the traces left on appendicular bones during the stages of defleshing. It is significant that the processing was conducted on rabbit carcasses in a variety of states, including fresh, roasted, dried with salt, and even dried and rehydrated. As in the preceding second set of studies, the data presented in these three experiments pertain to the individuals, anatomical groups, and lithic tools. In addition, the results include the number of marks, locations, and their characteristics.

Materials and Methods

For the current experimental program, 24 rabbits were processed after (or before in the case of the drying method) applying three different cooking or preservation techniques. All the rabbits were immature domestic rabbits (*Oryctolagus cuniculus*, Linnaeus, 1758), as indicated by their unfused long bone epiphysis. All specimens were free of pathologies and well preserved. Rabbits were purchased from a butcher shop without skin and partial viscera (*e.g.*, stomach, intestines), and they were sourced from a farmer in the Valladolid region in Spain. The rabbit individuals were not complete, as they had been cut at the distal portion of the limbs, at the carpal and tarsal level; however, no other parts of the skeleton were affected by metal knives. The rabbits were fresh, having been slaughtered 24–48 h in advance and then refrigerated.

For the cooking by smoking and roasting, a combination of pine (*Pinus sylvestris*) and oak (*Quercus* sp.) wood was used to prepare the hearths, which were lit using balls of pine wool. A total of 157.6 kg of wood, 21.6 kg of pine, and 136 kg of oak were used. This combination of wood was used because of its presence and abundance in Paleolithic archaeological sites in the area.

Finally, reproductions of 46 lithic tools made from Serreta-type local flint (Molina, 2016) were used to process the rabbit carcasses. Serreta-type flint was chosen because it is one of the dominant varieties of raw materials found in archaeological assemblages – both from the Middle and Upper Paleolithic periods – in the central Iberian Mediterranean area as, for example, Abrigo de la Quebrada, El Salt, or Abric Pastor (*e.g.*, Eixea *et al.*, 2014; Molina *et al.*, 2010, 2016).

The aim of the experimental program was to compare resulting assemblages with Middle and Upper Paleolithic collections. Therefore, both flakes and blades were reproduced to match the standard tools commonly recovered in these Paleolithic contexts (Supplementary Fig. 1). In addition, 11 of the pieces were retouched to assess potential differences in use wear for future research, while the remaining pieces were left with sharp edges. Eleven pieces were selected for the dried rabbits, 12 for the smoked rabbits, and only three for the roasted ones (Table 2). The rabbits still had the major edible organs (lungs, liver, and heart); therefore, two additional lithic tools were used to remove the organs and open the axillary area. The study of the lithic pieces and their use ware traces is ongoing and not included in the present work.

Experimental Protocol

The culinary process involved three distinct methods: drying, smoking, and roasting. Cooking methods and times were determined based on the cooking criteria used in today's restaurant kitchens (a consultation with chefs was convened), as well as reference publications on cooking and ethnographic studies (Mediani *et al.*, 2022; Myhrvold *et al.*, 2011; Spyrou *et al.*, 2019). Moreover, with respect to the preservation of meat, current culinary techniques, historical references, and ethnographic studies of indigenous populations in North America (Bean, 1974; Flandrin & Montanari, 2016; Kiple & Ornelas, 2008; Mediani *et al.*, 2022; Myhrvold *et al.*, 2011; Spier, 1978; Spyroua *et al.*, 2019) suggest that various methods such as cold or hot smoking, sun-drying, and salt-drying could be employed. Historically, smoking has been employed as a method of food preservation, particularly in contexts where refrigeration was not readily available. The smoke exerts an antibacterial effect on the surface of the food, while the desiccation process impedes the activity of microorganisms within the food (Myhrvold *et al.*, 2011). The process of cold drying, which typically occurs at temperatures ranging from 20 to 30 °C, necessitates a duration of approximately several days. This extended period of time renders the food susceptible to the contamination of microorganisms. Consequently, in numerous instances, salts are employed to preserve foodstuffs and impede bacterial proliferation. Furthermore, maintaining constant temperature and humidity levels in the smoke is a more complex task. Conversely, hot smoking necessitates elevated temperatures, approximately 400 °C, and a comparatively brief smoking duration. Of these, hot smoking and sun-drying have been selected for further examination.

The selection of a particular method of cooking is influenced by several variables, including environmental factors such as temperature and humidity, access to combustible materials, the availability of sustenance, and the urgency of preparing food, particularly meat. These factors could have led to variations in cooking methods among Paleolithic populations. Therefore, it was deemed appropriate to document the characteristics of the firewood, including its type and quantity, as well as the prevailing environmental conditions.

Most of the experiment was conducted in the village of Alcubillas, Ciudad Real, Spain, between May 6 and May 11, 2024 (drying, smoking, and roasting). However, the drying phase of the experiment was concluded between September 5 and September 11, 2024. In May, the environmental conditions were stable, with mostly sunny skies and some clouds. Temperatures ranged between 16 °C (minimum) and 28 °C (maximum), with low humidity levels between 20 and 47% and light winds ranging from 2 to 13 km/h during working hours. In September, temperatures ranged between 12 and 30 °C, with humidity levels between 21 and 75% and windier conditions ranging from 6 to 27 km/h. Consequently, the temperature and humidity conditions were found to be optimal at both times and did not exert a negative influence on the experiment.

For all phases of the experimentation, a database (DB) created specifically for this study was used to record all the data and to be able to manage its subsequent analysis more easily in Excel spreadsheets. The DB was created using the FileMaker program (Pro 16 Advanced). It consists of three interrelated digital databases (Supplementary Figs. 2–4), each one dedicated to a set of data. The DB is registered and freely accessible on the Zenodo platform (Real, 2024).

All phases of the experiment were recorded by photo and video with a Sony A7 III camera with a 90-mm objective (Sony FE 90 mm F2.8 Macro G OSS) and a 28–75-mm objective (Tamron 28–75 mm F2.8 Di III RXD). Three videos about the experimental protocol were created and are in the Zenodo platform (Real, 2025). Each video focuses on one type of cooking (drying, smoking, roasting) and includes all phases of the experiment, carcass preparation, cooking, and processing (see at https://doi.org/10.5281/zenodo.15715657).

The following section presents the steps that were followed during the experimental protocol.

Preparation of the Carcasses

The carcasses of the 24 rabbits were prepared: excess fat and the remaining organs (lungs, heart, kidneys, and liver) were manually removed (Fig. 1). This was to facilitate the drying process, both in the open air and through smoking. The rabbits for the smoking and roasting experiment were then weighed individually. In the case of drying, only the raw meat of the main anatomical parts (forelimbs, axial, hindlimbs) was weighed, as the carcasses had been defleshed first.

Finally, in order to make cooking (drying, smoking, roasting) more effective, the carcasses were opened axially along the sternum. This was achieved using manual pressure and two lithic tools, one unretouched flake and another unretouched blade.

Cooking and Processing of Rabbits

The processing of the rabbits was carried out by four of the authors of this study (CR, AR, MC, LP), all of whom were right-handed and two of whom had extensive knowledge on rabbit anatomy and previous experience butchering rabbits for experimental studies. Thus, rabbit processing was conducted by people with various levels of experiences butchering and processing a rabbit carcass. Rabbit processing was carried out in the open air in the same location as the cooking. The times of each processing phase (disarticulation, defleshing, fracture) were recorded. The temperature was measured with a temperature gun aimed at the smoked rabbits and a grill thermometer for the roasted rabbits (pricking the meat with the thermometer tip).

Lastly, it is important to note that the processing (disarticulation and defleshing) of the carcasses and the fracturing of the long bones described below were performed alternately by experienced and inexperienced members of the group. In this way, it will be possible to assess whether the results of the lithic and dental characteristics vary according to this variable and whether this is reflected in the archaeological assemblages.

Drying

During a first round of experimentation, eight rabbits where dried whole, so that the skull was preserved. They were hung on a wire, four from the hind legs and four from the forelimbs. They were left in the open air for 5 days, only covered with a mosquito net to prevent insects from entering. After 1 week, one of the rabbits was processed, but the meat was still too fresh. Thus, we decided to keep it longer. After some more days of drying, we tried to process the animals again. However, when trying to process the meat, it was excessively tough and practically impossible to deflesh. In addition, the presence of some fatty areas, as well as the viscera in the area of the skull, led to the emergence of decomposition larvae. Therefore, we considered the first round of drying unsuccessful due to too long drying time and the emergency of decomposition larvae, and we did a second operation with a new set of rabbits based on this previous experience.

In the second round of experimentation, another eight rabbits (referenced as Rabbit 26 to Rabbit 33) were defleshed while they were raw (Fig. 2a). Based on the experience acquired from the first round of drying, we realized that it was not feasible to process the rabbits after drying. Thus, for this round, it was decided to separate the meat from the bones when it was still fresh. First, the anatomical groups (cranial, axial, forelimb, hindlimb) were disarticulated using the lithic tools. Next, the axial area, the forelimb, and the hindlimb were separately defleshed, in an attempt to recover as much meat as possible in long strips, performing scraping movements along the bones with the use of lithic tools. Finally, the limb bones (scapula-humerus, humerus-radius/ulna, coxal-femur, femur-tibia) were disarticulated. Following disarticulation, the meat was left hanging on a wire in the open air for between 2 and 3 days, only covered with a mosquito net (Fig. 3). After drying, the meat was weighed.

Smoking

First, a structure was built with wood and stones to keep the rabbits hanging and protected from the direct action of the fire, at a distance of at least 50 cm (Fig. 4a, b). In addition, the structure was covered with branches to keep the smoke as concentrated as possible on the rabbits (Fig. 4c). Moreover, an excess of oxygen can exacerbate combustion, leading to diminished smoke production. This, in turn, compromises the efficiency of the cooking process. A round pit measuring 90 × 80 × 25 cm was dug in which to place the hearth. We lit the hearth in this pit twice, cooking four rabbits in each lit hearth. The rabbits were hung on a wire, the first four being hung from the hindlimbs and the other four from the forelimbs (Fig. 4d).

A total of 8.1 kg of pine and 68 kg of oak were used for the first fire. Pine was mainly used to start the fire, while oak was used to maintain the fire at a more stable temperature. The fire was burning for 7 h and 12 min, starting at 11:10 AM. Maximum temperatures of 546 °C were reached. For the second fire, 5.4 kg of pine and 51 kg of oak were used, following a similar procedure. The fire was allowed to burn for 8 h and 5 min, starting at 10:17 AM. Maximum temperature of 540 °C was reached.

After smoking, the rabbits were cooled and weighed to calculate the loss of mass and moisture in relation to their raw weight. The processing described below was applied to all eight rabbits. First, the anatomical groups (cranial-axial, axial-forelimb, axial-hindlimb) were disarticulated using the lithic tools (Fig. 5c). Next, the axial area, the forelimb, and the hindlimb were separately defleshed using lithic tools (Fig. 5d). Finally, the limb bones (scapula-humerus, humerus-radius/ulna, coxal-femur, femur-tibia) were disarticulated.

Table 2 Lithic tools used for the experimental processing

	Smoked rabbits	Dried rabbits	Roasted rabbits	Evisceration
Flake	**6**	**6**	**1**	**1**
Retouched	2	2		
Unretouched	4	4	1	1
Blade	**6**	**5**	**2**	**1**
Retouched	1	2	1	
Unretouched	5	3	1	1
	12	**11**	**3**	**2**

Roasting

A round pit measuring 90×60×20 cm was dug in which the hearth was placed and in which two fires were made to roast the rabbits (Fig. 6a). The rabbits were cooked whole four at a time, placed on a grill over embers. Only after the flames were extinguished and the embers remained were the rabbits placed on the hearth. This was to avoid direct fire contact and charring of the meat (Fig. 6b). For the first fire, 5.4 kg of pine and 8.5 kg of oak were used, while 2.7 kg of pine and 8.5 kg of oak were used for the second fire. The first set of rabbits were cooked for 46 min and the second for 60 min. In both cases, the rabbits were turned halfway through cooking (Fig. 6c, d). The fire reached temperatures of 527 and 502 °C, respectively.

After roasting, the rabbits were cooled down naturally and weighed to calculate mass and moisture loss in relation to their raw weight. The processing guidelines described for the smoking procedure were followed, with the exception that both disarticulation and defleshing were carried out manually in the case of the roasted rabbits (Fig. 7a–d), as we wanted to imitate the direct consumption of rabbits. The use of lithic tools was required only to separate the humerus from the radius/ulna and to complete the defleshing of humerus, femur, and tibia (Fig. 7e, f).

Bone Fracture

Finally, for each type of cooking, four of the eight rabbits in each cooking method were selected to have their main long bones (humerus, femur, and tibia) fractured due to their higher content of marrow. The aim was first to have access to the marrow to observe its condition after the cooking process, and second, to observe possible different types of fracture depending on the cooking method (Fig. 8). In all cases, attempts were made to affect the fracturing by hand, but as this proved impossible, biting or bending using teeth was used. The utilization of lithic tools for the purpose of bone fracture was dismissed on the basis of two key factors. First, given the specimen's small dimensions, the utilization of a lithic tool would not only fracture the bone but also potentially obliterate the diaphysis or epiphyses. Second, extant data from prior experiments and archaeological studies demonstrate the ease with which this method of consumption can be performed leaving cylinders as anthropogenic evidence, and ethnographic evidence further corroborates this finding, highlighting the prevalence of this practice among certain cultural groups (Cochard *et al.*, 2012; Hockett, 1994; Jones, 1983; Pérez Ripoll, 2005; Sanchis, 2012; Schmitt *et al.*, 2002). The dental action was carried out on the proximal and distal parts of the bones alternately in order to observe the type of fracture according to the density of the anatomical part.

Cleaning of the Carcasses

After freezing, the skeletons of the 24 rabbits were transferred to the *Gabinet de Fauna Cuaternària Inocenci Sarrión* of the *Museu de Prehistòria de València* where they were cleaned. Enzymes (proteases) from Neutrase 0.8 L diluted in water

(15 ml Neutrase into 2500 ml water) were used to help in eliminating the remains of meat and fat on the carcasses. After several phases of water and enzyme renewal, the bones were boiled in a solution of bleach and water (15 ml bleach into 3000 ml water) and air dried, avoiding direct sunlight.

Fig. 1 Preparation of the carcasses: base carcass (**a**); removal of fat and organs (**b**, **c**)

Taphonomic Analysis

All the bones from the experiment were studied at the *Laboratorio Gil-Mascarell del Departament de Prehistòria, Arqueologia i Història Antiga* of the *Universitat de València*. Thereafter, we analyze their anatomical composition and the age-at-death established based on epiphysis fusion (Cochard, 2004; Sanchis, 2012). The minimal number of elements (MNE) and the minimal number of individuals (MNI) have also been used (Lyman, 2008).

A taphonomic study of all bones was carried out with the aim of identifying cut marks, fractures, and tooth marks. Cut marks and tooth marks were classified according to type (incision mark, scraping mark, chop mark, pit, puncture, score, depression), orientation (longitudinal, oblique, transverse), location, quantity (simple, double, multiple), and length (short, long) (Cochard *et al.*, 2012; Landt, 2007; Lloveras *et al.*, 2009, 2011a, 2011b; Rosado-Méndez *et al.*, 2016; Pérez Ripoll, 1993, 2001, 2004; Sanchis *et al.*, 2011; Sanchis, 2012). The term"short"is employed to denote a cut mark that exhibits a reduced length, falling short of the anatomical dimensions of the bone in which it is situated. Conversely, a"long"cut mark is defined as one that extends over the majority of the surface area of the anatomical part in which it is located. In the context of long bones, for instance, the anatomical structure is traditionally categorized into three segments: the proximal, or upper, part; the diaphysis, which is the main body of the bone; and the distal, or lower, part.

A stereomicroscope (Nikon SMZ-10A) magnification up to 12 was used to analyze bone surface modifications and take detailed photos of the alterations. A specific database, different from the one designed for the experimentation, was used for all analyses (Real *et al.*, 2022).

Statistical Data Analysis

To provide statistical support for the observations made during the experimental phase, various univariate and multivariate statistical tests were applied (Student's *t*-test, hierarchical clustering analysis with Euclidean distance, and principal component analysis – PCA). These analyses help to validate the observed differences and suggest new interpretations based on the cooking method used across the 24 processed individuals. All statistical analyses were conducted using the software PAST 5.2.1 (Hammer *et al.*, 2001).

Results

Experimental Protocol

The skeletal specimens were missing a number of bones, as they had already undergone processing by the butcher; the phalanges were missing in all cases, the bones of the carpal and tarsal were often missing, and in some cases, the distal joints of

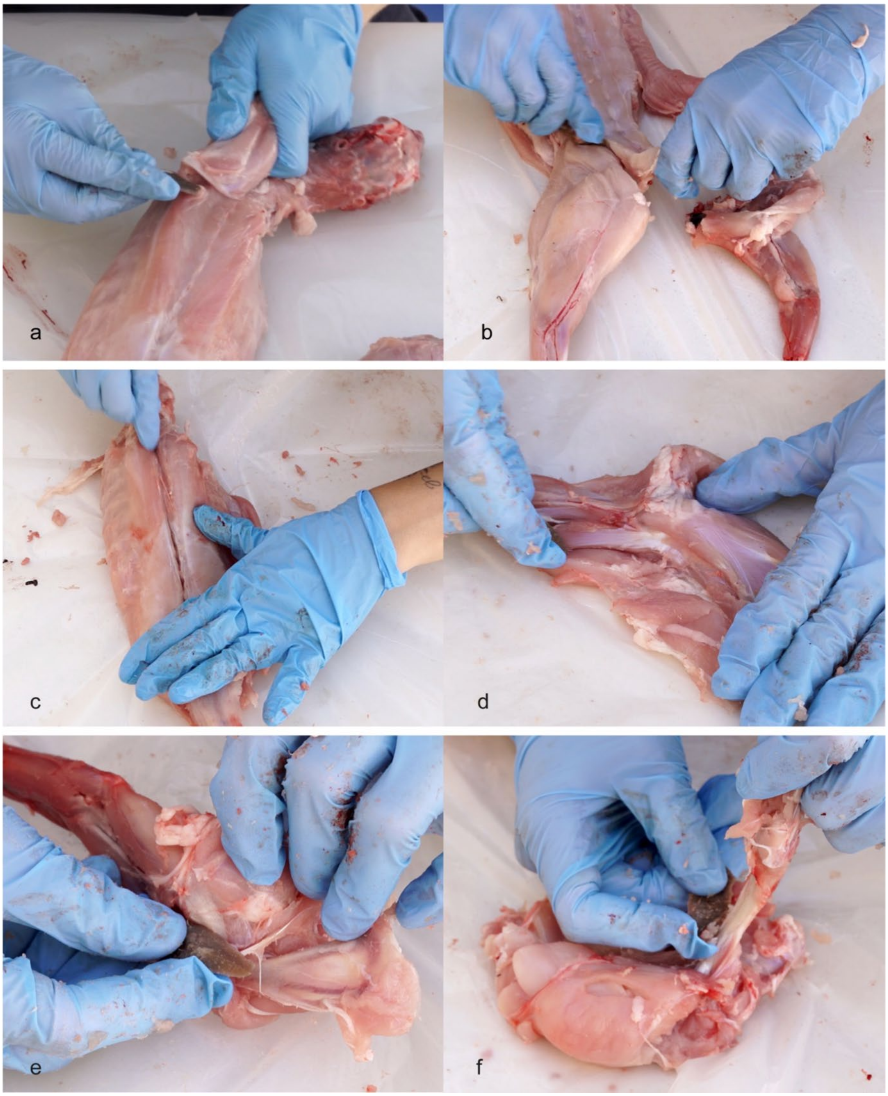

Fig. 2 Process before drying: disarticulating the forelimb (**a**) and hindlimb (**b**); defleshing the axial part (**c**) and the hindlimb (**d**). Examples of cutting (**e**) and scraping (**f**)

the long bones, such as the radius/ulna, were missing too. In one case, the tibia was already broken.

The weights of the rabbits (Table 3; Fig. 9) used for smoking ranged from 960 to 1100 g, with an average of 1010 g. After cooking, the carcasses lost a mean of 70.3%. The weights of the rabbits used for roasting ranged from 990 to 1260 g, with an average of 1100 g. After roasting, the carcasses lost a mean of 39.7%, a much

Fig. 3 Drying cooking: meat strips hanging in the open air (**a**); already dried meat from the axial part (**b**) and the hindlimb (**c**)

lower amount than that obtained with smoking. In the case of drying, as explained above, only the meat to be dried was weighed raw and dry, but the comparison is equally appropriate. The weights of the meat used for drying ranged from 360 to 480 g, with an average of 440 g. After drying, the mean loss of weight was 25.7%.

Fig. 4 Smoking cooking: fire (a, b); external view of the structure with the smoke (c); internal view of the structure with the rabbits hanging (d)

After verifying the normal distribution of the sample using the percentage of weight loss relative to the initial total weight of each individual, a Student's *t*-test yielded a value of 11.5 with a statistically significant probability ($p < 0.01$). This result confirms a clear and significant difference in weight loss among the individuals. To explore whether these differences are associated with the cooking method applied, a hierarchical clustering analysis with Euclidean distance was conducted, which identified three main groups that effectively classify the individuals based on the cooking technique used (Fig. 10; Supplementary File).

Regarding cooking time, in the case of the first round of smoking, the meat was left to cook for 7 h. As a result, the rabbit flesh exhibited exterior hardening or drying. The inner meat was cooked, although quite doughy, with soft, non-fibrous structure that resembled the texture of pastes. Therefore, in the second round it was decided to extend the time by 1 h to make the meat even drier. These carcasses, however, yielded a similar result in that the outer flesh was dry, yet the inside was still doughy. In some cases, the meat around the scapula was still a little raw, as shown by the red-pink color and the doughy or paste-like texture. However, this may be a result of the position of the carcass – that is, further away from the direct smoke and with the forelimbs further away than the hindlimbs (hanging with the forelimbs up). In relation to the roasting, the rabbits were first left for 45 min, which was extended to 60 min in the second block. This was because, although the meat of the former was drier on the outside but quite tender on the inside, in some cases, the joint area between the coxal and the femur was still a little raw (red-pink color).

Nevertheless, all rabbits could be eaten after both cooking methods (Fig. 11). The marrow of the bones that were fractured (four rabbits in each method) presented varying results (Table 4). The marrow of the raw rabbits is a soft, fatty tissue, with bright red color (Fig. 12d, e) (Myhrvold *et al.*, 2011).

The marrow of the rabbits smoked for 7 h was still somewhat uncooked (medium raw), in some cases even raw (Fig. 12a) as shown by the color and soft texture. However, when left for 8 h, the marrow of the femur and tibia was cooked (Fig. 12b). Only the humerus marrow remained half raw due to the fact that in the second round of smoking, the rabbits were placed upside down, with the humerus less exposed to the ember temperature. In the case of cooked marrow of the smoked and roasted rabbits, the color changed into brown and the marrow become semisolid with a firm, gelatinous texture (Fig. 12c, d).

Regarding the second round of the drying method, the timing varied somewhat between anatomical parts. The forelimbs and the axial package of meat were dried for 43 h. However, the hindlimbs were still slightly raw after that time, so they remained drying until the next day – for a total of 67 h. The marrow, which is accessible during processing of the raw carcass, was soft or liquid, depending on the bone (Fig. 12e, f).

The times of the processing phases of the various cooking methods were rather unequal (Table 3, Fig. 13). In terms of disarticulation, manual disarticulation (roasting method) was observed to be much faster, in no case lasting more than a minute. It is interesting to note that when the lithic tools were used (drying and smoking), the time taken exceeded 1 min, and 3 or 4 min were sometimes needed in the case of the smoked rabbits.

Something similar was observed in the case of defleshing. Defleshing was carried out more quickly by hand (roasting), with times of 5–13 min, and with only three cases exceeding 10 min (Table 3, Fig. 13). When the lithic tools were used to deflesh the rabbits (smoking), the time taken was considerably longer, 14–20 min, and on one occasion 11 min. The same was true for drying the meat of the raw defleshed carcasses, with a duration of 15–24 min. However, the fracture time of the long bones was shorter for smoked rabbits (approximately 2 min) than for roasted rabbits (approximately 4 min). For raw rabbits, it was always less than 1 min 50 s.

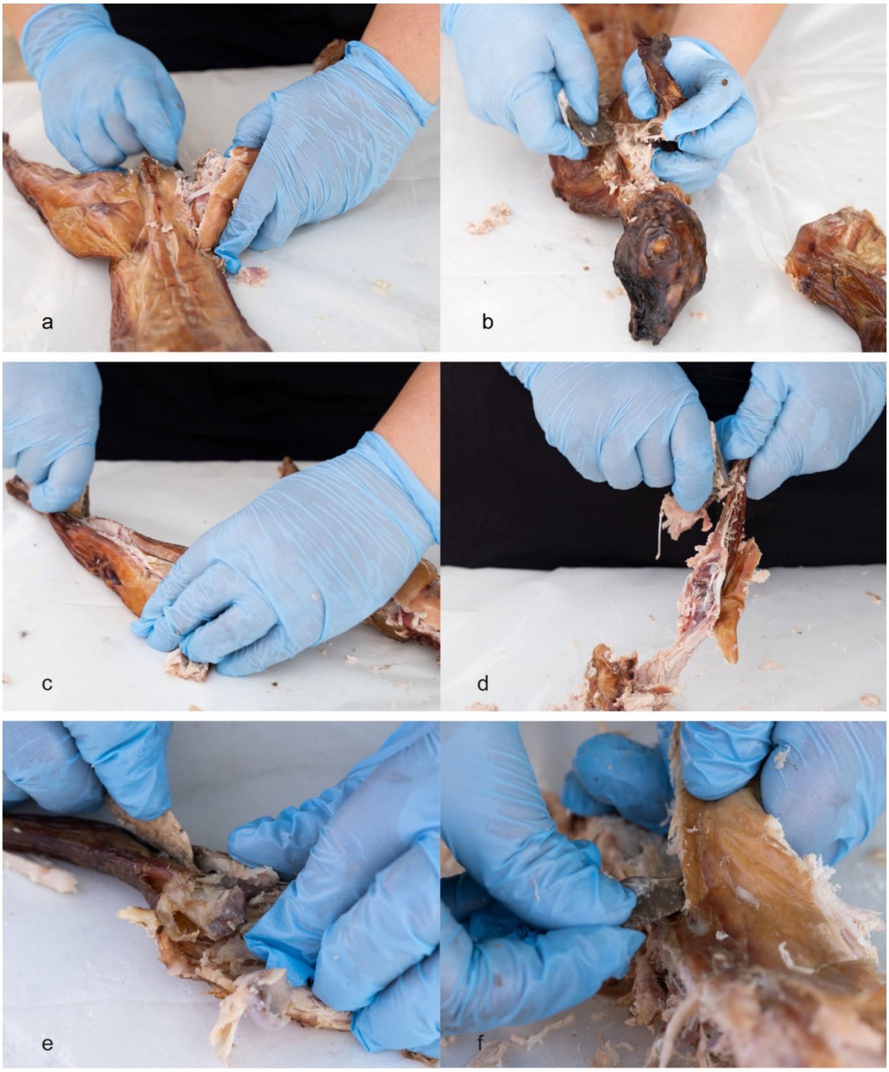

Fig. 5 Processing smoked rabbits: disarticulating the hindlimb (**a**) and the forelimb (**b**); defleshing the hindlimb (**c**, **d**) and the forelimb (**e**); detail of the defleshing the axial part (**f**)

At the statistical level, through a linear regression analysis between the variables "total processing time" and "number of cut marks," we were able to obtain a clear classification between processing time and the number of marks, with a value of 46 and a significant statistical probability < 0.01 (Fig. 14; Supplementary File).

To assess how the processed individuals are statistically distributed according to the relationship between cooking method, processing time, and the number of cut marks, a principal component analysis (PCA) was performed. Initially, the comparison between the variables "disarticulation time," "defleshing time,"

Fig. 6 Roasting cooking: fire (**a**); embers (**b**); raw rabbit over the embers (**c**) and turned halfway through cooking (**d**)

"total processing time," and "number of cut marks" reveals that the PC1 and PC2 explains ca. 95% of the variance, and that while PC1 is influenced by all variables of time (representing the general intensity of the processing tasks), the PC2 is more related with the variable "number of cut marks" (representing their specific dimension) (Supplementary File). The scatter plot suggests three bigger associations, which broadly correspond to the different cooking methods (Fig. 15). The RR (Rabbit-Roasted) group shows lower values in all variables, especially in cut marks, except RR22 with more lower values, indicating low processing task on the individuals. The RD (Rabbit-Dried) groups are influenced by PC1, related with high values in disarticulation, defleshing and total processing time, and medium–high values in cut marks. Only RD30 is located at right size, maybe by their intense processing. Finally, RS (Rabbit-Smoked) are located in the central and upper part of the scatter plot, conditioned by the PC2. Thus, the RD and RS groups seem to indicate greater processing work on the individuals. In this sense, the PCA (Fig. 15) and the dendrogram (Supplementary File) demonstrate a certain degree of similarity in the processing time between the smoked and dried samples. It is evident that certain individuals overlap within each other's boundaries in the PCA itself. Conversely, both groups display a marked distance from the roasted sample.

To further explore the participant experience variable, hierarchical clustering analysis with Euclidean distance was conducted (Supplementary File), where

Fig. 7 Processing roasted rabbits: disarticulating the forelimb (**a**) and detail of the process (**b**); defleshing the hindlimb (**c**) and the axial part (**d**); detail of the lithic tools used for cutting in the forelimb (**e**) and the hindlimb (**f**)

Kendall's tau correlation is the most appropriate analysis given the non-normalized data when comparing time on a per-second basis. The resulting value of 0.70 is statistically significant ($p < 0.01$), expressing a moderate significant statistical correlation between the processing time (disarticulation and deflesh) and the total processing time and the number of cut mark, but no differences are identified according to the participant's experience.

Fig. 8 Bone fracture: performing the dental action (**a**, **b**), fracture of a roasted femur (**c**), of a smoked femur (**d**), and of a raw humerus (**e**) and femur (**f**)

Finally, in relation to the experimental process, it is worth mentioning certain difficulties we encountered during the processing of the carcasses. There were two main hurdles. First, although we have already stated that it was quicker to deflesh by hand, it was also more difficult to extract packets of meat in cases where the meat was tender on the inside because it was still attached to the bone. Second, the areas with tendons, mainly the proximal part of the femur, and the joints were more difficult to deflesh. In addition, the areas with less meat, such as the distal part of the limbs (radio/ulna and tibia) or the rib area, were drier and therefore more challenging to separate the meat. In the case of roasted rabbits, it became necessary to use lithic tools, as already mentioned. In the case of smoked rabbits, the use of lithic tools was sometimes combined with the use of hands for easier handling in the defleshing process. In the case of raw rabbits, it was difficult to extract a whole package of meat from the areas of the radius/ulna, from the scapula, or even the coxal.

Taphonomic Analysis

Before presenting the results of the taphonomic analysis, it is imperative to consider several factors. First, the roasted individuals were primarily processed manually, with the exception of evisceration and the occasional use of disarticulation. Second, the objective of extracting the meat in the form of package in the case of smoked and dried individuals has resulted in the cranial area remaining unprocessed.

The analyzed assemblage contains a total of 2371 bones from 24 rabbits. A total of 719 cut marks were identified (Table 5).

Drying

A total of 779 skeletal remains from eight individuals were examined, and 437 cut marks were identified on 272 of the remains. Of these, 369 (84.4%) were classified as incisions, while 68 (15.6%) were classified as scraping marks. No chop marks were registered in this assemblage, as any strong cut has been done during the processing.

The prevalence of scraping marks was found to be significantly higher on the femur (NM = 11), with lesser but notable presence on the tibia, humerus, and scapula, with counts exceeding five (Table 6). The majority of them were classified as long (68.8%), with only a slight predominance of short scraping marks observed on the tibia. The majority of these marks manifest as longitudinal or longitudinal/oblique (75%), with a significant proportion classified as simple (46.9%) and of low intensity (53.1%), though medium intensity is also observed on the scapula and femur. On the femur, these scraping marks are predominantly concentrated from the middle of the diaphysis to the proximal epiphysis (Fig. 16a), with a preponderance in the anterior and medial areas. On the tibia and humerus, the marks are located in the middle of the diaphysis, while on the scapula, they are distributed along the body on both sides.

In the case of incisions, the bones with the greatest number of marks are the ribs (27.2%), femur (14.3%), lumbar vertebrae (10.9%), humerus (8.9%), scapula (8.6%), and coxal (8.1%). However, when the proportion of cut marks is calculated as a function of the MNE, the axial zone takes second place, followed by the femur, humerus, scapula, and coxal (Table 6).

The majority of the incisions are short (89.6%), though there is also a notable presence of long incisions (10.4%), particularly on the scapula, femur, humerus, and coxal where longer movements were performed. The medium intensity category (51.1%) is noteworthy when considered against the lower intensity categories, namely, low (41.2%) and high (7.7%). The predominant orientation identified

Table 3 Data recorded for the experimentation

Individual	Code	Weight (g)				Age	Cooking		Processing			
		Before	After	Loss	% Loss		Method	Duration	Disarticulate	Deflesh	Fracture	Total
Rabbit 26	01–26	444	132	312	70.3	Immature	Dry	43 h/67 h	2′	17′ 01″	–	19′ 01″
Rabbit 27	01–27	429	128	301	70.2	Immature	Dry	43 h/67 h	1′ 49″	16′ 69″	–	17′ 08″
Rabbit 28	01–28	360	103	257	71.4	Immature	Dry	43 h/67 h	1′ 44″	17′ 29″	–	19′ 13″
Rabbit 29	01–29	394	115	279	70.8	Immature	Dry	43 h/67 h	2′ 13″	19′ 37″	–	21′ 50″
Rabbit 30	01–30	459	132	327	71.2	Immature	Dry	43 h/67 h	2′ 44	24′ 30″	1′ 21″	28′ 35″
Rabbit 31	01–31	463	142	321	69.3	Immature	Dry	43 h/67 h	2′ 33″	21′ 34″	1′ 24″	26′ 31″
Rabbit 32	01–32	453	138	315	69.5	Immature	Dry	43 h/67 h	1′ 53″	22′ 04″	1′ 40″	25′ 37″
Rabbit 33	01–33	480	145	335	69.8	Immature	Dry	43 h/67 h	1′ 21″	19′ 61″	1′ 38″	23′ 00″
Rabbit 09	02–09	1042	591	451	43.3	Immature	Smoke	7 h 12′	1′ 21″	15′ 07″	1′ 32″	18′ 00″
Rabbit 10	02–10	987	600	387	39.2	Immature	Smoke	7 h 12′	2′ 16″	11′ 39″	2′ 29″	16′ 24″
Rabbit 11	02–11	1103	693	410	37.2	Immature	Smoke	7 h 12′	3′ 19″	16′ 55″	–	20′ 14″
Rabbit 12	02–12	959	560	399	41.6	Immature	Smoke	7 h 12′	3′ 21″	20′ 24″	–	23′ 45″
Rabbit 17	02–17	1017	618	399	39.2	Immature	Smoke	8 h 5′	1′ 54″	17′ 42″	2′ 28″	22′ 04″
Rabbit 18	02–18	985	556	429	43.6	Immature	Smoke	8 h 5′	1′ 41″	14′ 56″	2′ 24″	19′ 01″
Rabbit 19	02–19	1022	644	378	37.0	Immature	Smoke	8 h 5′	3′ 18″	15′ 7″	–	18′ 25″
Rabbit 20	02–20	976	616	360	36.9	Immature	Smoke	8 h 5′	4′ 7″	17′ 55″	–	22′ 02″
Rabbit 13	03–13	1111	871	240	21.6	Immature	Roast	46′	30″	12′ 45″	5′ 45″	19′ 00″
Rabbit 14	03–14	1257	948	309	24.6	Immature	Roast	46′	12″	8′ 43″	6′ 14″	15′ 09″
Rabbit 15	03–15	1060	802	258	24.3	Immature	Roast	46′	21″	7′ 35″	–	7′ 56″
Rabbit 16	03–16	1107	792	315	28.5	Immature	Roast	46′	23″	7′ 57″	–	8′ 20″
Rabbit 21	03–21	992	767	225	22.7	Immature	Roast	60′	36″	12′ 29″	3′ 36″	16′ 41″
Rabbit 22	03–22	1007	679	328	32.6	Immature	Roast	60′	25″	5′ 51″	4′ 19″	10′ 35″
Rabbit 23	03–23	1136	822	314	27.6	Immature	Roast	60′	19″	8′ 23″	–	8′ 42″
Rabbit 24	03–24	1100	842	258	23.5	Immature	Roast	60′	46″	13′ 15″	–	14′ 01″

The weight of the dried rabbits corresponds only to the weight of the meat from forelimbs, axial, and hindlimbs. The first number of the duration of the drying corresponds to the forelimbs and the axial, the second number corresponds to the hindlimbs was oblique (47.2%), followed by transverse (41.2%), in comparison to longitudinal (8.1%) and combinations of these orientations (3.5%). Finally, a comparable number of multiple (35.8%) and single (35.1%) marks were identified, with a smaller number of double/triple (29.1%) marks.

Most of the incisions on long bones are located on the diaphysis (78.8%), with the exception of the ulna, where incisions on the proximal joint are also noteworthy. On the humerus, oblique incisions on the posterior and medial area of both the proximal and distal diaphysis are particularly abundant (Fig. 16b). On the radius, these incisions are found in the anterior and medial part of the diaphysis and are typically short, simple, oblique, and slight. In contrast, the ulna exhibits a different distribution, with incisions primarily located on the posterior part of the diaphysis. The femur shows a non-homogeneous distribution of incisions, with some present on the anterior part of the proximal diaphysis, but also along the entire length of the diaphysis on its various surfaces. These incisions are predominantly of a short, medium-intensity, oblique, or transverse nature, and may occur as isolated or in multiple instances. On the tibia, the most prominent incisions are located on the anterior/lateral zone of the distal diaphysis and the posterior/medial zone of the middle diaphysis (Fig. 16c). These incisions are of slight intensity, short, and oblique.

Incisions have also been identified on the articular areas of the long bones (51.9%), primarily on the proximal epiphysis of the femur, but also on that of the humerus, radius, and ulna, and the distal epiphysis of the humerus and femur. These marks are characterized by their short, oblique orientation and profound depth. On the femur, these incisions have been observed on the anterior and posterior regions of the proximal epiphysis, as well as at the base of the distal epiphysis. On the humerus, these marks are found at the base of the distal epiphysis and at the top of the proximal epiphysis. The ulna exhibits these marks uniformly across the entire proximal epiphysis, including the anterior, posterior, lateral, and medial zones (Fig. 16d).

There are also cut marks on the scapula and the coxal. On the scapula, the incisions are predominantly distributed over the body (94.3%) and medially. On the coxal, the incisions are predominantly located on the ilium (36.4%), with smaller percentages found on the ischium (33.3%) and near the acetabulum (30.3%), and are generally concentrated on the lateral area.

On the axial zone, the majority of cut marks on the ribs (60%) are located on the proximal part of the diaphysis, on the external zone, and with a high intensity. The incisions on the vertebrae manifest in 67.6% of cases within the spinal processes (Fig. 16f), predominantly in the external region. These incisions are characterized by their multiplicity, short morphology, medium intensity, and oblique and transversal direction. Additionally, single or double longitudinal incisions, albeit somewhat long, have been identified on the dorsal region of the body of the thoracic vertebrae (25.4%).

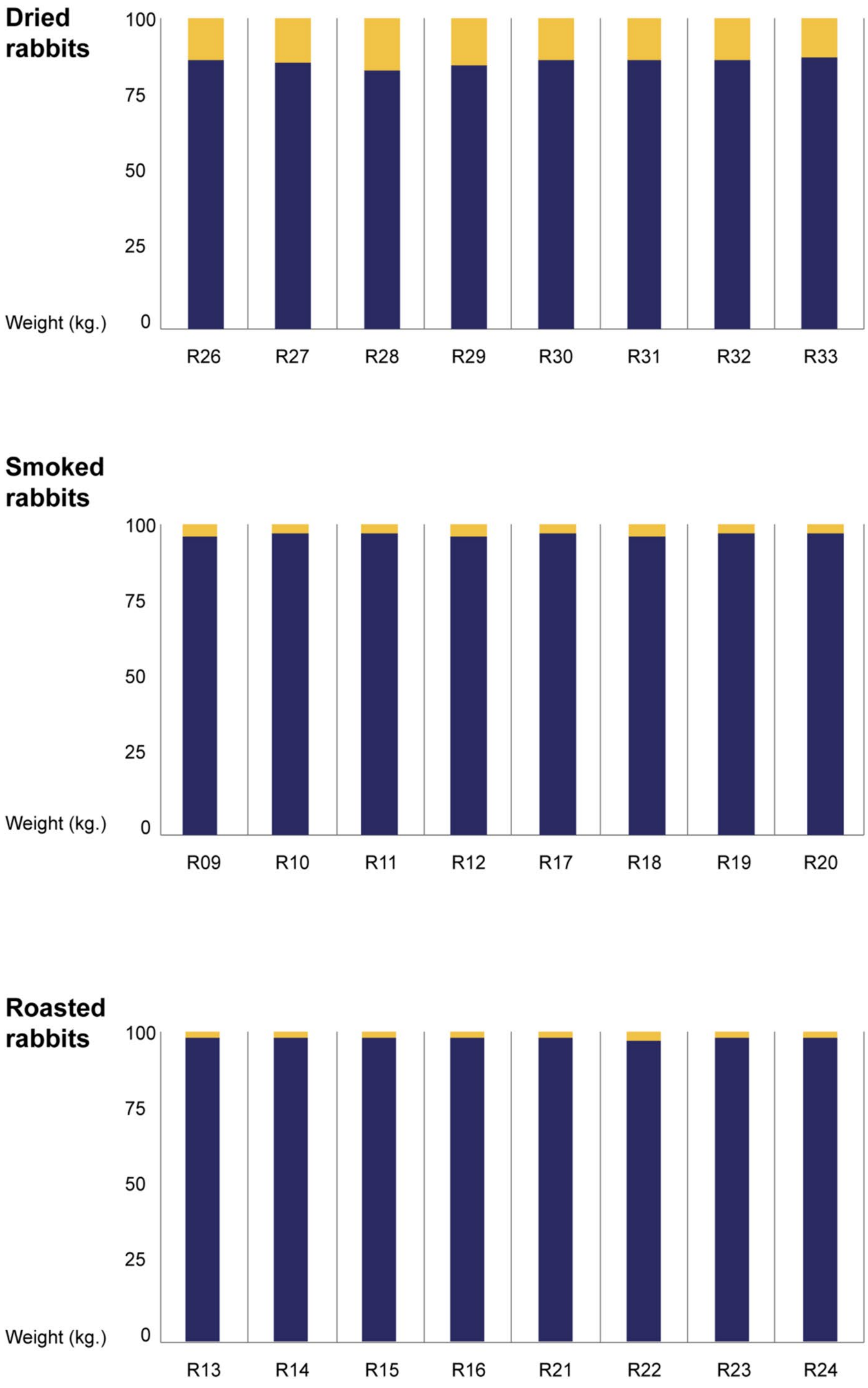

Fig. 9 Loss of weight based on the cooking method: percentage of weight before cooking (yellow), percentage of weight after cooking (blue)

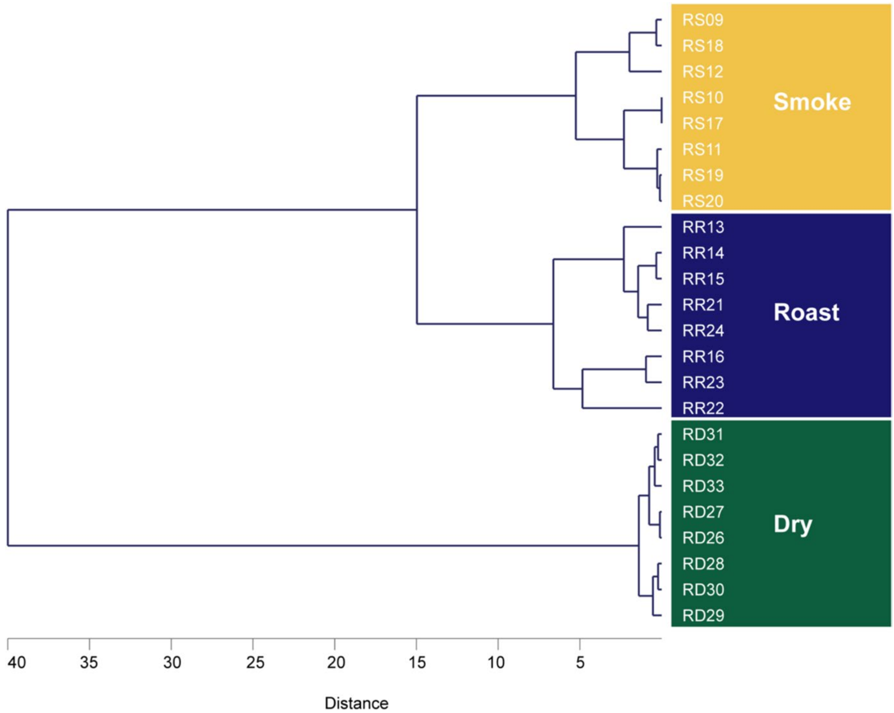

Fig. 10 Hierarchical clustering analysis with Euclidean distance shows weight loss associations by cooking methods: dry (green), smoke (yellow), and roast (blue). RS = smoked rabbits, RR = roasted rabbits, RD = dried rabbits

Smoking

A total of 796 skeletal remains belonging to 8 MNI (Table 5) were subjected to analysis. A total of 271 cut marks were identified on 158 remains, including 247 incisions (91%), 12 scraping marks (4.4%), and 12 chop marks (4.4%) (Table 6).

The scraping marks primarily affect the femur (NM = 10), and in a single instance, the coxal and scapula, respectively. The majority of these marks were characterized as being long, slight, and multiple, with a predominant longitudinal orientation. In the case of the femur, these marks were observed to be distributed along the entire diaphysis, both anteriorly and posteriorly, and could present a combination of short and multiple (Fig. 16g). In contrast, the chop marks are predominantly located on the ribs (NM = 4) and the lumbar vertebrae (NM = 4) (Fig. 16h), though there is also evidence of their presence on other vertebrae, the scapula, and the ulna. These chop marks are characterized by their short, deep, and isolated nature, with a transverse orientation.

In the case of incisions, the bones with the greatest number of marks are the ribs (19.4%), the lumbar vertebrae (16.2%), the femur (14.2%), and the coxal (13.8%). However, when the proportion of incisions is calculated according to the NME, the

Fig. 11 Rabbit carcass after disarticulation and defleshing: smoked (**a**) and roasted (**b**)

axial zone emerges as the second most prevalent, with the femur, coxal, scapula, humerus, and tibia also demonstrating high incidence (Table 6).

The majority of these incisions are of a short nature (83.8%), though there is also a notable presence of long incisions (16.2%), particularly on the coxal, femur, and scapula. Furthermore, medium-intensity incisions are observed to be prevalent (38.9%), surpassing the slight (32%) and more intense (29.1%) categories. The predominant incision direction is oblique (55.9%), followed by transverse (34.7%),

Table 4 Marrow conservation characteristics

Individual	Code	Cooking method	Marrow		
			Humerus	Femur	Tibia
Rabbit 30	01–30	Dry	Raw	Raw	Raw
Rabbit 31	01–31	Dry	Raw	Raw	Raw
Rabbit 32	01–32	Dry	Raw	Raw	Raw
Rabbit 33	01–33	Dry	Raw	Raw	Raw
Rabbit 09	02–09	Smoke	Cooked	Medium	Medium
Rabbit 10	02–10	Smoke	Cooked	Raw	Medium
Rabbit 17	02–17	Smoke	Medium	Cooked	Cooked
Rabbit 18	02–18	Smoke	Medium	Cooked	Cooked
Rabbit 13	03–13	Roast	Cooked	Cooked	Cooked
Rabbit 14	03–14	Roast	Cooked	Cooked	Cooked
Rabbit 21	03–21	Roast	Medium	Cooked	Cooked
Rabbit 22	03–22	Roast	Cooked	Cooked	Cooked

longitudinal (2%), and combinations of these orientations (7.3%). Additionally, a higher frequency of single (43.3%) and double/triple (34%) marks was observed, compared to multiple (22.7%) marks.

The majority of incisions on long bones are located on the diaphysis (76.7%), with the exception of the ulna, where incisions on the proximal joint are particularly notable. On the humerus, oblique incisions on the lateral area near the distal joint, oblique/transverse incisions on the anterior area, and longitudinal/oblique incisions on the lateral and medial areas of the diaphysis are particularly noteworthy (Fig. 16i). On the femur, the distribution of incisions is not homogeneous; incisions are present in similar numbers on the anterior and posterior zones, as well as on the medial zone (Fig. 16j). However, on the lateral zone, the number is smaller. These incisions are predominantly short, single, or double, of medium/high intensity, and oblique, longitudinal/oblique, or transverse. In contrast, the tibia exhibits a greater prevalence of marks on the posterior region, characterized by medium intensity and short and variable direction. In some cases, these marks extend to the fibula. Additionally, incisions have been identified on the articular regions of long bones, accounting for 23.3% of cases. These incisions are located on the proximal epiphysis of the humerus and ulna, and the distal epiphysis of the humerus and femur (Fig. 16k, l). These marks are characterized by short, oblique, and deep characteristics. The femur exhibits these marks on both the medial and lateral regions, as well as at the base of the distal joint. On the humerus, these marks are found at the base of the distal epiphysis and at the top of the proximal epiphysis. The ulna demonstrates these marks across the entire proximal joint, including the anterior, posterior, lateral, and medial areas.

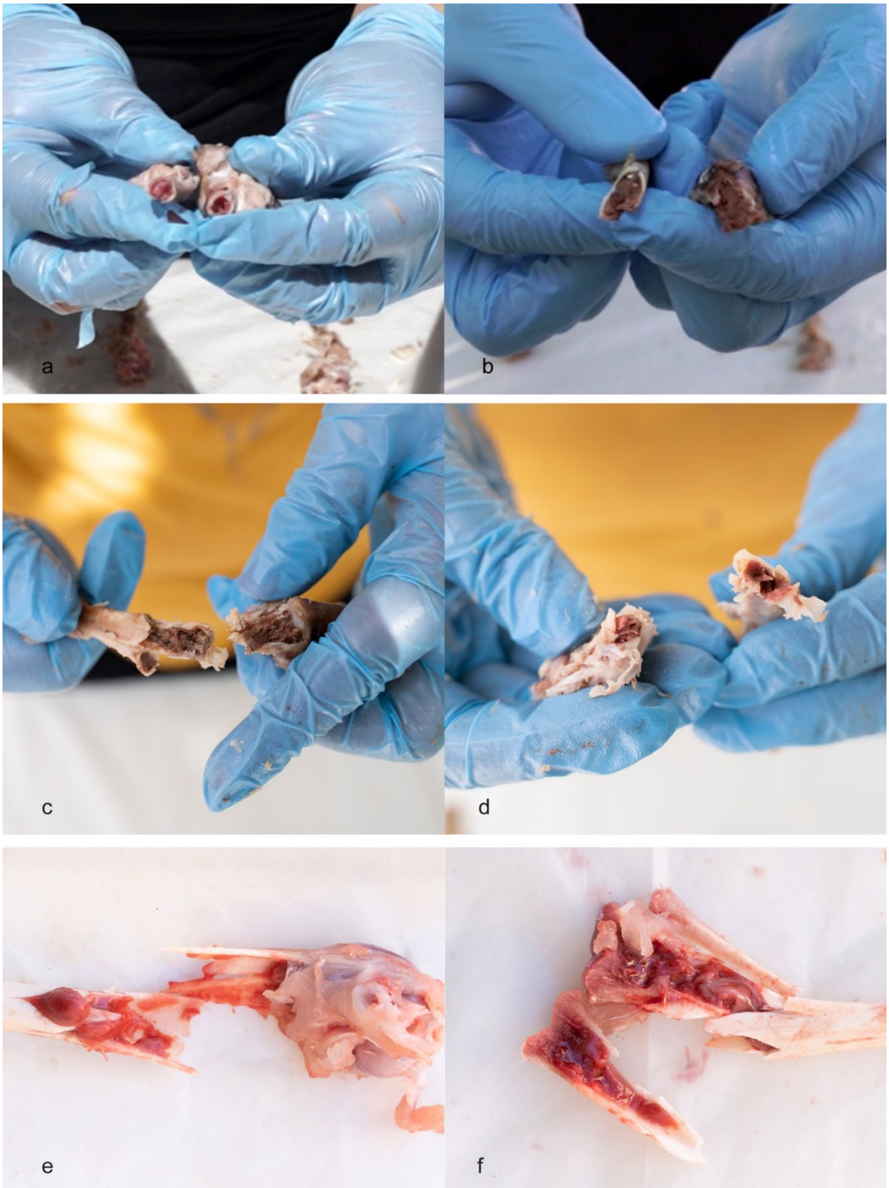

Fig. 12 Marrow preservation status based on cooking process: smoked femur (**a**–**b**); roasted tibia (**c**) and humerus (**d**). Marrow from raw carcass before drying: femur (**e**) and tibia (**f**)

On the scapula, the incisions are predominantly distributed throughout the body (91.3%), while on the coxal, they are primarily located on the ilium (41.2%) and ischium (38.2%), and more broadly on the lateral region. In the case of the axial zone, the incisions on ribs are primarily located on the plantar area

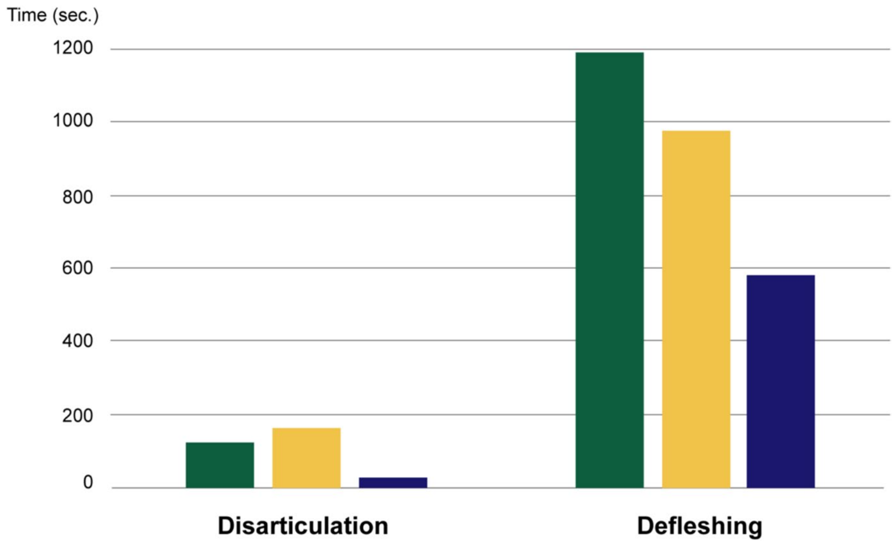

Fig. 13 Total time of disarticulation and defleshing based on cooking methods: dry (green), smoke (yellow), and roast (blue). Time expressed in seconds

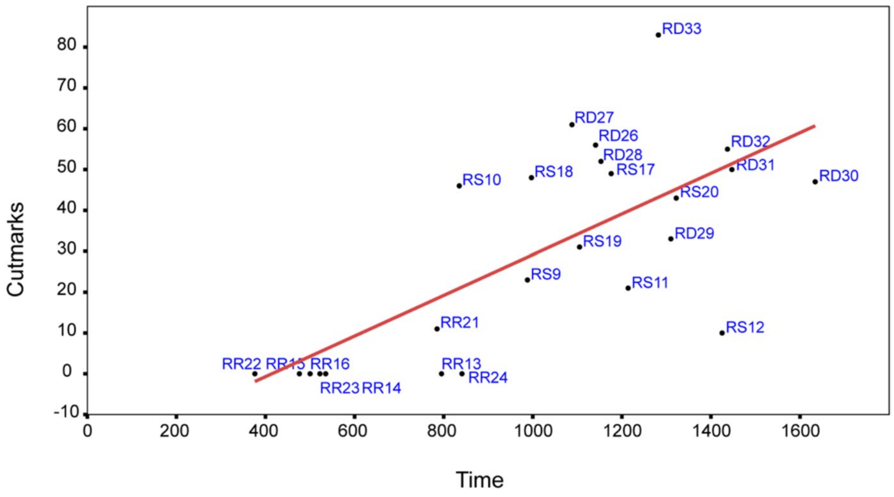

Fig. 14 Linear bivariate regression between total processing time and number of cut marks. RS = smoked rabbits, RR = roasted rabbits, RD = dried rabbits

of the diaphysis and close to the proximal epiphysis. The incisions on the vertebrae are identified in 90.7% of the cases on the processes. In both cases, the incisions are of short morphology, of medium intensity, and of oblique and transversal direction.

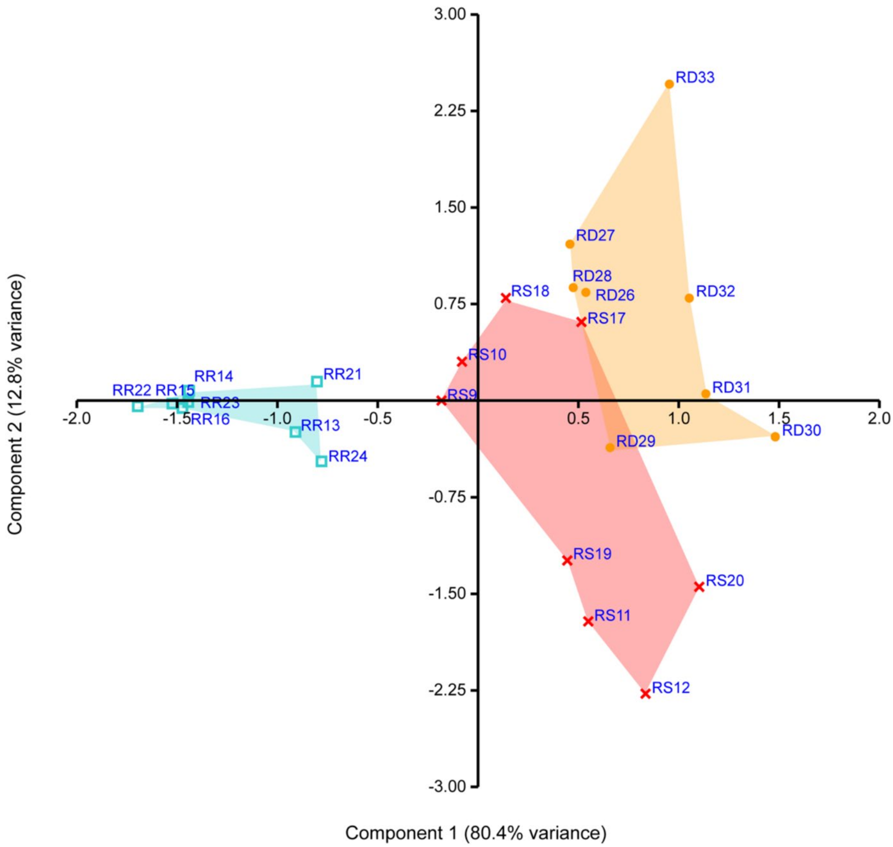

Fig. 15 PCA scatter plot of butchery data. RS = smoked rabbits, RR = roasted rabbits, RD = dried rabbits

Roasting

With regard to the taphonomic analysis of the roasted bones, there is little evidence of human activity. First, the fire has not altered the bone surface, and there is no change in coloring in any area. Second, the number of cut marks is also limited due to the facility of doing manual processing by cooking using this method. A total of 796 remains from 8 MNI were studied (Table 5), yielding a total of 11 cut marks on seven bones (Table 6), which have been identified only in one of the individuals.

The lithic tools were used during the defleshing of the scapula/humerus and femur/tibia, mainly to cut tendons and separate flesh. The marks are all incisions (NM = 9), with the exception of two scraping marks on the diaphysis of a femur and a tibia. The incisions are predominantly short and oblique on areas in close proximity to the articulation, or alternatively, more longitudinal and oblique along the diaphysis. All of them are related to the defleshing phase (Table 6).

Regarding the correlation between the marks and the various processing phases (Table 6), it is evident that a greater proportion of marks pertain to defleshing (87.5%) in comparison to disarticulation (10.8%) and evisceration (1.7%). It is noteworthy that the incisions observed on the distal portion of the rib diaphysis could be associated with the evisceration phase. This is attributable to the fact that the ribs were separated from the sternum by a longitudinal incision that resulted in the presence of deep and transverse cut marks. Evidence of disarticulation is observed on the joints of the long bones, particularly on the joint between the femur and the coxal and the ulna with the humerus. Additionally, a few cut marks have been identified on the first cervical vertebrae. The defleshing process involves the application of incisions and scraping marks to all the long bones. In the axial skeleton, the marks located on the spinal processes and on the dorsal area of the thoracic vertebrae, as well as on the proximal part of the ribs, are also related to this activity since longitudinal cuts were made on the vertebral column to first separate the meat and then to extract the meat package on block in the direction of the ribs.

Discussion

The methodological approaches of the previously experiments described in "Neotaphonomic Framework" section have become increasingly detailed over the years and have been reproduced on a more consistent number of individuals. Nevertheless, the experiments conducted to date have focused primarily on the butchering process and the roasting method of cooking. Three studies describe thermal alterations; one focuses on cut marks, another on consumption patterns (fractures and tooth marks), while the remaining two studies include a combination of features such as cut marks, fractures, tooth marks, and even burnt bones (Table 1).

Faced with this scenario, our work went one step further by considering the butcher's processing, methods of consumption, the various forms of cooking, and possible methods of meat preservation. None of the previous experiments tested the possibility of smoking, while only one experiment focused on drying, but with the use of salt (Rosado-Méndez *et al.*, 2016). In addition, our experiment was based on a minimum of eight individual rabbits per cooking type (24 rabbits in total) in order to obtain sufficient and statistically representative quantitative data. By following this approach, clear guidelines have been established from the beginning regarding the use of lithic tools, the number of rabbits, and the number of bones fractured in each block of the experiment. This allows for comparison of the results between various forms of cooking and consumption to identify any potential differences.

Cooking and processing times were recorded, and it was observed that smoking is a relatively short process that can be completed in approximately 8 h if the temperature is kept constant. However, in some cases there were still some raw areas of wax from the joints. It would therefore be advisable to keep the rabbits a little longer if the aim is to get drier meat that can be preserved for longer. Drying in the sun takes longer, with variations in drying time depending on the thickness of the meat strips.

Table 5 Type of cut marks by individual and cooking method

Individual	Code	Cooking method	NISP	CM		
				Incision	Scrape	Chop
Rabbit 26	01–26	Dry	95	56		
Rabbit 27	01–27	Dry	90	60	1	
Rabbit 28	01–28	Dry	98	46	6	
Rabbit 29	01–29	Dry	91	27	6	
Rabbit 30	01–30	Dry	100	43	4	
Rabbit 31	01–31	Dry	100	43	7	
Rabbit 32	01–32	Dry	102	52	3	
Rabbit 33	01–33	Dry	103	74	9	
Rabbit 09	02–09	Smoke	110	15	1	7
Rabbit 10	02–10	Smoke	96	42	4	
Rabbit 11	02–11	Smoke	89	19	2	
Rabbit 12	02–12	Smoke	97	10		
Rabbit 17	02–17	Smoke	106	45	3	1
Rabbit 18	02–18	Smoke	100	47	1	
Rabbit 19	02–19	Smoke	93	27	1	3
Rabbit 20	02–20	Smoke	105	42		1
Rabbit 13	03–13	Roast	105			
Rabbit 14	03–14	Roast	103			
Rabbit 15	03–15	Roast	87			
Rabbit 16	03–16	Roast	96			
Rabbit 21	03–21	Roast	109	9	2	
Rabbit 22	03–22	Roast	113			
Rabbit 23	03–23	Roast	94			
Rabbit 24	03–24	Roast	89			
			2371	**657**	**50**	**12**

CM cut marks

Hindlimbs, which have more meat, take longer to dry than axial and forelimbs. The drying process ranged from 43 to 67 h, but the end result was satisfactory as the meat was completely dry.

Recording the weight of the rabbits before and after processing made it possible to evaluate moisture loss. The average weights of the whole carcasses intended for roasting and smoking were 1100 and 1010 g, respectively. After cooking, the smoked rabbits lost much more moisture than the roasted ones, almost half of their weight. In the case of dried rabbits, with an average of 440 g (only the meat was weighed), more than half of the weight was lost. Samples of meat from various anatomical regions and from each cooking method have been submitted for analysis. The analysis of these samples will yield results pertaining to various parameters,

Table 6 Classification and quantification of cut marks by type of cooking and anatomical elements, and related to the processing phase

		NISP	NISP with CM	% NISP with CM	CM/NME	CM				Processing phase		
						Incision	Scrape	Chop	Total	Evisceration	Disarticulation	Defleshing
Drying	**Sc**	18	16	88.9	2.5	35	5		40		1	39
	H	25	18	72.0	2.6	36	6		42		3	39
(MNI 8)	**R**	16	13	81.3	1.2	18	1		19		1	18
	U	16	9	56.3	0.9	14			14		8	6
	Cx	16	15	93.8	2.1	33	1		34		10	24
	F	31	28	90.3	4.3	58	11		69		21	48
	T	23	15	65.2	2.4	30	8		38			38
	Rb	222	99	44.6	0.5	110			110	6		104
	Vc	54	2	3.7	0.1	3			3		3	
	Vt	96	24	25.0	0.3	24			24			24
	Vl	57	33	57.9	0.8	44			44			44
	TOTAL	**574**	**272**	**47.4**	**0.8**	**405**	**32**		**437**	**6**	**47**	**384**
Smoking	**Sc**	16	9	56.3	1.4	23	1	1	25		2	23
	H	29	12	41.4	1.2	19			19		5	14
(MNI 8)	**R**	16	3	18.8	0.2	3			3			3
	U	15	5	33.3	0.8	12		1	13		10	3
	Cx	16	14	87.5	2.2	34	1		35		7	28
	F	27	19	70.4	2.1	35	10		45			45
	T	29	13	44.8	1.2	19			19			19
	Rb	224	38	17.0	0.2	48		4	52	6		46
	Vc	56	4	7.1	0.1	3		1	4		4	
	Vt	99	12	12.1	0.7	11		1	12			12
	Vl	55	29	52.7	0.1	40		4	44			44

Table 6 (continued)

		NISP	NISP with CM	% NISP with CM	CM/NME	CM				Processing phase		
						Incision	Scrape	Chop	Total	Evisceration	Disarticulation	Defleshing
	TOTAL	**582**	**158**	**27.1**	**0.5**	**247**	**12**	**12**	**271**	**6**	**28**	**237**
Roasting	**H**	4	2	50.0	1.5	3			3			3
	F	4	4	100.0	2.5	4	1		5			5
(MNI 1)	**T**	4	1	25.0	1.5	2	1		3			3
	TOTAL	**12**	**7**	**58.3**	**0.9**	**9**	**2**	**0**	**11**			**11**
TOTAL		**1168**	**437**	**37.4**	**0.7**	**661**	**46**	**12**	**719**	**12**	**75**	**632**

CM cut marks

Fig. 16 Examples of cut marks. Drying: defleshing cut marks on femur (**a**), humerus (**b**) and tibia (**c**), disarticulation cut marks on proximal ulna (**d**) and coxal (**e**), and defleshing cut marks on vertebrae (**f**). Smoking: defleshing cut marks on femur (**g**), rib (**h**), humerus (**i**), and femur (**j**), and disarticulation cut marks on distal femur (**k**) and humerus (**l**)

including but not limited to fat quantities, presence of fatty acids, and moisture content. These results will contribute to a more comprehensive understanding of the influence of this loss of moisture on the nutritional value of the meat depending on the cooking method. However, these analyses are still in process and more detailed data will be informed in future research.

Challenges during the process included difficulties in defleshing tender meat still attached to bones, especially around joints and tendons. The use of lithic tools became necessary for dried rabbits that had already been defleshed, as well as for smoked ones, while roasted specimens sometimes required a combination of hand and tool techniques. Overall, the results highlight the significant differences in processing times and outcomes associated with each cooking method, as well as the practical difficulties encountered in the processing of the carcasses.

A comparison of the results obtained in the current study with those of the other experimental programs (see Table 1) reveals a degree of overlap. Of the various cooking methods, roasting received the most attention in those works. On the one hand, as all the studies demonstrate, eating a rabbit directly is a straightforward process and there is no need to deflesh the meat. Therefore, the presence of tooth marks left during consumption is further evidence of this cooking method and may correspond to biting or chewing actions to consume the meat that remains attached to the bone (Sanchis, 2012). In our experiment, this pattern could not be tested because all the meat had to be removed for chemical analysis. This, however, will be addressed in ongoing experiments. Nevertheless, some tooth marks were observed on the long bones that were intentionally fractured to access the marrow and check its condition and possible consumption. An initial analysis of these remains revealed some tooth marks in the areas near the epiphysis related to the fracture. These are slight pits in the areas of the diaphysis and punctures in the less dense parts, such as the proximal femur. These tooth marks are consistent with those identified in other experimental works and archaeological studies (*e.g.*, Pérez Ripoll, 2005; Real, 2020; Sanchis *et al.*, 2011; Sanchis, 2012). On the other hand, as demonstrated by our experiment and confirmed by other studies (*e.g.* Alonso *et al.*, 2024), the application of fire may not lead to any observable changes when the rabbits are roasted whole since the meat acts as a protective barrier for the bones and the duration of exposure to the coals is relatively short. In the most extreme cases, color changes may occur on the outermost parts of the limbs if the bones in these areas are exposed due to the absence of meat or poor coating (*e.g.* Fernández-Peris *et al.*, 2007; Lloveras *et al.*, 2009). It is conceivable that if the skeletons are not roasted whole but dismembered, there may be a greater incidence of burning. However, given the relatively small size of the rabbit, it is possible to cook it whole in a relatively short amount of time, thereby reducing the overall cooking time. It should also be taken into account that the rabbits used for the experiments were already acquired without the lower part of the limbs (metapodials and phalanges). When roasting, these areas would potentially be more affected by thermal alterations, as they are not covered by meat. However, as they were not present, we cannot make further comparisons in that sense.

Some of the already published studies (Table 7), for example, Sanchis (2012), as well as our own, reveal that it is feasible for no traces to be left during the process of disarticulation, even when a lithic tool is used, particularly during the roasting and smoking processes. The lithic tool would be employed to incise the flesh, and the separation of the anatomical groups – namely, the head from the axial postcranial skeleton, as well as the anterior and posterior limbs from the axial one – would be readily accomplished manually. In contrast, the separation of certain anatomical elements requires the use of a lithic tool. In our experiment, it is evident that the cut marks on the joints are present, albeit not in a systematic manner because these marks are not consistently observed in each individual rabbit. A higher frequency of these marks, however, was observed in individuals that underwent processing in a raw state, coinciding also with Lloveras *et al.* (2009). A comparison of the location of the results with those of other studies reveals a preponderance on the proximal area of the femur and its articulation with the coxal, characterized by stronger ligaments and tendons and greater muscle mass (Sanchis, 2012). There is concurrence with the findings of Sanchis (2012) concerning the proximal epiphysis of the ulna and humerus; however, there is divergence in the distal articulation of the tibia found by Lloveras *et al.* (2009). This divergence can be explained because of the absence of paws of the processed rabbits in the current study. In the case of Lloveras *et al.* (2009), the individuals still preserved the lower parts of the limb, thus some ligaments would be still attached to the metapodials and the tarsal bones. While releasing the muscles attached to these areas, they would have inflicted more marks on these portions.

If the meat was treated to preserve it for later consumption, it is possible that hot smoking or sun-drying was used, as demonstrated in ethnographic studies of indigenous populations in North America (Bean, 1974; Spier, 1978) and following the methods explained in "Experimental Protocol" section. In this case, the patterns followed were different, and therefore the evidence could be revealing. However, the dendrogram (Supplementary File) and the PCA (Fig. 15) demonstrate that certain individuals exhibit similarities between both forms of cooking with respect to processing time and the number of cut marks. This phenomenon has been demonstrated to be unrelated to the individual responsible for the defleshing process. Consequently, the underlying cause may be associated with the specific movements employed for the purpose of extracting entire strips of meat, which are common in both samples. Notwithstanding the aforementioned, disparities have been identified concerning the quantity of cut marks and their characteristics. First, according to the results of the present study, a greater number of cut marks and percentages of bones with marks are recorded in the case of individuals prepared for drying (CM: 437, 47.4%) than in those processed after smoking (CM: 271, 27.1%). Additionally, a discernible variation in the typology of the cut marks is evident. The dried group exhibited a higher frequency of scraping marks (15.6%) compared to the smoked group (4.4%), and the latter exclusively exhibited chop marks (4.4%) due to the necessity of make more incidence on some specific areas when processing. In the case of smoking, the whole rabbit could have been cooked without the skin and without prior defleshing. This implies that the cut marks on the bones could correspond to a posteriori defleshing or disarticulation actions, although the meat was also easily extractable by hand. The results of the study indicate that the predominant orientation is oblique (51.7%) and transverse (35.3%), which aligns with the findings reported by Rosado-Méndez *et al*. (2016). However, it should be noted that the percentages observed in this study are notably more disparate than those reported by Rosado-Méndez and colleagues. In contrast, the most prevalent intensity in our set is medium (42.3%), although the number of superficial cut marks also present important values (33.6%), and in the other set it is somewhat stronger. The most affected bones are the coxal and femur, followed by the scapula, humerus, and tibia, which are also highlighted in the work of Rosado-Méndez and colleagues.

In the case of drying, it was found advisable to deflesh the rabbits first and to dry only the meat in strips. This means that the cut marks found were related to as complete as possible extraction of the meat packages to be able to hang them. In this last case, movements of the lithic tools were observed that could leave both longitudinal cut marks to open the meat packages, as well as oblique ones to extract them from one piece. Likewise, we can assume that longitudinal scraping movements were employed to aid in such extraction. A direct comparison can be made between our results and the works that demonstrate raw defleshing (Table 7). In these works, the cut marks, incisions, and scraping marks exhibit a predominantly transverse and oblique orientation, along with a slight intensity (Table 7). Their orientation is coincident, with oblique (43%) and transversal (40.2%) being equally relevant, and medium (50.1%) and slight (44.7%) intensity being practically equally relevant. The distribution of the cut marks aligns with the anatomical structures of long bones and the spinal processes of vertebrae, corroborating the experimental findings. In our case, femur, humerus, scapula, and tibia stand out above all, although we also observe localized incisions on the coxal, as previously reported by Lloveras *et al.* (2009). This outcome contrasts with the results reported by Rosado-Méndez *et al.* (2016), who observed that the scapula, ulna, and innominate were less affected.

Finally, it is important to point out a difference between drying and smoking concerning the state of the marrow and its use. The marrow of smoked bones is cooked during the smoking process, while the marrow of bones to be dried is raw since it is obtained without fire treatment. This makes it more convenient to consume the marrow raw. However, this does not mean that the marrow of smoked rabbits could not be used directly (by fracture) or with another type of processing such as boiling or bone crushing. In fact, boiling would be another potential way to obtain nutrients from bones, but it was not explored in the current experiment because it falls outside the main scope of the project.

Table 7 Comparison of different experimental results. Modified from Sanshis (2012)

	Disarticulating	Defleshing	
		In raw	After cooking
Sanchis, 2012	Orientation mainly transverse. Strong intensity. Localization: – Coxal: neck of the ilium, acetabulum, and ischium – Femur (neck) – Humerus (diaphysis and distal epiphysis) – Ulna (olecranon in lateral face)	Incisions and scrapings (long and oblique). Light intensity. Localization: – Diaphysis of long bones on four sides – Apophyses and vertebral bodies and ribs	
Lloveras *et al.*, 2009	Mostly transverse orientation (72%) and to a lesser extent oblique (18%) or longitudinal (9.9%). Moderate to severe intensity. Localization: – Body of the vertebrae – Coxal (ischium and acetabulum) – Joints of long bones (especially the proximal femur and distal tibia)	Oblique and longitudinal (54%) and transverse (46%). Slight intensity. Localization: – Apophysis and vertebral body – Ribs – Coxal (ischium and ilium) – Long bones (especially diaphysis and some epiphyses)	
Rosado-Méndez *et al.*, 2016	–	Marks were transversal (40.7%) and oblique (59.3%) in orientation, short and of light intensity. Localization: – Proximal and distal epiphysis of long bones (femur, humerus) – Scapula, ulna and innominate are the elements less affected	Marks were transversal (80.8%) and oblique (19.2%) in orientation, short and moderate/strong intensity. Localization: – The whole surface of bones – The most affected are the femur, humerus, and scapula

Conclusion

In summary, the proposed objectives of our study were achieved. We have presented an experimental methodology that tests three forms of rabbit processing and cooking (drying, smoking, roasting), two of which are related to the hypotheses of meat preservation in the Paleolithic. In addition, we have presented a critical review of previous experimental work on rabbits, which formed the basis of our approach and provided useful data. However, our work goes further and provides a more compact and systematic methodology in which the three forms of processing/cooking are replicated on a minimum of eight rabbits. Moreover, quantitative data such as weights and times were recorded.

Furthermore, the results of the taphonomic analysis of the skeletal remains of 24 rabbits from the experiment are presented, and a comparison is made with previous experimental works. Roasting, as highlighted in multiple studies, leaves tooth marks on the bone, which are indicative of biting and bending actions during consumption. These marks typically appear on areas near fractures, especially on the femur and diaphysis, and are consistent with findings from other archaeological and experimental studies. However, roasting whole rabbits may not leave noticeable changes due to the protective effect of the meat covering the bones, with only slight color alterations observed on the exposed parts. In contrast, if the rabbit is dismembered before roasting, more pronounced changes from fire exposure may occur.

Additional analysis of bone cut marks related to preservation methods reveals distinct differences between smoking and drying. In both cases, the study confirms that lithic tools used for disarticulation often leave cut marks on bones, especially in areas with stronger ligaments and tendons. Dried rabbits, however, exhibited more frequent scraping marks and a higher percentage of bones with cut marks compared to smoked ones, as they were processed raw before the drying of the meat. These findings suggest that smoking might involve whole rabbits being cooked with minimal disarticulation, while drying necessitated more careful meat extraction for preservation. The observed bones in both cases predominantly exhibit oblique and transverse orientations cut marks, consistent with previous studies. The most affected bones include femur, humerus, and scapula, with the presence of localized cut marks aligning with findings from prior research. These results provide valuable insights into prehistoric meat processing techniques, demonstrating the variation in bone marking patterns based on cooking and preservation methods.

In addition to the taphonomic study of the bones, various other analyses must also be completed. First, a chemical analysis of the meat should be conducted in order to determine the nutritional quality of the meat obtained after different types of cooking and to determine its influence on the diet of Paleolithic human groups. To this end, several analyses were carried to determine the amount of fat, fatty acids, moisture, and proteins contained in each package of meat, and which cooking method yields the most nutritious meat. Second, the microwear analysis of the lithic tools will provide a comparative framework for the archeological assemblages and will aid in interpreting the use of tools in the various phases of butchering small animals.

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Data Availability The author confirms that all data generated or analysed during this study are included in this published article.

Declarations

Competing interests The authors declare no competing interests.

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