HISTORICAL BIOLOGY
https://doi.org/10.1080/08912963.2023.2220005

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Neanderthal brown crab recipes: A combined approach using experimental, archaeological and ethnographic evidence

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ABSTRACT
In order to gain better understanding of the Neanderthals' subsistence exploitation of marine crustaceans, this work presents evidence on the consumption of brown crabs using experimentation following-up from the archaeological evidence recovered from the 2010-2013 excavation of Gruta da Figueira Brava (Portugal). Amongst the aquatic fauna from occupation phase FB4, which dates to MIS-5b, brown crabs *(Cancer pagurus)* are numerous. The average carapace width estimated from their remains is 16 cm, and skeletal part analysis reveals the introduction of complete animals and their on-site processing. Due to the lack of a referential corpus for the interpretation of archaeological crab taphonomy, we experimented with the processing of two raw, two boiled, and two roasted brown crabs. We found that manual processing of large adult *Cancer pagurus* is only possible for the disarticulation of the walking legs, and the separation of the claws. Experimental results indicate that archaeological crabs were roasted, which weakened the shell and facilitated breaking it open. Though it is also possible to manually disarticulate the fingers, most times it requires a small hammerstone. Impact scars and longitudinal fractures bear witness to the use of such tools to access the meatier parts of both the propodus and the dactylopodus.

ARTICLE HISTORY
Received 4 January 2023
Accepted 26 May 2023

KEYWORDS
Cancer pagurus; taphonomy; experimentation; subsistence; Middle Palaeolithic; Portugal

Introduction

Gruta da Figueira Brava is located 30 km south of Lisbon (as the crow flies), in Portugal (Fig. 1A). Currently, it is positioned at the bottom of an escarpment on the southern slope of Serra da Arrábida, at 5 metres above sea level. Its surroundings are characterised by a thermo-mediterranean environment, where evergreen trees are predominant, as well as many Mediterranean shrubs and herbs, like thyme and lavender, among others (Ribeiro 1945).

The cave has three main entrances, but currently, access to its interior is only possible through Entrance 1, since all others are speleothem-cluttered (Fig. 1B). In the 1980s, excavations were conducted in Entrance 2 (or Area C; Antunes 2000), whereas the most recent archaeological works (between 2010 and 2013) were performed in Entrance 3. The last excavations revealed an inner chamber interiorly of Entrance 3 (or Area F; Fig. 1C) where an untouched infill has been sealed by flowstone (Fig. 1D). Exteriorly to Entrance 3, another trench was opened revealing brecciated deposits also rich in Last Interglacial archaeological materials, like stone tools, bones, shells and charcoal (Zilhão 2012; Zilhão et al. 2020).

The human occupation was dated by U-series and OSL, spanning the ca. 86–106 ka interval. They correspond to four human occupation phases, where several terrestrial and aquatic animal remains were recovered (Zilhão et al. 2020). Most of the faunal remains including almost all crab remains come from the last phase of occupation – phase FB4 – dated to early MIS-5b. The preceding phase FB3, which dates to the end of MIS-5c, held only two crab remains (Zilhão et al. 2020; Nabais et al. 2023). Palaeobotanical reconstructions indicate that climatic conditions and the plant cover during the MIS-5 sequence were similar to today's (Badal et al. 2011, 2012). However, due to lowered sea levels, the coastal topography and the position of the shoreline were very different. They varied significantly throughout the time of occupation, and in phase FB3 the coastline was about 1500 m away from the cave, whereas in phase FB4 that distance corresponded to about 2000 m (Zilhão et al. 2020).

Gruta da Figueira Brava Neanderthals' intake of marine foods was regular. Adult brown crabs (*Cancer pagurus*) with an average carapace width of 16 cm were specifically targeted; they were brought to the cave, and processed and consumed therein (Zilhão et al. 2020; Nabais et al. 2023). This resource was part of a broad spectrum subsistence strategy that provided them with an ample array of important nutrients. Marine resources have been considered as marginal foods for most of the Palaeolithic (e.g. Colonese et al. 2011; Jerardino 2015). This is especially true whenever the caloric value and energy intake of different animals are compared (e.g. Stiner 2001; Dusseldorp 2010) since, for instance, one deer provides higher quantities of food than a single crab. However, the paradigm changes when many nutrients which are essential to a healthy diet are considered, like vitamins, iron, calcium, omega-3, among others (e.g. Hockett and Haws 2003; Haws and Hockett 2004). Even today, brown crabs are widely consumed in southern

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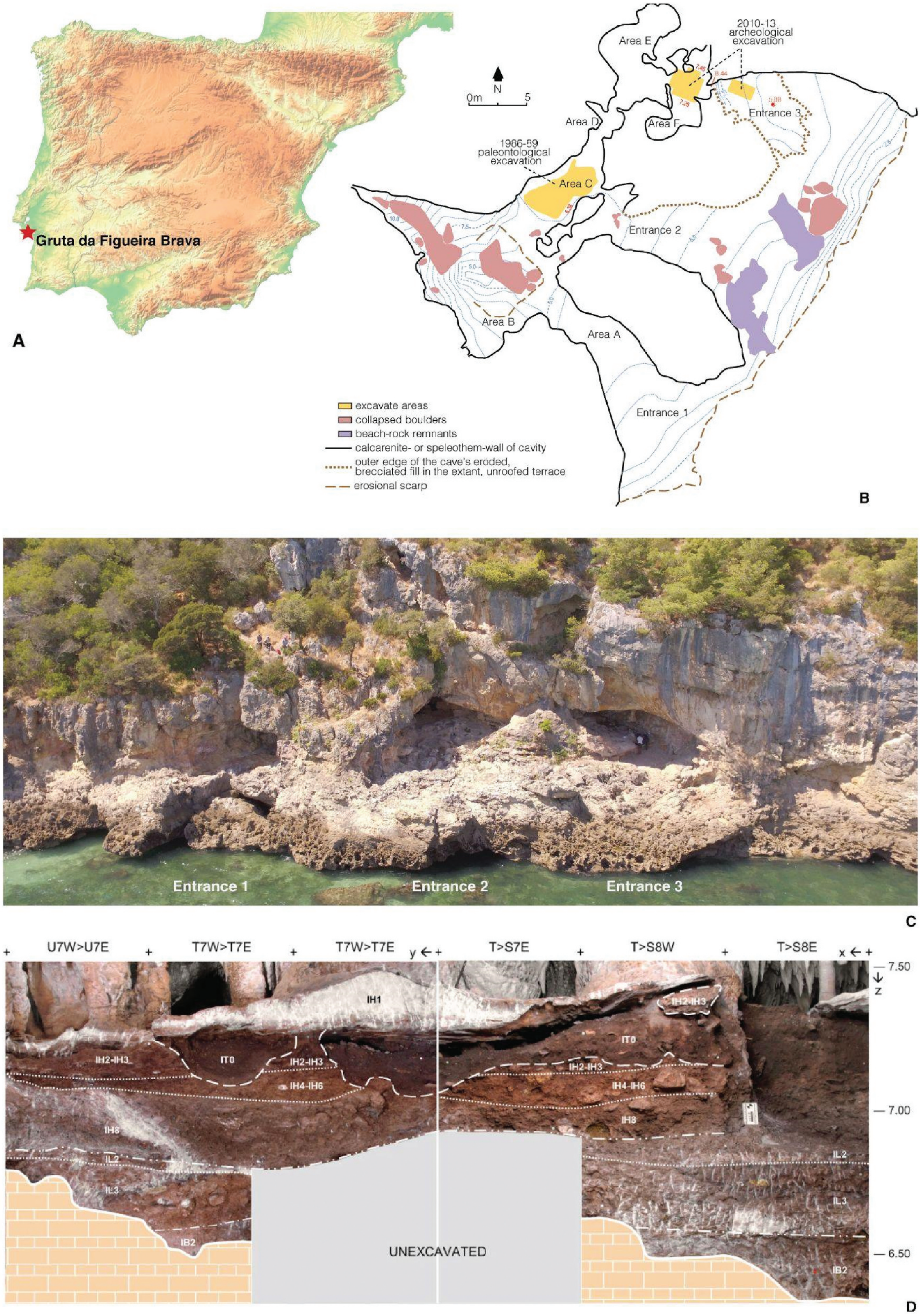

Figure. 1. Gruta da Figueira Brava. A) Site location. B) Plan of the cavities (elevations are in m above sea level). C) The cave seen from the sea, with identifications of the three different entrances. D) Stratigraphic profile of Area F; units IL2 and IL3 correspond to phase FB3; units IH2-IH3 to IH8 correspond to phase FB4; IT0 denotes the reworked deposit. (Panels B and D are reproduced from Zilhão et al. (2020), published under a CC BY licence, with permission from The American Association for the Advancement of Science, original copyright 2020).

European countries, Portugal in particular. They are sold alive and eaten all year-round, peaking during the Summer and the Christmas holidays (Barrento et al. 2008, 2009). Normally, they are boiled or steamed, and both the brown meat from the carapace and the white meat from the muscles in the claws are consumed (Maulvault et al. 2012).

Given the lack of a referential corpus for the interpretation of archaeological crab taphonomy, we undertook experimental work to better understand shell modification patterns observed on Gruta da Figueira Brava's brown crab assemblage. Based on observations derived from studies of mammal bone surface modification, our hypotheses were that (1) dactylopoda and propoda got separated manually, or by using a hammerstone; (2) the use of the latter would have left diagnostic impact scars on the ventral side of the proximal dactylopoda; (3) opening the claws to access the white meat inside would result in longitudinal fracturing; and (4) if the crabs were roasted, roasting-induced thermo-alterations (e.g. blackening) would be apparent in the cracked open remains of fingers.

Materials and methods

A total of seven live brown crabs (*Cancer pagurus*) were acquired from 'Aki-D'El-Mar Mariscos', an aquafarm in Caldas da Rainha (Portugal) that supplies shellfish to restaurants in the region. As shown in Table 1, all were of similar size and weight: 18 cm of average carapace width and around 1 kg each. All measurements (Fig. 2B) were taken with a precision of 0.5 mm using a Digital Caliper Metrica 10008. Weight was measured with a 1 g precision on a Tristar KW2447 scale. The general state of conservation of all specimens was good with all elements of the body present, except for three individuals (crabs 2, 3 and 6) that lacked some of the pereiopods, or their distal parts (Table 1).

The crabs were processed immediately after the animals were put to death. The traditional Portuguese household procedure of washing their eyes and mouth with vinegar was used. Traditional recipes advise on briskly killing the animals before cooking in order to avoid the detachment of the pereiopods, thus preventing water or charcoal from getting inside the carapace. Therefore, the vinegar does not affect the experimentation itself since it is only used to quickly put down the animals before heat exposure.

In order to gain insight into various possible methods of Palaeolithic brown crab consumption, two of the experimental specimens were processed raw, two other were roasted on coals, and two other were boiled (the traditional Portuguese cooking method; Maulvault et al. 2012). After cooking, the claws were removed and processed, and the surface modifications of the remains resulting from the different gestures and specific interactions were examined macro- and microscopically.

Mariana Nabais and Rodrigo Portero processed three crabs each, one from each category: raw (crabs 1 and 2), boiled (crabs 3 and 4), and roasted (crabs 5 and 6). Mariana is a right-handed adult woman who processed all odd-numbered crabs; Rodrigo is a right-handed adult man who processed all even-numbered crabs. In order to understand the patterns forming on a naturally broken shell, our control was crab 7, which was left intact and exposed to the elements in order to investigate the taphonomical marks caused by weathering. Considering that after 15 months of weather exposure crab 7 has not yet decayed completely, we will only advance preliminary results. Crabs 1 to 6 were processed manually (Fig. 2D) and using the same hammerstone, an unmodified rounded quartz cobble (Fig. 2C) similar to those found in the surroundings of Gruta da Figueira Brava, which were the most common raw material used for on-site stone tool making (Zilhão et al. 2020).

Crabs 3 and 4 were boiled whole, separately, on a modern stove; each animal was placed in an aluminium pan containing 2 litres of water at 100°C, for 15 minutes (Maulvault et al. 2012). Crabs 5 and 6 were put directly on coals that had reached a temperature of 490°C, and they were both roasted for 30 minutes; crab 5 lying on the ventral side and crab 6 on the dorsal side, both turned around after 15 minutes. The temperature of water and embers was regularly checked with an Infrared Thermometer Tarcher IR02B (−50°C to 800°C). After cooking, crabs 3 to 6 were left outside to cool down. When cold, they were weighted again in order to assess weight loss. Once processed and broken, all shell fragments from crabs 1 to 6 were rinsed and cleaned with toothbrushes, and then left outside to air dry before labelling and cataloguing.

All actions were photographed and filmed using a Nikon D5300, a GoPro HERO3+ and an iPhone 8. Using a MS100 microscope (200x), the shell surfaces of crabs 1, 3 and 5 were examined at three specific points of the right side propodus: at the start of the ventral sulcus of the propodus, where it shows a natural black colour; at the end of that same ventral sulcus, where it presents a white colour when raw; and close to the articulation of the propodus with the dactylopodus, on the ventral surface, where there is a curvy sulcus (Fig. 3).

Results

We focused on the claws (Fig. 2A), since these are the skeletal parts that retain archaeologically identifiable processing marks; the carapaces and walking legs were left intact and unprocessed after disarticulation (Fig. 2D).

No results are yet available for the non-processed, control individual left outside exposed to weathering (crab 7), as it is still naturally decomposing. However, after 15 months of weather exposure, few preliminary results can be advanced. Crab 7 has completely lost its colour, and it is now showing a whole white surface, which is also visible on broken sections (Fig. 4). The damage observed so far refers only to the left claw, with a propodus showing a very clean transversal fracture, and the dactylopodus presenting a very straight L-shaped fracture (Fig.4), which do not seem to match any of the fractures recorded in the archaeological material (Fig. 6). It should be highlighted, however, that the decomposition process of crab 7 is not yet finished, and further analysis will be conducted whenever that process is concluded.

Raw crabs

Crabs 1 and 2 were processed raw immediately after the animals were put to death. Crab 1 was positioned on the floor with its ventral side upwards; the left side claw and each pereiopod were manually and individually disarticulated by pulling and rotating the claw and legs at the joint with the belly. The same was then made to the right claw and legs. This was followed by breaking of the joint between the left claw's merus and carpus (Fig. 2A), using direct percussion with the quartz hammerstone on the joint's ventral side. The same strategy was used to separate the carpus from the manus. To access the muscle inside the manus and its fingers, a single blow was then applied on the ventral side of the manus, resulting in the manual detachment of the dactylopodus from the propodus during which, one of Mariana's fingers, was cut clean by the sharp edges of the shells' fractures. The procedure was repeated for the right claw, except that the fingers were pulled apart and hammered at their articulation, which turned out to be less efficient, and so accessing the flesh inside required additional hammering of the manus' ventral side.

Table 1. Specimens used in the experiment, actions performed, and weights before and after cooking.

	CRAB 1	CRAB 2	CRAB 3	CRAB 4	CRAB 5	CRAB 6	CRAB 7
Carapace width (mm)	186.02	180.44	180.77	183.47	179.79	191.47	180.57
Carapace breadth (mm)	111.53	112.47	108.64	110.57	109.82	111.03	111.03
Dactylopodus Left (mm)	43.06	45.67	45.44	43.95	45.61	41.95	46.81
Propodus Left (mm)	39.06	40.75	39.53	36.35	38.07	38.51	39.51
Dactylopodus Right (mm)	42.17	47.36	47.56	43.07	47.29	46.44	46.36
Propodus Right (mm)	35.64	35.35	37.07	35.89	38.62	37.58	38.72
State of Conservation	All elements present	Missing the penultimate pereiopod from left side	Missing the dactyls of the two posterior pereiopods of the right side, and one dactyl from the last pereiopod from the left side	All elements present	All elements present	Missing the posterior pereiopod from left side	All elements present
Actions	Raw	Raw	Boiled	Boiled	Roasted	Roasted	Weathering
Temperature exposure	-	-	100°C	100°C	490°C	490°C	Variable
Weight before cooking	1045 g	1128 g	1133 g	1240 g	1171 g	1247 g	1248 g
Weight after cooking	-	-	972 g	963 g	708 g	616 g	-
Weight loss (g)	-	-	161 g	277 g	463 g	631 g	-
Weight loss (%)	-	-	14.21%	22.34%	39.54%	50.60%	-

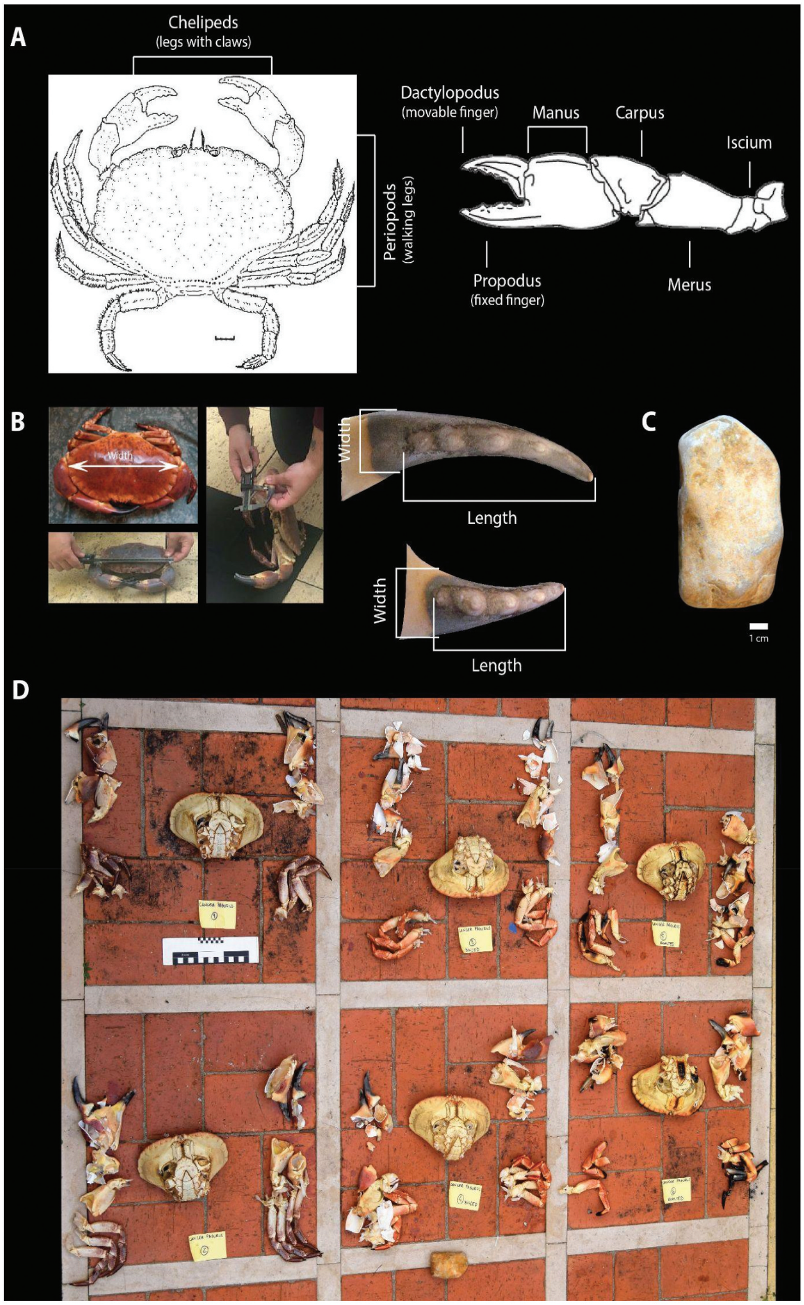

Figure. 2. A) Schematic diagram of *Cancer pagurus* anatomy with particular focus on cheliped anatomy (first image from Dupont et al. 2010; second image adapted from; Einarsson et al. 2016). B) Measurements taken on *Cancer pagurus* carapace and claws. C) Quartz hammerstone used for processing crabs 1 to 6. D) *Cancer pagurus* crabs 1 to 6 after being experimentally processed.

Crab 2 had its ventral side facing upwards on Rodrigo's hand. Firstly, all right walking legs were manually disarticulated at the same time, by pulling and rotating them on their joints. Then the right claw was detached likewise. The same procedure was used for the left side's legs and claw. The disarticulation of the merus from the carpus was done manually by pulling and rotation, but direct percussion was necessary to separate the carpus from the manus. Manual separation was performed on the left claw by pulling apart the propodus from the dactylopodus, resulting in a clean cut in Rodrigo's hand. In the right claw, a blow inflicted on the manus' ventral side separated the fingers, shattering the shell and allowing immediate access to the flesh.

Processing times were 3:10 minutes for crab 1 and 1:25 minutes for crab 2. Although access to the flesh was easily gained, its gelatinous nature and the fact that it remained glued to the inside of the shell hindered consumption.

Boiled crabs

The claws and legs of crab 3 were manually disarticulated following the same procedures used for crab 1 but with less effort, as cooking had notably loosened the joints. The separation of the merus from the carpus was easily done manually, but the disarticulation of carpus and manus required a single hammerstone blow, and one or two additional blows on the ventral side of the manus were necessary to separate the dactylopodus from the propodus.

Crab 4 was manually disarticulated in the same fashion as crab 2: all walking legs removed at the same time and the claws one by one.

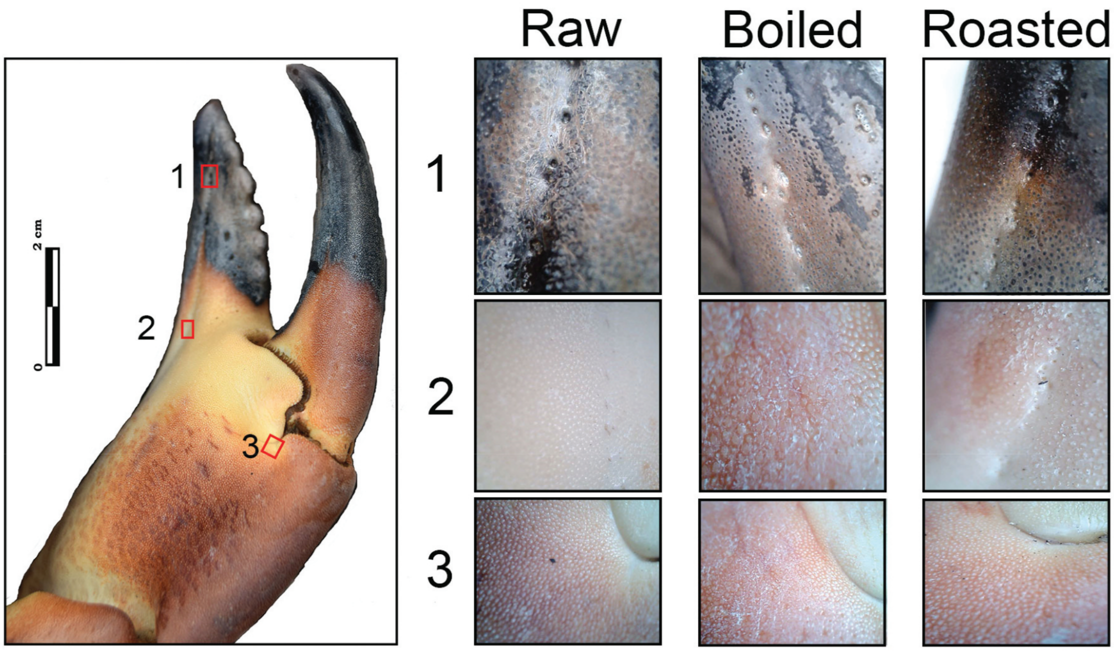

Figure. 3. Shell surface modifications observed on the experimentally processed crabs at 160x magnification.

The merus-carpus joint was removed by hand, but separation of the carpus-manus joint needed one or two hammerstone blows. The right dactylopodus and propodus were detached by direct percussion, but the left side fingers were manually disarticulated; use of a hammerstone remained necessary to have access to the flesh inside the ventral side of the left manus.

Crab 3 was processed in 2:03 minutes, and crab 4 in 1:28 minutes. Access to the flesh was easy and its consumption effortless, since the cooked meat detached from the inner shell could be extracted as a block. After boiling, crab weight loss varied between 14% and 22%.

Roasted crabs

Crab 5 was easily processed by hand in the manner of crabs 1 and 3. As before, manual rotation effortlessly detached the merus-carpus joint, but direct percussion was needed to break the carpus-manus joint. The separation of the left dactylopodus and propodus was done manually with no resistance and at the first attempt, but a hammerstone was necessary for the detachment of the right claw's fingers.

The manual disarticulation of crab 6 used the procedure described for crabs 2 and 4. All joints (merus-carpus, carpus-manus and propodus-dactylopodus) could be pulled apart by hand, and no percussion of the manus was necessary to access the flesh inside.

Overall, the joints were very loose, and the shell was extremely fragile, thus prone to breakage into small fragments, sometimes as a secondary effect of the disarticulation activity. Access to the flesh was particularly easy as it could be pulled out whole from inside the shell. Processing times were 2:38 minutes for crab 5, and 1:52 minutes for crab 6. After roasting, crab weight loss varied between 39% and 50%.

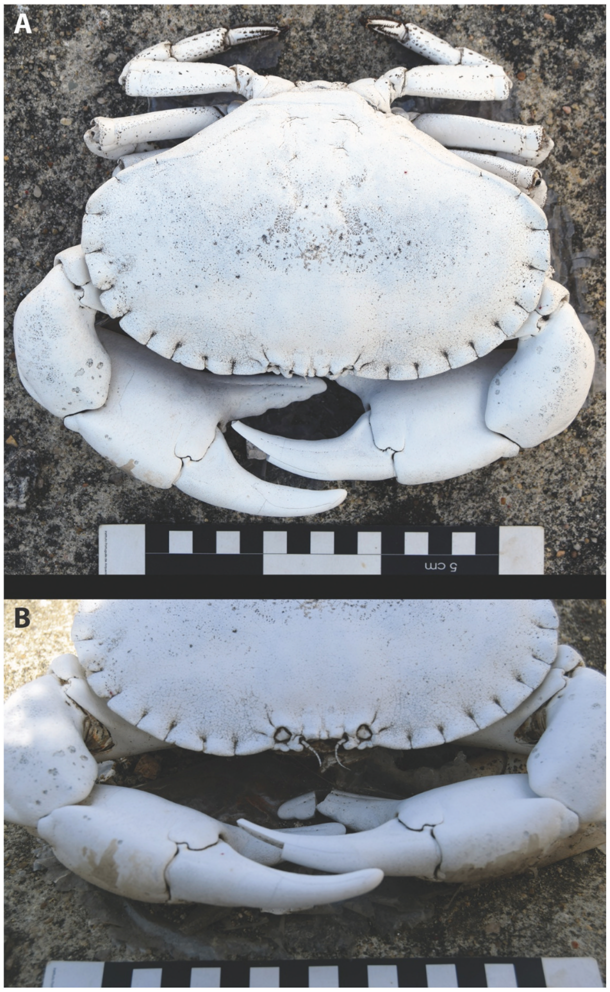

Figure. 4. Crab 7 after 15 months of weather exposure. Note the colour loss on both exterior and interior surfaces, and the very clean fractures on the left claw that do not match the breaks from processed animals.

Thermo-alterations

Under the microscope, crystallisation of shell surface was observed on all the cooked crabs, whether boiled or roasted. Additionally, the colour of the boiled specimens' shell changed from white to red, and a crazing surface with fine cracks formed. In the roasted animals, shell surface reddening occurred in areas that were not in direct contact with the coals, whereas those parts that were in

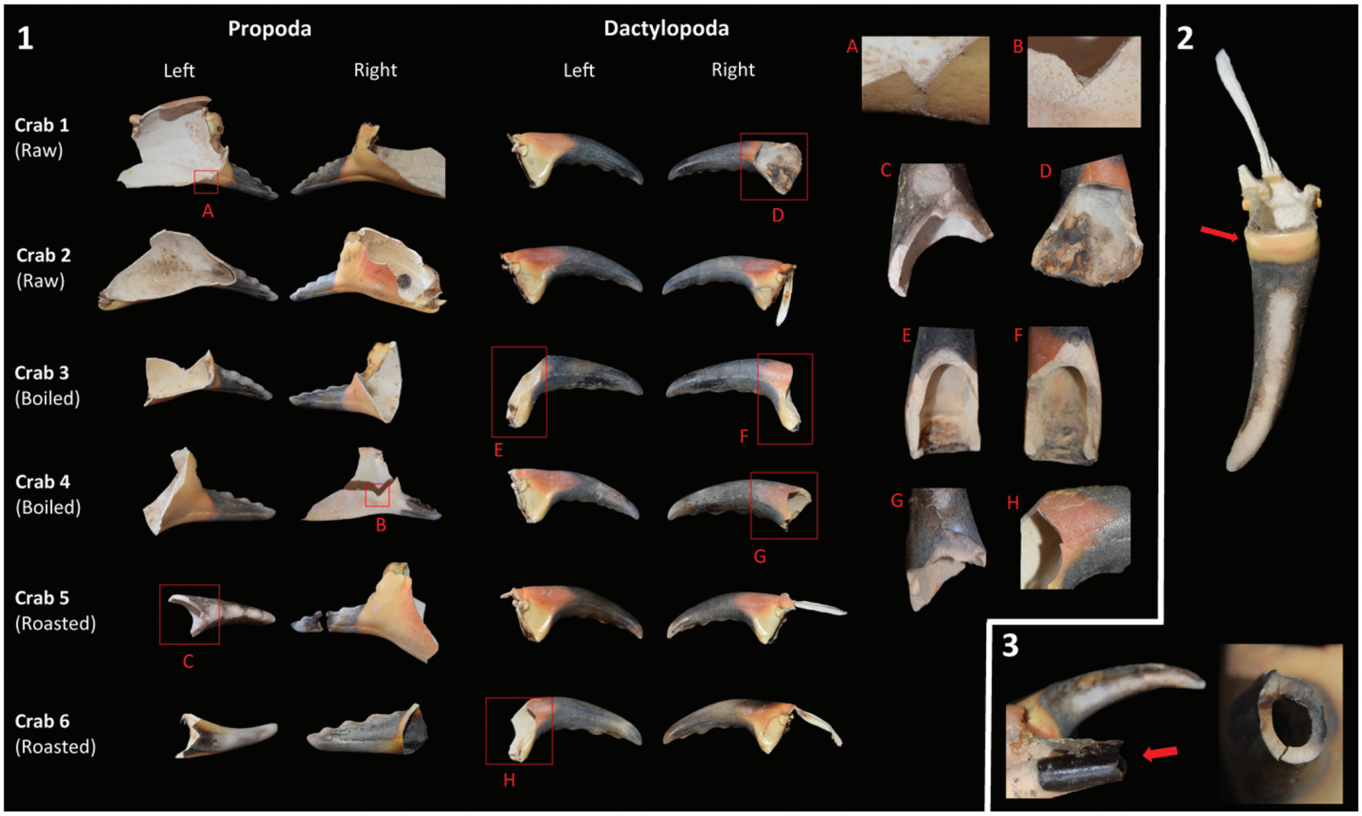

Figure. 5. 1) Experimental results and close-up modifications on propoda and dactylopoda from crabs 1 to 6: A and B are percussion notches with associated fine cracking; C and D are V-shaped impact flakes; E and F are examples of longitudinal breaks on the dorsal side of dactylopoda; G and H show impact scars on the dorsal side of dactylopoda. 2) Natural line-like feature on the ventral side of the dactylopodus. 3) Section view of the thermo-alteration of a broken crab finger.

direct contact with the coals showed dark brown and black burns. In the burnt shell fragments of roasted crabs, such colour change was also apparent in cross section.

To sum up, cooked crabs presented a more fragile shell and looser joints than raw crabs and were thus easier to break and disarticulate. This was the more so in the case of the roasted specimens, possibly due to the higher temperature exposure.

Percussion and type of fracture

Most processing damage was observed on the propoda. Raw propoda fragments tended to be larger than cooked ones (Fig. 5), among which roasted specimens were observed to break into more numerous and smaller fragments. Fractures were mostly longitudinal, and percussion notches, sometimes in association with fine cracks, were observed (Fig. 5A and B). The propodus of roasted crab 5 also featured an impact scar (Fig. 5C).

The dactylopoda presented less processing damage, but longitudinal fractures were observed on the dactylopoda of crabs 1, 3 and 4 (Fig. 5D-F), and there were impact scars on the dorsal side of the dactylopoda of crabs 4 and 6 (Fig. 5G and H).

Discussion and conclusions

These experimental results (Figs. 4 and 5) contribute to the interpretative framework for the identification of archaeological crab surface modification (Fig. 6). They demonstrate that the higher the temperature the crabs are exposed to during cooking, the higher the animals' weight loss, the easier and faster it is to process them, and the smaller the size of shell processing debris. Weight decrease is mostly due to water loss, which is a naturally occurring phenomenon in the cooking and preparation of food, in this case clearly evident by the transformation of the raw gelatinous flesh in a ready-to-eat, solid meat block.

Separation of claw joints demanded the use of a hammerstone in raw crabs, but could be carried out manually in cooked crabs. Breaking the carpus-manus joint, however, required direct percussion in all experiments, while no hammerstone use was required to separate the propodus and dactylopodus of cooked crabs, which tended to break into smaller size fragments due to crystallisation and attendant increased splintery.

Except for Hypothesis 2 – use of a hammerstone would leave diagnostic impact scars on the ventral side of the proximal dactylopoda – our initial hypotheses were confirmed. With regards to the separation of the dactylopodus from the propodus, our experiment revealed surface damage on the dorsal side instead, and consisting of longitudinal fractures rather than impact scarring. Explanations for the different archaeological pattern (Fig. 6, and Fig. 4 in Nabais et al. 2023) could lie in the type of technical gesture used, or that the ventral 'scar' could simply represent a natural feature of the proximal dactylopoda, whose ventral side does present a bump-like feature associated with a transverse line. However, this relief is considerably less pronounced in our experimental specimens, and was not visible on all Middle Palaeolithic crab proximal

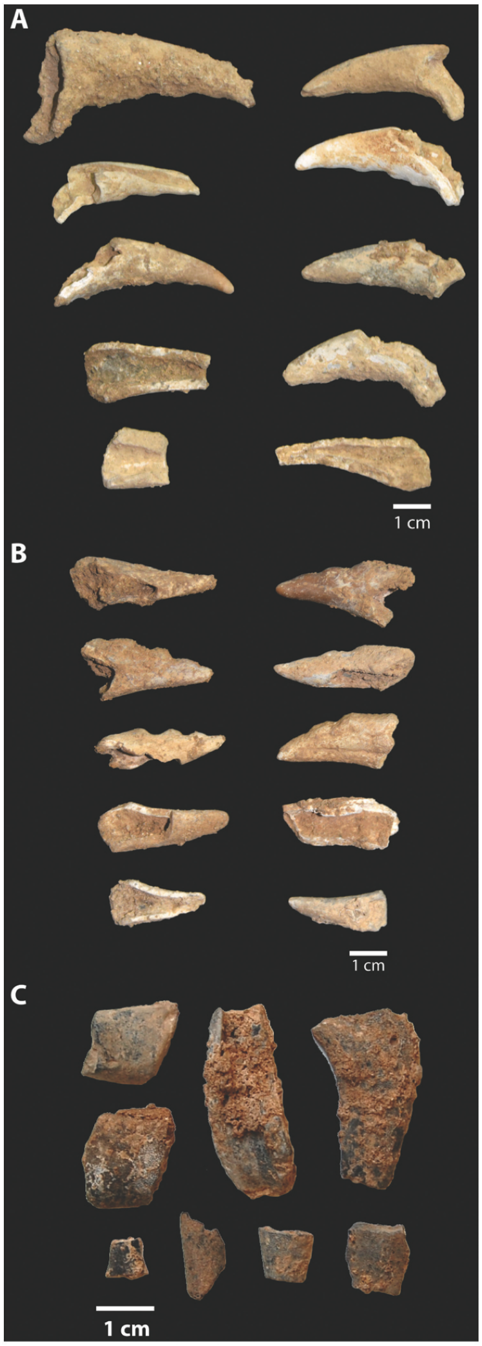

Figure. 6. Archaeological crab remains recovered from occupation phase FB4 from the most recent excavations (2010–2013) in Gruta da Figueira Brava. A-B) Examples of fractured left and right *Cancer pagurus* dactylopoda (A) and propoda (B); note the preference for longitudinal breaks. C) Black thermo-alterations on *Cancer pagurus* claw fragments; note that burns are located on exterior and interior surfaces.

dactylopoda. For now, the nature of this feature must therefore remain an open issue. Otherwise, our experiment supports that, at Gruta da Figueira Brava, brown crabs were roasted in direct contact with the coals, due to the ample evidence of burning, and then processed after cooling using hands and hammerstones to better disarticulate the tougher joints, and gain access to the flesh inside.

Much as ethnographically observed among northern North America indigenous peoples (Murdock 1963; Wolcott 1967; Conner and Bethune-Johnson 1986), Gruta da Figueira Brava's MIS-5b Neanderthals must have manually collected their brown crabs in shallow water intertidal pools along a seashore that, at the time, was within easy reach of the site (Zilhão et al. 2020; Nabais et al. 2023). Based on both the archaeological and the experimental evidence, the cave's inhabitants ate them cooked, in accordance with ethnographic evidence for crabs to always be boiled, steamed, or roasted (Suttles 1974; Batdorf 1990; Emmons 1991).

Nowadays, seafoods are highly recommended to prevent hypertension, coronary heart disease, and cancer. They are low in cholesterol and in saturated fatty acids, and rich in omega-3 polyunsaturated fatty acids (namely EPA and DHA), essential amino acids, vitamins, and trace elements (Sioen et al. 2007; Maulvault et al. 2011). Brown crabs (*Cancer pagurus*) are amongst such highly nutritional quality foods, and are currently one of the major marine resources of economic importance in southern Europe (EUMOFA 2021; Maulvault et al. 2011). Additionally, it is currently accepted that cooked brown crabs have increased values of constituents such as proteins, carbohydrates, copper (Cu), zinc (Zn), bromine (Br) and chlorine (CI) (Maulvault et al. 2012). However, there seems to be differences in the toxicological hazards associated with different parts of the crab, mainly related to cadmium (Cd), which is considerably more abundant in the brown meat of the carapace than in the white meat of the legs, underpinning recommendations for white flesh to be consumed independently of the type of preparation, and for brown meat to be ingested parsimoniously (Maulvault et al. 2011, 2012).

Brown crab carapace remains were found at Gruta da Figueira Brava, suggesting that complete animals were brought back to the cave (Nabais et al. 2023). However, most remains are of the fingertips of claw elements. A parsimonious explanation of this pattern is that, due to their lower density (the mineral, calcium carbonate content is higher in the claws; Bosselmann et al. 2007), carapace fragments preserve less well in the archaeological record (Krause et al. 2011). Alternatively, crab carapaces could have been used for other purposes, as among the Wampanoag, who, after consuming the crabs' legs and eggs, use the shells to make instruments, needles, awls, spears and good luck charms (Speck and Dexter 1948).

Acknowledgments

We thank João de Brito Vidigal for all the assistance given to us during our experimentation.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This research was supported by Mariana Nabais' one-year postdoc contract within the project "Archaeology and Evolution of Early Humans in the Western façade of Iberia (ARQEVO)" (PTDC/HAR-ARQ/30413/2017), UIDB/00698/2020 and UIDP/00698/2020, funded by the Fundação para a Ciúncia e Tecnologia (FCT), Portugal. Additional financial support has been provided by Mariana Nabais' two-year postdoc contract for project "Neanderthal and Anatomically Modern Human interactions with small prey in Atlantic Iberia throughout the changing environments of the Pleistocene", as part of the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 101034349, and from the State Research Agency of the Spanish Ministry of Science and Innovation through the Program Maria de Maeztu Unit of Excellence (CEX2019-000945-M). This research has also been possible thanks to a Margarita Salas postdoctoral fellowship awarded to Rodrigo Portero by the University of Salamanca and the Spanish Ministry of Science (Plan de Recuperación, Transformación y Resiliencia) with UE-Next-Generation funds.

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