***Corema album* archaeobotanical remains in western Mediterranean basin. Assessing fruit consumption during Upper Palaeolithic in Cova de les Cendres (Alicante, Spain)**

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Abstract

Information about plant gathering by Palaeolithic hunter-gatherers in Europe is scarce because of the problems of preservation of plant remains in archaeological sites and due to the lack of application of archaebotanical analysis in many of them. Botanical macrorremains –wood charcoal, seeds, fruits, leaves, etc. – provide information not only about palaeoeconomy of hunter-gatherers, but also about climate, landscape and vegetation dynamics.

In Gravettian and Solutrean levels of Cova de les Cendres, *Corema album* pyrenes (*Empetraceae* or crowberries family) have been identified. On the contrary, wood charcoal of this species has not been documented among the remains of firewood. This differential presence of plant organs, together with the nutritional value of its fruits, which is presented here, make us hypothesize the systematic gathering of *C. album* fruits for human consumption. They have a high content in vitamin C, as well as potassium, magnesium and copper.

Corema album is a unique species, nowadays in danger of extinction. Its main population is located on the Atlantic coast of Iberian Peninsula, but in 1996 a small population was discovered on the Mediterranean Iberian coast (Benidorm, Spain). Archaeobotanical data from Cova de les Cendres (Teulada-Moraira, Spain) presented here point to a larger population of *camariña* during Upper Palaeolithic on the coast of Alicante. The harsh climatic conditions of the Last Glacial Maximum during Solutrean period, with colder temperatures and aridity increase, could explain the reduction of the presence of *C. album* remains until its absence in Magdalenian. The climatic amelioration during Upper Magdalenian did not mean the recovery of *camariña* population in the Moraira headland area. Probably, the rising of the sea level would affect them destroying its habitat in the dunes.

1. Introduction

Global climatic changes and human activities, among other elements, shape the landscape physiognomy throughout history. Landscape is the stage of human activity since Prehistory. There, human groups have found food, fuel, raw material, productive areas, etc. These uses imply an interrelation between two actors –humans and vegetation-, in a way that changes in vegetation condition human activity and human actions modify vegetation. Archaeological data evidence that these transformations take place since Pleistocene, and increasingly in the Holocene, when new more potent technologies generate anthropogenic landscapes (Boivin et al., 2016; Briggs et al., 2006; Erlandson and Braje, 2014; Ruddiman et al., 2015). This environmental impact has got worse fast in the last century. On the other hand, climatic changes throughout History as Pleistocene glacial and interglacial periods and finally Holocene have modified continuously the vegetation formations. Pleistocene flora distribution was different to Holocene once, especially in the coastal areas, where another factor must be kept in mind: sea level fluctuations. Archaeobotany, here understood as recovery, analysis, identification and interpretation of plant remains from archaeological sites, focus on the interrelation between human groups and vegetation in the past, as well as on paleolandscape and paleoclimatic conditions reconstruction. Hence, archaeobotanical information shows these transformations in the regional biodiversity and could be useful in the design of environmental management policy and conservation strategies.

Archaeobotanical studies also provide economic and cultural information. Plant foods provide some nutrients essential for human health: minerals as iron, calcium and magnesium among others, vitamin C, proteins and carbohydrates. A diet based only in animal protein causes health problems (Noli and Avery, 1988; Speth and Spielmann, 1983). Nevertheless, their role in Palaeolithic diet has been underestimated because of their scarce archaeological evidence, especially comparing with zooarchaeological remains. Moreover, plants can be used as raw material for basketry, weaving, ropemaking, etc. Only in the last 15 years a real effort has been carried out to go deep into the plant use by hunter-gatherers.

This question has been tackled by several analyses: dental calculus, phytoliths, stable isotopes, microwear analysis of tools, etc. (e. g. (Hardy, 2018; Henry et al., 2014; Revedin et al., 2015; Richards and Trinkaus, 2009). Macrofossil analyses have provided new and interesting data (e. g. (Baines et al., 2015; Holst, 2010; Lev et al., 2005; Melamed et al., 2016; Pryor et al., 2013; Weiss et al., 2004b), proving a relevant use of plant resource from Middle Palaeolithic to Mesolithic. Regarding Western Mediterranean Basis, in Iberian Peninsula, carpological analyses have been carried out in few Palaeolithic sites (Aura et al., 2005; Badal García, 2001; Freeman et al., 1988; Gale and Carruthers, 2000; Mason et al., 1999; Vidal-Matutano et al., 2018). In North Africa, interesting results have been recently published from Later Stone Age and Capsian sites (Carrión Marco et al., 2018; Morales, 2018; Morales et al., 2015). Cova de les Cendres (Teulada-Moraira, Alicante) has provided significant preliminary results (Badal and Martínez Varea, 2018; Martínez Varea and Badal, 2018; Villaverde et al., 2017). Here, part of the carpological assemblage from its Pleistocene levels is analyzed and interpreted from a palaeoethnobotany point of view, pointing to a possible human use of *C. album*, and from a palaeobotany perspective, to know the evolution of the distribution of this unique species, which is nowadays 'In danger of extinction' (Aguilella et al., 2009) in Valencian Community. This paper combines archaeobotanical and biological data in order to define the nexus between Upper Pleistocene and present on Alicante coast (Spain).

2. Regional setting

Cova de les Cendres (Teulada-Moraira, Alicante, Spain) is located at the cliffs of the Moraira headland, at 60 m.a.s.l., just at the coastline (Fig. 1a). A wide archaeological sequence has been documented. Pleistocene levels have been dated to Aurignacian, Gravettian, Solutrean and Magdalenian periods (Table 1) (Villaverde et al., 2017, 2012). Along the whole sequence, archaeobotanical analyses have been carried out (Badal and Carrión, 2001; Badal and Martínez Varea, 2018; Martínez Varea and Badal, 2018; Villaverde et al., 2017).

From Cap de la Nau to Moraira headland, strike-slip and normal faults shape the coast with promontories of flat summits and subvertical cliffs, known as "*morres*". They are interposed by inlets and beaches, besides Eemian eolianites dated by thermoluminiscence in 112000 ± 17000 BP (Fumanal, 1995; Fumanal et al., 1993a; Fumanal and Viñals, 1988). These fossil dunes were formed during the Last Interglacial (MIS 5e) when the position of the seashore was near to the current. They extend under the sea, probably because they were part of a bigger dune system on the continental shelf (Fumanal et al., 1993a).

The current bioclimatic conditions of the Moraira headland are thermomediterranean (Rivas Martínez, 2007), with a mean annual temperature of 17 °C and a mean annual precipitation around 500 mm. The landscape is characterized as an impoverished shrubland, composed mainly by heliophillous shrubs as *Rosmarinus officinalis, Erica multiflora, Lavandula dentata* and *Ephedra distachya.* There are some taxa characteristic of maquis as *Olea europaea* var. *sylvestris*, *Pistacia lentiscus*, *Quercus coccifera* and *Chamaerops humilis.* Moraira headland is a botanical microreserve (Laguna et al., 2004), where some endangered species are present (*Silene hifacensis, Helianthemum caput-felis, Convolvulus valentinus,* among others).

3. Material and methods

A multidisciplinary approach has been applied in this research so different materials have been analysed. Archaeobotanical remains have been processed first and given the obtained results, we have carried out analysis of fresh material of *C. album*.

3.1. Archaeobotanical methods

Archaeological samples from Gravettian (XVIa and XV), Solutrean (XIII), Middle (XII) and Upper Magdalenian (XI) levels of Cova de les Cendres have been analysed. All the sediment was processed with a flotation machine with a 1 mm sieve cloth mesh for the heavy residue and a 0.25 mm sieve cloth mesh for the light fraction. Both fractions were splited with a sieve stack with 4, 2, 1, 0.5 and 0.25 mm sieve meshes to make easier the sorting of plant remains. This was carried out under a low power stereo microscope (Leica M165C) and fruits, seeds, leaves and other charred, mineralised and uncharred plant remains were recovered (Martínez Varea, 2016). The identification of the archaeobotanical remains was done based on morphology and anatomy compared with the reference collection of the Laboratori d'Arqueologia of Universitat de València and of Servicio de Vida Silvestre-CIEF of Generalitat Valenciana and with specialized bibliography (Bojnănský and Fargašová, 2007; Cappers et al., 2006). Photographs were taken with a Leica DFC425 camera and with Leica Application Suite V3 and Helicon Focus 3.10.3 software.

3.2. Fresh material analysis

The number of pyrenes by fruit has been checked with the analysis of 100 *C. album* fruits from the current population of National Park of Doñana (Huelva, Spain) (Table 2) in order to calculate the minimum number of fruits that were carried to the cave in each archaeological level.

On the other hand, chemical composition of *C. album* fruits from National Park of Doñana was analysed in order to know their chemical properties. Moisture was determined using the fruit samples weight before and after drying at constant weight, using the formula 100 * (water weight/fresh weight). Soluble solids (SS) were measured refractometrically using a drop of juice using a hand-held refractometer. The pH was determined in juice using an automatic pHmeter. Total titratable acidity was determined potentiometrically by titrating a 100 ml diluted (1:5) sample of juice with 0.5 N NaOH to pH 8.1, and expressed as percentage of citric acid. The ripening index was determined as the quotient between the soluble solids and the titratable acidity. Ascorbic acid (mg/100 g fresh fruit) was determined by potentiometric titration with a Titrino 702 (Metrohm, Herisau, Switzerland) using a Metrohm 6.0420.100 combined Pt selective electrode and a 0.005 M chloramine T as standard.

Protein content was calculated as N * 6.25 from the N content values determined with the Kjeldahl method (Foss Tecator, Högamäs, Sweden). For the analysis of minerals, 2 g of the dry fruit samples were calcined in a furnace at 450 ºC for 2 h. Subsequently they were weighted and dissolved in 2 mL of HCl. The mixture was heated until vapors appeared, after which immediately several mL of distilled water were added. After filtration, the extract volume was brought to 100 mL with distilled water. The following methodologies were used for the different minerals: P was determined by spectrometry (UV-VIS Jenway 6305) using the molibdovanadate method, K by flame photometry (Jenway PFP7, Essex, United Kingdom), and Ca, Mg, Fe, Cu and Zn by atomic absorption spectrophotometry (Thermo Elemental SOLAAR AA, Cambridge, United Kingdom). All minerals results of composition determinations are reported on a 100 g fresh weight basis. The fiber content (%) is determined by extraction with a hot neutral detergent solution and subsequent calcinations.

Total phenolics (mg caffeic acid.kg^{-1} fresh fruit) were determined according to the Folin–Ciocalteu procedure after extraction with acetone (70% v/v) and acetic acid (0.5% v/v). Absorbance was measured at 750 nm and caffeic acid (Sigma–Aldrich Chemie) was used as a standard. Antioxidant activity was estimated using the colourimetric DPPH (1,1-diphenyl-2-picrylhydrazyl) and expressed as Trolox (6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid) equivalents.

In order to analyze the anatomical features of *C. album*, a wood fragment 10 cm long and 2 cm diameter from the current population of National Park of Doñana (Huelva, Spain) was charred in an open fire. The resultant wood charcoal fragments were analyzed under an incident light microscope (Leica DM6000M). Specific features and pictures were taken with a scanning electron microscope (Hitachi S-4100) with spotlight of field emission and digital image acquisition system QUANTAX 200, held at the Servicio Central de Soporte a la Investigación (SCSIE) at Universitat de València. Wood anatomy of *C. album* was checked with the descriptions of vegetal anatomy atlas (Schweingruber, 1990).

4. *Corema album*

The genus *Corema* has been traditionally placed into *Empetraceae* –crowberries family–, a small family of heath-like shrubs having flesh fruits, containing only 3 genus (*Empetrum, Corema* and *Ceratiola*) and 4-6 species, and showing major biogeographical disjunctions (Moore, 1998). *Corema* comprises 2 species: *C. conradii* Torrey, which occurs in the eastern coast of North America (Martine et al., 2005; McEwen, 1894; Redfield, 1884), and *C. album* (L.) D. Don ex Steudel, living in the Atlantic coasts of the Iberian Peninsula, from Gibraltar to Finisterre (subsp. *album*, see (Boratyński and Vera de la Puente, 1994; Villar, 1993; Webb, 1972)), and in the Azores (subsp. *azoricum* Pinto da Silva, see (Clavijo et al., 2002; Pinto da Silva, 1966)). In 1996, a small and extreme disjunct population of *C. album* was found in the Mediterranean basin, in the coastal cliffs of Serra Gelada near Benidorm (Alicante, Spain) (Aguilella et al., 2009; Solanas and Crespo, 2001). Serra Gelada is placed more than 550 km far from the closest Atlantic population, in Tarifa sands, near the Strait of Gibraltar (Fig. 1a).

Despite *Empetraceae* has been maintained as an independent family since its description by Hooker and Lindley (Hooker, 1821), Wood and Channell (1959) recommended its inclusion into the *Ericaceae*, and recent phylogenetic studies based on morphological and molecular characters (Anderberg, 1994; Kron et al., 1991; Kron and Chase, 1993; Li et al., 2002) and comparative morphology and embryology (Reveal and Chase, 2011) demonstrate its better inclusion into this family.

Corema album is described as a dioecious perennial shrub although some hermaphrodite individuals are known in the southern populations of its biogeographical area (Díaz-Barradas et al., 2000; Zunzunegui et al., 2006). This plant is a perennial medium-size shrub, up to 1 meter in height, with numerous branches and flowers grouped in closely packed racemose inflorescences, bearing scented leaves and stems. The linear leaves are in whorls of three or four, and give the plant a heath aspect. The fruits are berry-like drupes, white or pale pink, 5-8 mm in diameter, often containing 3 seeds -pyrenes-, c. 0.5 cm long, with a thick woody endocarp. Flowering occur from March to April and fruiting from April to September (Fig. 1b and c). On its Atlantic Iberian distribution area (subsp. *album*), this species grows on sites ranging from the thermomediterranean to the mesomediterranean and thermotemperate termotypes, under dry-subhumide to hyperhumide ombrotypes, according to the classification of Rivas-Martínez (2007). Annual rainfall on its Atlantic distribution ranges from 550 to 1600 mm. It is a dominant species in several types of coastal shrublands on sand dunes (Rivas Martínez et al., 2002).

On its unique Mediterranean site, the most relevant for this article, *C. album* is only spread on a small sector of the coastal mountain Serra Gelada in Benidorm, colonizing relict fossil dunes, where it characterizes the plant association *Coremato albi-Juniperetum macrocarpae* Alcaraz, M. Costa, M.B. Crespo, De la Torre & Solanas 2002. It deals with an endemic open shrubland, exclusive from Serra Gelada (Solanas and Crespo, 2001; Aguilella et al., 2009; Rivas Martínez et al., 2002). This site is strongly different than the Atlantic areas for the same species, due to its extreme aridity -annual rainfall around 300 mm-. It is placed on the northernmost range of the so-called Spanish Southeastern desert. The Mediterranean population is extremely small and is placed on an extremely inaccessible place. According to our data, only 11 very aged individuals (4 female and 7 male, last census in 2016) grow on 400 m^2 and rarely produce viable seeds . Although the population has been regularly visited since its discovery, no young plants have been found (Aguilella et al., 2009).

On the basis of the IUCN criterion D2 (IUCN, 2012), the Mediterranean population of *C. album* can be evaluated as “Critically Endangered” (see Aguilella et al., 2009). Consequently, both species and the site are significantly protected by the environmental authority of the Valencian Community. The whole population is included in the Plant Micro-reserve “Serra Gelada Sud”. The mountain range Serra Gelada, its coastal cliffs and close small islands are enclosed into the boundaries of a Natural Park, which is additionally included in the European Union’s Natura 2000 network of protected sites –as Site of Community Importance, SCI “Serra Gelada”-. The species is strictly protected in the Valencian region at the highest legal category ‘In danger of extinction’, included in the Valencian Catalogue of Threatened Plant Species (Aguilella et al., 2009). In order to ensure its surviving, the Centre for Forestry Research and Experimentation (CIEF) of the Valencian Community, started in 2009 a recovery program through propagation by seeds in order to obtain new seeds/plants for its maintenance in the CIEF's nurseries as mother plants to produce new seedlings.

Growing pressure from human activities and climate change impacts, threat the functional integrity of the coastal ecosystem affecting *C. album* populations, which decline in different areas of the western coast of the Iberian Peninsula (Fernández de la Cigoña, 1988; Parra et al., 2000), although the current distribution of this species remains constant (Gil-López, 2011). Sand dune ecosystems are affected since early twentieth century by large plantations of pine trees, causing the reduction of incident sunlight, the presence of nitrophilous invasive plants, as well as the recession of specialized fauna for seed dispersal. These reasons conduced to a considerable decrease in fruit production of *C. album* and were decisive in the cessation of its traditional commercial activity (Gil-López, 2011). Facing the ongoing habitat loss and disturbance in *C. album* communities, natural regeneration of this species is really low. Seed ecology has extensively been studied and reports low germination under natural (Álvarez-Cansino et al., 2016; Zunzunegui et al., 2006) or controlled laboratory conditions (Sousa et al., 2014), presenting physiological dormancy (at least 1 or 2 years in natural habitats), which is partially broken after consumption by vertebrates like seagulls, rabbits, and foxes. Also, the coastlines face high risks of damage from certain types of natural disasters as strong winds, hurricanes or cyclones.

Corema album branches and fruits have traditionally played a useful role for local people in the Atlantic side of the Iberian Peninsula. The plant was used to make rustic brushes, which may explain the origin of the generic name, from Greek verb '*korema*' which means 'broom' (Huxley, 1992). The fruits, commonly known as '*camariña*' or '*camarinha*', are edible, slightly acid and traditionally consumed in some parts of Portugal (Andrade et al., 2017a) and Spain (Gil-López, 2011), either in the raw state or transformed into acid-tasting lemonades, jams or liquors, being also used for cooking preparations or as appetizers (León-González et al., 2013b). They constitute an important source of water, fibers and sugars (Andrade et al., 2017a). The extracts of their leaves and fruits are rich in polyphenols and phenolic acids (León-González et al., 2012, 2013b) which are becoming relevant because of their bioactive and medical properties as vermifugal and febrifugal (Andrade, 2016; Andrade et al., 2017a, 2017b), and particularly as chemotoxic for carcinomes (León-González et al., 2012, 2013a; Macedo et al., 2015), and neuroprotective against Parkinson's disease (Gonçalves, 2014; Jardim, 2012). In fact, due to its relevant properties and edible fruits, *C. album* has been proposed as a new crop (Oliveira and Dale, 2012). No ethnobotanical references about ancient *C. album* uses in Mediterranean coast have been found.

Regarding archaeological evidences, a compilation of finds has been carried out by I. López-Dóriga (2018). Up to now, the most ancient evidences of *C. album* in Iberian Peninsula come from Portuguese Early Neolithic sites. It has been also documented in some later archaeological sites until Medieval period on the Atlantic coast. The only evidence that predates these chronologies comes from the British Pleistocene site Pakefield-Kessingland, dated to 700,000 years (although a possible contamination with recent material could not be dismissed). Having said that and as it is indicated by the author, the lack of evidence from Mediterranean sites could be explained by a misidentification of the remains of *camariña* (López-Dóriga, 2018).

5. Results

5.1. Archaeological results

The Pleistocene sequence of Cova de les Cendres is extremely rich in archaeobotanical remains, specially in charcoal and seeds. Regarding carpological remains, the density varies from 28.98 remains/litre of sediment in the richest level (XVIA) to 0.77 remains/litre in the poorest (XIII). At least 90 different species have been documented, being *C. album* one of the most abundant of the assemblage. *Corema album* pyrenes (see Fig. 2) have been identified abundantly in three of the five Palaeolithic analyzed levels. Nevertheless, its presence is not homogenous throughout the sequence. In fact, a clear decrease from the bottom to the upper part of the sequence is detected. Together with the pyrenes, few leaves fragments have been identified, but no wood charcoal fragments of *C. album* have been documented.

In the Gravettian level XVIA, 5936 pyrenes have been recovered, that is the 21.83% of the carpological assemblage. This high quantity of remains is equivalent to a minimum of 1061.58 fruits of *C. album.* In level (XV), also dated to Gravettian, the presence of *C. album* starts to decrease, with 871 remains (16.97% of the assemblage), and representing 131.5 fruits. This drop in the number of remains consolidates in the Solutrean level XIII. There, only 32 remains of *C. album* have been identified (8.63%), so the minimum number of fruits is 5.42 (table 3; Fig. 3).

Finally, *C. album* remains are not present in the Middle and Upper Magdalenian levels. This absence is not due to a sampling bias, since an amount of litres of sediment similar to level XV was analysed. The explanation of its decrease and final disappearance must be looked for in their availability evolution on the Moraira headland.

5.2. Composition of *C. album*

The nutritional characterization of *C. album* fruit has been evaluated by moisture, soluble solids (SS), total titratable acidity, pH, ripening index, vitamin C, fiber, protein, mineral content (phosphorus, potassium, calcium, magnesium, iron, copper and zinc), total phenolic compounds and antioxidant activity, differentiating in some parameters between complete fruit (including seeds) and fruit without seeds (Table 4).

The moisture of the fruit without seeds is superior to the humidity of the fruit with seeds. In both cases, the water levels of the fruit are higher than indicated by Santos et al. (2014) (83.4%), possibly because the fruit is more mature, which is corroborated by increased soluble solids content, the lower acidity and higher index of maturity compared to what described previously (Santos et al., 2014).

Levels of vitamin C are especially high, in contrast to the value of 5.4 mg / 100 g reported elsewhere (Pimpão et al., 2013). The state of maturation, the ecotype, the edaphoclimatic conditions and the methodology used, can be at the origin of these differences.

The fruit is rich in fiber, coinciding with the results of Andrade et al. (2017a). Fiber levels are 90% higher in fruits with seeds. Protein levels are low, and similar to those found in citrus fruits. The protein content is higher in the fruit with seeds, due to the greater accumulation in this part of the fruit.

The total polyphenolic content is higher than that reported by León-González et al. (2013b) for this species, but lower than levels of other berries. These results are explained by the lack of anthocyanins in *C. album* fruits, since they are the main substances responsible for the polyphenolic concentration and the colors of most of the berries fruits, contrasting with the whitish color of the *C. album* fruits. The antioxidant activity of the fruits is superior to that recorded in the literature.

This work is unprecedented in the contribution of data on mineral content, so our results are compared to mineral concentration of a similar fruit, cranberry (BEDCA, n.d.). The mineral concentration is higher in the fruit with seeds, except for potassium, magnesium and copper, where the pulp concentrates higher percentage contents of these minerals. In comparison with cranberry, *C. album* fruits present lower content of phosphorus and iron, but the concentrations of the rest of minerals are higher.

In conclusion, *C. album* is a fruit, very rich in vitamin C, with an adequate antioxidant capacity and a very balanced mineral concentration, which is more important in the fruits with seeds.

5.3. Wood anatomy of *Corema album*

C. album has a heterogeneous wood with diffuse-porous to slightly semi-ring-porous, pores very small (10-15 μm diameter), numerous, solitary or in small groups. Growth ring boundaries are very distinct and rays in transverse section rather indistinct. In longitudinal sections, *C. album* has uniseriate and homogeneous rays, composed only by procumbent cells.

The vessels have scaleriform perforation plates with ten or twelve bars, visible in the three sections of wood (Fig. 4).

Corema album wood is really particular and it has genuine features, such as the scaleriform perforation plates, so it could not go unnoticed within the Palaeolithic charcoal assemblage of Cova de les Cendres.

6. Discussion

6.1. Paleolandscape of the Moraira headland

The archaeobotanical analysis of the Pleistocene sequence of Cova de les Cendres (Badal and Carrión, 2001; Badal and Martínez Varea, 2018; Villaverde et al., 2017), as well as the studies of the evolution of the coastline (Fumanal et al., 1993a, 1993b; Fumanal and Viñals, 1988; Hernández-Molina et al., 1994) prove the existence of an Upper Pleistocene landscape on the Moraira headland extremely different from the current one (Fig. 5).

Nowadays, Cova de les Cendres is located just on the coastline. However, geomorphological analyses have revealed that during Upper Pleistocene the coastline was far away from the cave entrance. During the Last Glacial Maximum (23500-21800 cal BP), coinciding more or less with the Solutrean period, sea level was 120 m less than the current, so the seashore was 15-20 km away from the current position (Fumanal et al., 1993b). On the emerged continental shelf, there were a paleovalley, a small hill and some ponds. Sandspits and restingas developed on the coast of the light sloped platform and talus deposits next to the cliffs made easier the access to the karst formations (Fumanal et al., 1993a).

In 11500 BP, with the sea level rise, coastline advanced gradually until 4-9 km to the cave, where it remained until 9000 BP. In 6000 BP the current coastline was configured, with its characteristic cliffs (Fumanal and Viñals, 1988). The Holocene marine transgression covered and destroyed the eolianites so that nowadays just a small part of the Eemian dune system is visible along the coast or submerged under the sea (Cova Tallada, Portet de Moraira, Torre de Moraira, Serra Gelada, etc.) (Fumanal et al., 1993a, 1993b; Fumanal and Viñals, 1988).

The identified flora among archaeobotanical remains fits perfectly with these geomorphological results. Through the Palaeolithic anthracological sequence, 8736 wood charcoal fragments have been analyzed and 21 woody taxa have been identified. This list increases to 26 taxa with the identification of seeds of five *Juniperus* species (Badal and Martínez Varea, 2018). Anthracological sequence is dominated by cryophilous pines, followed by *Juniperus* and shrub taxa, some of them clearly Mediterranean, such as *Rosmarinus officinalis*, *Pistacia* spp., *Erica multiflora* or *Ephedra* spp. The most xeric moments with the most open landscape are documented at the bottom of the diagram (XVIC) and during Middle Magdalenian (XII), as the significant increase of *Juniperus* spp. and shrub plant shows (Fig. 6). Maximum expansion of woodland is documented in Gravettian levels XVIA and B and during Upper Magdalenian (XI and IX), which must be the most humid moments of the sequence.

Pine forests would develop on rocky and limestone soils, together with *Juniperus sabina* and *J. thurifera*. The spread of these formations changes slightly throughout the sequence. The understory would be formed by *Fabaceae*, *Cistaceae*, *Lamiaceae* and other thermophile shrubs. A coastal dune system was developed, as the presence of *C. album* prove, especially during Gravettian. Other species documented in the archaeobotanical assemblage would grow there, as *Buglossoides arvensis* or *Echium vulgare* (*Boraginaceae* family). Some *Juniperus* species grow also in coastal sand dunes, as *J. oxycedrus* subsp. *macrocarpa* and *J. phoenicea* subsp. *turbinata*. Some *Cyperaceae* would grow at the edges of the ponds on the continental shelf.

The presence of *C. album* in the archaeological sequence of Cova de les Cendres shows a clear descending evolution, from Gravettian levels (XVIA and XV) when it constitutes one of the most frequent taxa, with a great reduction during Solutrean occupations and a final absence in Middle and Upper Magdalenian (Fig. 3). Harsh climatic conditions of Last Glacial Maximum during Solutrean, with colder temperatures and, specially, an aridity increase, which increment during Middle Magdalenian, could affect the regeneration of *C. album*. The climatic amelioration during Upper Magdalenian did not mean the recovery of *C. album* population in the Moraira headland area, as probably the sea level rise would affect them destroying its habitat. In fact, this was the period of its final disappearance. The impact of the sea level changes on landscape and resources availability has been recently evaluated also in the Eastern Mediterranean site Franchthi Cave (Asouti et al., 2018).

Up to now, evidences to explain the presence of the unique Mediterranean population of *C. album* in Serra Gelada (Benidorm) were scarce. Different hypothesis were considered: originated by a bird migration input or relictual population. Nowadays, thanks to its preservation in Cova de les Cendres, at least since 29170 cal BP, we know the existence of a population near the Moraira headland, so being its ancient Mediterranean distribution larger than today, as it has also been suggested by López-Dóriga (2018). Probably, during Magdalenian, the Eemian inland dunes were already lithificated, so *C. album* populations faced with sea level rise could not migrate to them and their regeneration was limited to the better preserved dunes, maybe in the Serra Gelada area. In fact, the most developed *C. album* populations nowadays grow in sand dunes in the National Park of Doñana and along the Portuguese coast. Nevertheless, more archaeobotanical research in this region is essential to know the real extension of the ancient *C. album* populations and its reduction process until the current situation, probably related to the Last Glacial Maximum climatic conditions and the Holocene marine transgression.

6.2. Origin of the assemblage

The interpretation of the archaeobotanical assemblage must be found on a correct definition of its origin, that is, the routes of entry of the remains. Defining the deposition processes is not easy. Three different origins can be considered in the case of *C. album* in Cova de les Cendres: natural, biological and human processes.

-Natural deposition: *C. album* is not an anemochore plant. The morphological configuration of the cave and the possible distribution of *C. album* plants in the environment, far from the cavity, make us reject also a natural deposition by water.

-Animal deposition: *C. album* fruits are consumed by different animals. In fact, this is its seed dispersal mechanism (Calviño-Cancela, 2004). Microsedimentological analyses have documented the presence of insectivorous bats in some moments of Gravettian and Upper Magdalenian, as well as the presence of birds only in some Gravettian phases. Although we do not completely discard that these birds carried some seeds to the cave, we consider that they were not the main agent of introduction, since their presence is not frequent. In the archaeological levels analyzed here, there is no evidence of activity of other mammals (Villaverde et al., 2017). Another possibility is the incorporation of the grains within the stomach of the preys (Vaquer and Ruas, 2009).

-Human deposition: based on the large number of remains, especially in Gravettian levels, the charred state of most of them and its undeniable alimentary usefulness, we consider that *C. album* remains were carried to the cave intentionally by humans. It would be illogical that human groups that visited Cendres discarded the use of these fruits, keeping in mind their vitamin C richness and their easy gathering. Moreover, the lack of *C. album* wood charcoal suggest a protection of these plants, avoiding their use as firewood.

6.3. Palaeoeconomy

Plants (fruits, seeds, leaves or stems) provide essential nutrients, some of which are not found in other types of food. In plants we found minerals as calcium, magnesium, manganese, iron and potassium. Plant foods are source of carbohydrates, fiber, fatty acids, amino acids and proteins (Slavin and Lloyd, 2012). A diet based principally on animal protein intake is cause of serious health problems (Butterworth et al., 2016; Noli and Avery, 1988) and diseases as rabbit starvation (Speth and Spielmann, 1983), hyperammonemia, hyperaminoacidemia or calciura

(Hardy, 2010, pp. 666–667). In fact, the under-consumption of some of these vegetable nutrients has serious consequences for fertility, pregnancy and post-partum (Hockett, 2012). Among the vitamins of vegetable origin, vitamin C stands out, since humans need ingest it, as we cannot produce ascorbate acid (Milton, 1999). In this sense, we found specially interesting that *C. album* fruits have a high content in vitamin C (97 mg/100 g). Moreover, they have a high content in potassium, magnesium and copper. So, Palaeolithic hunter-gatherers of Cova de les Cendres could find near the cave a vitamin, antioxidant and high-mineral-content fruit. *Corema album* fruits are also vermifuge and antipyretic, and they quench the thirst (León-González et al., 2012, 2013b).

Corema album fruits gathering could have had an important role in Cendres hunter-gatherers' diet, especially during Gravettian, when they represent more than 21% of the carpological assemblage. *Camariña* fruits, as other plant foods, are stable, predictable -available during summer-, and easily gathered -knocked down to a container- and consumed. Their flesh can be ingested raw, throwing away their hard endocarp, maybe to the hearths, making possible their archaeological detection. It is also possible that hunter-gatherer prepared some kind of beverage with the fruits juice, discarding the pyrenes as by-products of processing, which could be thrown to the fire. These are just hypothesis, as we cannot prove the mode of consumption of the *C. album* fruits. Therefore, these fruits could have been an important source of vitamin C, and minerals. Moreover, their vermifugal and febrifugal properties could have been known by hunter-gatherers. Their key role in the diet of the groups that visited the cave could explain why no *C. album* pieces of charcoal have been identified within the anthracological assemblage, which is not due to problems in the identification, as its anatomy is really characteristic (Fig. 4). Gatherers may have managed the species that provided them food, they probably protected the plant, avoiding cutting down it for fuel, despite the high calorific power of its wood (López-Dóriga, 2018). Only some parts of the plant were selected and carried to the cave. This behaviour was detected in Cueva de Nerja with *Pinus pinea* (Aura et al., 2010; Badal García, 2001).

Through the sequence, the gathering of other fleshy fruits has been documented, as *Sorbus* spp., *Sambucus nigra*/*racemosa* and *Ficus carica*, although its presence is reduced (Martínez Varea and Badal, 2018; Villaverde et al., 2017). *Rosaceae* family, specially genus as *Prunus* spp., *Malus* spp., *Sorbus* spp. or *Rubus* spp., is frequently documented in Palaeolithic and Mesolithic sites where they have been considered as an essential component of diet: Santa Maira (Aura et al., 2005), Aizpea (Zapata, 2001), Balma Guilanyà (Allué et al., 2012), Tybrind Vig (Kubiak-Martens, 1999) or Öküzini (Martinoli and Jacomet, 2004). In Cendres just a few remains of *Rosaceae* have been documented, probably because of its scarce availability in the environment of the cave. Thus, we hypothesize that the role of *Rosaceae* fruits in other sites was played by *C. album* fruits during Gravettian and Solutrean. In Grotte de l'Abeurador and Theopetra a similar situation has been detected, as the more frequent fleshy fruit is *Hippophaë rhamnoides*, which, as *C. album*, is rich in vitamin C (Kotzamani, 2009; Vaquer and Ruas, 2009).

Together with *Rosaceae* fruits, seeds of *Poaceae* and *Fabaceae* are commonly present in Palaeolithic and Mesolithic sites. Small-grained wild grasses gathering seems to undergo a gradual rise during the Palaeolithic and Mesolithic, which could be related to the detected increase of food processing intensity (de Beaune, 2000; Power and Williams, 2018). They have been documented in Ghar e-Boof (Baines et al., 2015) or Franchthi Cave (Hansen, 1980), but they form the bulk of the gathered plants in Ohalo II (Weiss et al., 2004a), where they could have been even cultivated (Snir et al., 2015). Wild legumes were widely used as food since Middle Palaeolithic in different regions, as the results of Franchthi Cave (Hansen, 1980), Theopetra and Schisto (Kotzamani and Livarda, 2014), Ghar-e Boof (Baines et al., 2015), Taforalt (Humphrey et al., 2014) or Santa Maira (Aura et al., 2005) show. *Fabaceae* and *Poaceae* remains have been documented in Cendres as well. These three types of plant food – fleshy fruits, grains and legumes–, provided carbohydrates, fiber, proteins, minerals and vitamins to prehistoric hunter-gatherers.

In the last years, the increasing evidences disclosed by different disciplines strengthen the role of plants in prehistoric hunter-gatherers' economies. Nevertheless, an effort on the application of sampling methodologies and new research questions are needed to leave the biased image of Palaeolithic groups which emphasized the role of hunting activities behind.

7. Conclusion

Plants provide nutrients and minerals that humans cannot find in other sources. Therefore, combining meat intake with other elements, as plant food, is essential to health. Palaeolithic hunter-gatherers would not elude that, and unlike what traditional research shows, they probably combined different food sources: hunt, fishing, shellfishing and plant gathering. The carpological analysis of Cova de les Cendres evidences the consumption of *C. album*, among other plant foods, by human groups that visited it, at least since Gravettian until the end of Solutrean, being an essential part of diet. Moreover, these groups managed their ecosystem, since *C. album* is not present among the residues of domestic fires: they avoided cutting down it for fuel, as this plant provides them with fruits rich in vitamin C and minerals.

These data not only provide palaeoeconomic information, but also palaeoecological and palaeobotanical, as they shed light on the presence of the unique Mediterranean population of *C. album* and on the Upper Pleistocene coastal dune systems of Alicante. The dynamic of the most sensitive species to climatic and geographic changes, as *C. album*, can be correlated with global climatic changes of the Last Glacial Maximum and subsequent periods. The destruction of the coastal dunes by sea level rise and the lithification of the inner dune system probably prevent the regeneration of *C. album* populations, which became restricted to more limited areas on the Mediterranean coast, whose last refuge is Serra Gelada (Benidorm). More research in these terms is required in order to better know the real ancient extension of *camariña* populations, and genetic analysis could be carried out on the archaeological uncharred pyrenes of *Corema*.

Several reasons uphold the importance of preserving endangered species. Maintaining the biological and genetic diversity is required for the conservation of ecosystem or habitat where plants and animals live. In nature, each species plays a role in the ecosystem. The loss of a plant or animal species could yield serious consequences for the ecosystem -affecting the interspecific relationships, unbalancing trophic functions, etc.-, even collaterally endangering other species. Its impact is not always evident and sometimes can be difficult to be predicted at short and mid time. A second main reason to preserve an endangered species is to keep its genetic variability, as its progressive or sudden reduction can increase its risk of extinction. The conservation of genetic variability is also crucial to adapt the individuals to new environments, including those derived from climate change. Finally, the endangered species must be maintained as a future source of promissory benefits to humans, as already indicated for *C. album* regarding its medicinal uses.

An interdisciplinary research where botanists and archaeologists work together is essential to understand how ecosystems have changed through history, how humans have had to adapt to these changes and how human activities have altered the landscape.

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Figure legends:

Fig. 1. a- Cova de les Cendres location and current distribution of *Corema album* in bioclimatic belts (based on www.anthos.es); b- *C. album* on dunes of Doñana, and c- detail of fruits.

Fig. 2. *Corema album*: fresh (a), archaeological charred (b) and mineralised (c) pyrenes.

Fig. 3. Evolution of *Corema album* remains through Cendres Palaeolithic sequence.

Fig. 4. Wood anatomy of *Corema album*: a-Transversal section: growth ring boundaries are distinct; b- Transversal section, scalariform perforation in vessel (detail); c-Radial section, scaleriform perforation in vessel with several bars; d- Tangential section with uniseriate rays.

Fig. 5. Current topography and coastline of Moraira area (a) and geomorphology of the continental shelf (results of the geosysmic surveys of 1993) (redrawn from Fumanal et al., 1993a) (b).

Fig. 6. Anthracological diagram of Cova de les Cendres.

Archaeological Level	Cultural adscription	Lab ID	Material	Age BP	Level age cal BP (95%)
IX	Final Upper Magdalenian	Beta-142284	*Pinus nigra/sylvestris* (charcoal)	12470±100	15180 - 14100
X	Steril				
XI	Upper Magdalenian	Beta-189079	*Pinus nigra/sylvestris* (charcoal)	13120±60	16240 - 15530
		Beta-287538	*Pinus nigra/sylvestris* (charcoal)	13350±50	
XII	Middle Magdalenian	Beta-118022	*Pinus nigra/sylvestris* (charcoal)	13690±120	19570 - 16140
		Beta-287541	*Pinus nigra/sylvestris* (charcoal)	16030±60	
XIII	Solutrean	Beta-287542	*Pinus nigra/sylvestris* (charcoal)	16790±60	23230 - 20050
		Beta-118026	*Pinus nigra/sylvestris* (charcoal)	18920±180	
XIV	Solutrean	Beta-287545	*Pinus nigra/sylvestris* (charcoal)	20200±80	24620 - 24030
		Beta-287544	*Pinus nigra/sylvestris* (charcoal)	20280±80	
XV	Gravettian	Beta-142282	*Pinus nigra/sylvestris* (charcoal)	21230±80	26700 - 25340
		Beta-437194	*Pinus nigra/sylvestris* (charcoal)	22190±80	
XVIA	Gravettian	Beta-437195	*Pinus nigra/sylvestris* (charcoal)	22750±110	29170 - 26750
		Beta-437196	*Pinus nigra/sylvestris* (charcoal)	24850±110	
XVIB	Gravettian	Beta-437823	*Acer* sp. (charcoal)	25590±100	31000 - 29350
		Beta-437198	*Pinus nigra/sylvestris* (charcoal)	26580±90	
XVIC	Late/Evolved Aurignacian	VERA-6428ABOxSC	*Pinus nigra/sylvestris* (charcoal)	27560±240	34140- 31020
		VERA-6427ABOxSC	*Pinus nigra/sylvestris* (charcoal)	29490±260	
XVID	Late/Evolved Aurignacian	Beta-458346	*Juniperus* spp. (charcoal)	31080±170	35340 - 34620
XVII	Cultural adscription pending				

Table 1. Chronological limits and cultural adscription of Palaeolithic archaeological levels of Cova de les Cendres (Villaverde et al., 2017) (Calibration obtained with CalPal-IntCal 13).

Number of seeds/fruit	**Number of individuals**
1	2
2	30
3	68
Total of fruits	**100**
Number of seeds	**266**
Mean number of seeds/fruit	**2.66**
Mode	**3**

Table 2. Number of seeds per fruit of *Corema album*

		Level XI	Level XII	Level XIII	Level XV	Level XVIA
	Litres of sediments	270	138	483	198	938,4
	Reproductive remains	1730	843	371	5131	27192
	Total *Corema album* remains	0	0	32	871	5936
Corema album	Charred endocarp			11	257	2284
	Charred endocarp fragment			17	550	3579
	Charred seed			1	31	12
	Charred seed fragment			0	23	2
	Mineralised endocarp			1	0	4
	Mineralised endocarp fragment			0	0	9
	Mineralised seed			0	0	12
cf. *Corema album*	Charred endocarp			0	0	1
	Charred endocarp fragment			2	10	26
	Mineralised endocarp fragment			0	0	0
	Charred seed			0	0	6
	Mineralised seed			0	0	0
	Mineralised seed fragment			0	0	1
	MNI *Corema album*			16,25	394,5	3184,75
	MNF			5,42	131,5	1061,58

Table 3. *Corema album* remains in Cova de les Cendres (MNI: Minimum Number of Individuals or endocarps; MNF: Minimum Number of Fruits).

	Fruit with seeds	Fruit without seeds
Moisture (%)	97,66	98,32
Soluble solids (°Brix)	8,5	
Total titratable acidity (% citric)	0,89	
Ripening index	9,55	
pH	3,3	
Vitamin C (mg/100 g)	97	
Fiber (%)	10,43	1,04
Protein (%)	0,44	0,19
Phosphorus (mg/100 g)	3,75	1,4
Potassium (mg/100 g)	121,3	129,1
Calcium (mg/100 g)	21,36	17,88
Magnesium (mg/100 g)	4,78	7,35
Iron (mg/100 g)	0,29	0,13
Copper (mg/100 g)	0,19	0,22
Zinc (mg/100 g)	0,22	0,09
Total phenolic compounds (mg caffeic acid/kg)	1801,55	
Antioxidant activity (µmoles ET/g)	70,2	

Table 4. Results of the chemical analysis of *Corema album* fruits.