Differential preservation of anthracological material and mechanical properties of wood charcoal, an experimental approach of fragmentation

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Summary: *The question of the fragmentation of archaeological charcoal is particularly interesting, since anthracology relies on a quantitative analysis of identified* taxa*. The undertaking of mechanical compression tests on carbonized wood cubes from ten woody species allows an evaluation of their preservation potential, as well as their possible over- or underrepresentation in archaeological samples. Our tests evidence a differential behavior of the species in what regards mechanical resistance and modalities of fragmentation.*

Key words: *wood charcoal, experimental compression, mechanical properties, fragmentation, taphonomy, archaeology.*

INTRODUCTION

Anthraco-analysis is based on the relative frequencies of taxa, calculated from the number of fragments of each species identified in the sample. Only this quantitative approach allows us to gain access to a structural and dynamic image of the vegetation. In this sense, although the palaeoenvironmental representativeness of charcoal is further proof, the question of fragmentation on charcoal material is of particular importance. Each stage, from the burning of wood through the burial and sampling conditions, take part in the fragmentation process (Chabal, 1994, 1997; Théry-Parisot *et al*., 2010 a, b). However, the behavior of different species when exposed to charring, or the effects of post-depositional processes on the charcoal are poorly known. In the 90's, L. Chabal demonstrated on archaeological material that the fragmentation process of charcoal is the same for all species. According to the author, the fragmentation law is dependent on the archaeological site and the processes that led to its formation. The variety of processes involved, bring to the same level of fragmentation the different species (Chabal, 1997). Most post-depositional processes induce significant mechanical pressure on charcoal (Théry, 2001). Even though experimentation can never be able to reproduce the complexity of these processes, it allows us nevertheless to characterize the physical properties of different species. In this work, we studied the different behavior towards compression of ten common species often found in archaeological contexts: *Acer pseudoplatanus, Betula pubescens, Carpinus betulus, Corylus avellana, Fagus sylvatica, Fraxinus excelsior, Populus alba, Pinus pinaster, Pinus sylvestris, Quercus pubescens.* The production of this raw data allows us to evaluate the potential of preservation of the tested species and their possible under-or overrepresentation.

MATERIAL AND METHODS

For each species, 30 cubes of 2 cm^2 were cut with a band saw and charred in a muffle furnace in the CEPAM laboratory. Each cube was wrapped in aluminum foil and placed in a ceramic crucible and covered with sand to reduce thermal shock and to prevent the cubes of cracking. Carbonization temperatures were determined by considering both the thermal conditions of charcoal formation and the temperature range that can be reached in an open fireplace (charring temperatures: 400, 500 and 750 ° C).

Compression tests were performed on the samples in the CEMEF (Polytech, Sophia-Antipolis) in collaboration with Gilbert Fiorucci and Alexandre Ducom on a tension-compression machine equipped with a hydraulic sensor 10kN. The descent rate was set at 0.1mm/s for 30 seconds from contact with the sample (Ducom, 2010). For all tests, the stress was applied on the transverse face of the cube of charcoal, perpendicularly to the wood fibers. In this direction the material has the greatest strength. Data collected at the end of the tests were used to calculate the stress (force/section of the cube in mm²) expressed in Mega Pascal and the strain (position/height of the cube in mm) expressed in percentages, in order to extract the stress-strain curves, which allow interpreting the mechanical tests (Fig. 1).

The charcoal was placed under the press in small plastic bags so no fragments produced by the compression after the rupture of the material could be lost. We sieved the contents of each package in a column of sieves of 1 mm, 2 mm and 4 mm. The fragments were counted per mesh for each cube with the image analysis software "Image J ". A total of 57,372 fragments for the 315 successful tests were recorded.

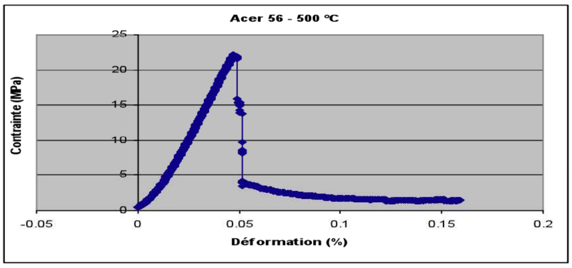

*FIGURE 1: Example of "stress-strain" curve from a compression test of a cube of charcoal (*Acer Pseudoplatanus*).*

RESULTS

Differences in the fragmentation of the species were noticed, which led to the establishment of different groups according to their behavior (Fig. 2).

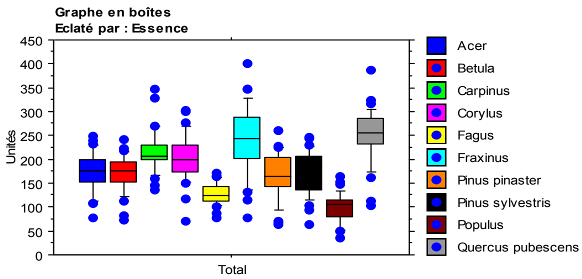

FIGURE 2: Specific variability of the fragmentation.

The temperature of carbonization has obviously an impact on fragmentation. Moreover, if all species produce more small fragments, these do not have the same distribution by size class (Table 1).

Species	>4mm	[2 - 4mm]	[1 - 2mm]	Total
Acer	19	60	94	173
Betula	16	38	117	171
Carpinus	17	44	156	217
Corylus	16	49	137	203
Fagus	17	42	68	127
Fraxinus	18	54	169	242
Pinus pinaster	20	57	89	166
Pinus sylvestris	20	56	96	172
Populus	15	34	50	99
Quercus	35	80	136	251

TABLE 1. Average number of fragments per size class for each species.

Statistical analysis allows determining which factors, among those taken into account, influence most the fragmentation process and its modalities (carbonization temperature, mass loss, density, porosity, anatomical characteristics of species, proximity to the heart of wood, etc.). The identification of influential factors can partially extrapolate our results to other species.

DISCUSSION

As often in experimental studies, our results are not directly transferable to the archaeological material. Several stages are needed to make them suitable:

- New experiments must be carried out to 1) expand the repository of data, 2) simulate other post-depositional processes (freeze-thaw, wetting-drying, shrinkage and swelling cycles of the sediment, diagenesis, biological alterations, etc.). In the same way, the behavior towards fire of the tested species should be taken into account (in particular the number of remains). This will eventually permit to model the preservation potential and "quantitative representativeness" of different species.

- In addition, experimental data does not replace a detailed study of the formation and disruption processes of the archaeological site. A good understanding of the taphonomical processes taking place in the archaeological site crossed with a fine knowledge of the behavior of the species (or type of species) will enable a better evaluation of the potential biases when interpreting anthracological assemblages.

CONCLUSION

Compression tests performed on charcoal from ten woody species showed differences in their mechanical strength and modalities of fragmentation.

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* Caution: the present abstract deals with a work which is still in progress. The results are likely to evolve towards slightly different conclusions. Please cite the definitive publication, when available.March 2011.