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Wine production and consumption in context: organic residue analysis in the so-called *thermopolium* V 4, 6-8 at Pompeii

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***Abstract* – This paper presents the results of an interdisciplinary study of the building V 4, 6-8, at Pompeii. The building was previously interpreted as a wine production installation (Brun and Neyme, 2008). Later, it was further investigated by a team from Ca' Foscari University of Venice. Archaeological excavations and further studies revealed that this building underwent a series of changes through time, being gradually converted into a space dedicated to food processing and serving. The organic residue analyses carried out by the University of Barcelona using gas chromatography-mass spectrometry (GC-MS) confirm that this building was used for the production of wine. The identification of other residues (compatible with plant oil and animal products) can be related to the re-use of some of the dolia, reinforcing the evidence of different types of food and beverages being sold in the last phase of life of the building, when it appears to have functioned as a caupona.**

I. INTRODUCTION

This paper aims to shed light on the function of the building V, 4, 6-8 located in the Regio V, insula 4, number 6-8 at Pompeii (Fig. 1), by carrying out an interdisciplinary study that integrates archaeological data with organic residue analysis of samples recovered from a production installation and eight dolia still in situ. In particular, it aims at confirming that wine production was carried out at the building, as suggested by Brun and Neyme in 2008 [1], exploring, at the same time, the possible re-use of the dolia for food storage and/or processing during the last phase of life of the complex.

During the last period of use, the building had two main entrances from Via di Nola (V, 4, 6 and 7) and a secondary access from Vicolo dei Gladiatori (V, 4, 8) (Fig. 1 and 2). Via di Nola was one of the main thoroughfares of Pompeii: before the Plinian eruption, several buildings facing onto this street were devoted to food production and sale [2, 3]. Excavations directed by A. Sogliano and carried out between 1899 and 1904 showed the presence of a "tavern" [1, 4, 5, 6]. In 2007, a team of the Centre Jean Berard of Naples, led by J. P. Brun, undertook new archaeological investigations of this area that provided new evidence, suggesting that the building was a wine production installation. Significantly, they identified the presence of a so called *foloir a vin* (vat in English) in room E, and interpreted the eight dolia in the adjunct room (room F), as dolia de fossa connected with the production and storage of wine [2] (Fig 1).

For a long period, the specific function of this complex remained doubtful and modern literature referred to this building using different terms, as shown below:

- taberna, a generic word to indicate retail shops.
-Thermopolium, technically a space devoted to sell hot drinks, especially wine, and snacks.
- Taberna with thermopolium or taberna with wine installation.

-Caupona, an articulated space intended for sale and on-site consumption of hot food and drinks.

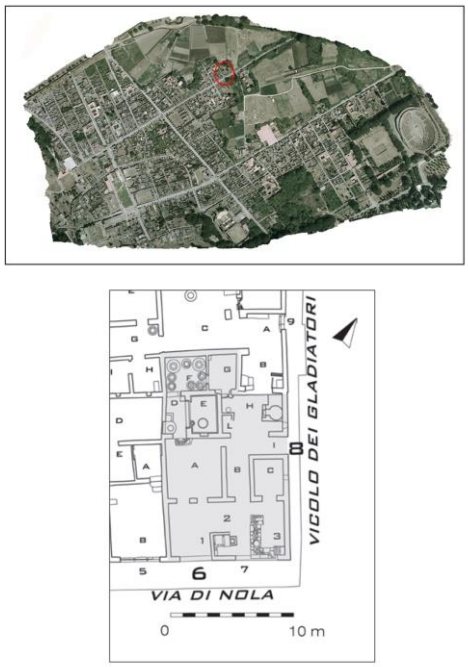

Figure 1. General plan of Regio V, 3 and 4 in Pompeii. The building V,4,6-8 is located between via di Nola and vicolo dei Gladiatori (Archives Universtità Ca' Foscari Venezia "Pompeii Regio V Project").

During its final stage of use and function (79 AD), the building was organised in a series of rooms devoted to the production and selling of food. Space H was equipped with a large baking oven. Room E (Fig. 1) was interpreted as a wine production installation, equipped with a flat and shallow vat which bottom and walls were coated with plaster (opus signinum), and a cut amphora located in its south-western corner. Brun and Neyme, [1] suggested that the pressing of the grapes was carried out in the vat (in French foloir a vin) and that the amphora was probably used to collect the liquid extracted in the vat. Significantly, among the paintings located in this room, the east wall displayed a painting of Dionisus watering the panther in the company of a Menade [1]; the latter reinforced the idea that the activity carried out in the room was somehow related to wine. Room F displayed eight dolia still in situ (Fig. 2) and largely buried below the ground level. Brun and Neyme [1] suggested that they were originally dolia de fossa of the wine cellar, and that they were buried to allow a better preservation of the fermenting must/wine.

In 2008-2009 a team from Ca' Foscari University of Venice, under the scientific direction of A. Zaccaria Ruggiu, undertook a new excavation project, focused on understanding the modifications of both the plan and the function of this complex through time [2, 3, 4]. The research allowed to determine that the plan of the building V, 4, 6-8 underwent several modifications, a phenomenon well attested in Pompeii. Excavations established that in the 1st century AD, the complex was used for wine production; however, in the second half of this century, its plan was modified with several rearrangements, including the insertion of the so called wine cellar, equipped with the eight dolia still in situ (Zaccaria Ruggiu et al., 2010, 2015).

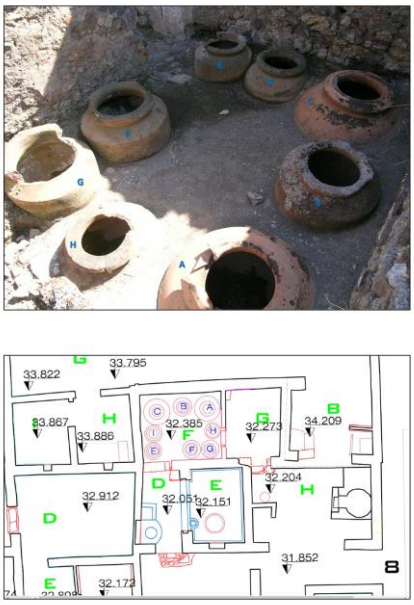

Figure 2. Detail of the building V,4,6-8. In room F, it is possible to observe the presence of the dolia analysed in this paper (Archives Universtità Ca' Foscari Venezia "Pompeii Regio V Project").

In order to confirm the original use of the installation as wine production and shed light on the use, and possible re-use of the dolia, organic residues analysis was performed on samples from the dolia preserved in room F, in order to identify possible grape juice/wine biomarkers. A further research aim was to understand whether, in the last phase of use of the building, some dolia could have been used to store (and therefore process/sell) products other than wine. The sale of food, in addition to beverages, would have taken place in the interconnected spaces C, 3 and 2 (Fig. 2), as suggested by the presence in room 3 of an L-shaped table, typically equipped with spaces for food/drink storage and heating. [2, 3, 4].

2. MATERIALS AND METHODS

To confirm the original function of the production installation for wine production, samples of the eight

dolia (samples 1-11) were collected in order to confirm that they were originally devoted to wine fermentation and storage and to understand if they had undergone a change in use over time. Dolia A and C bear stamps on their rims reading "C. Naevius Vitalis" and grape depictions. Interestingly, dolium C also shows a further possible allusion to its vine content: a graffito reading "DIONVSIVS FEC(it)" located on the rim [3]. At the time of the archaeological investigations in 2009, the dolia did not display any *operculum* (lid); however, from original excavations reports and from Valentini's drawings, we know that at least four dolia originally had a lid still in situ [5]. The dolia had been emptied during ancient excavations but at the time of sampling they had been partially filled again with soil. Small fragments of building materials and ceramic vessels had also fallen into the dolia. Therefore, after removing the post-depositional soil and cleaning with a scalpel the interior surface of the dolia, eight samples were collected from the wall close to the bottom of the containers. In the case of dolium B, two samples were taken (samples 3 and 4): sample 3 was collected from the wall that had been exposed for years while sample 4 was taken after removing the soil of the filling. Moreover, to check for post-depositional contamination, soil samples collected from the filling of dolium G (sample 15) and dolium H (sample 17) were analysed.

The sherds were mechanically cleaned to remove post-depositional contamination, then sub-sampled in the laboratory and pulverized. The powders were extracted by using two different extraction methods (see below) and the extracts were analysed by gas chromatography-mass spectrometry (GC-MS). The extraction methods are the following:

i. Chloroform/methanol extraction was performed on 2 grams of powder following Charters et al. [7].

ii. The alkaline extraction proposed by Pecci et al. [8], was carried out on 1 gram of powder.

The extracts were trimethylsilylated with BSTFA for analysis by GC-MS. Analyses were carried out with a chromatographer Thermo Scientific TS GC ultra, with a silica capillary column (30m x 0.25 μm) and a mass spectrometer Thermo Scientific ITQ 900 operated in electronic ionisation (70 eV). The mass range was m/z 40-900.

3. RESULTS AND DISCUSSION

Extracts ii. of the eight dolia, revealed the presence of both tartaric and succinic acids (Fig. 3). The samples also displayed malic and fumaric acids. Worth to note is that no tartaric acid was present in the soil samples, indicating that (i) the identified tartaric acid does not derive from post depositional contamination and, (ii) although tartaric acid is soluble in water, the ceramic matrix of the archaeological samples (pottery and plaster) allows its preservation, confirming the data provided by the existing literature. While some other fruits, such as tamarind, may contain tartaric acid [9, 10], this acid is particularly abundant in grape [9-20]. The identification of succinic acid in the extracts further suggests that the juice was fermented and, therefore, that wine, or its derivatives, were present in the samples [11]. Malic and fumaric acids are not specific wine biomarkers but they can be related to the presence of wine or its derivatives in the dolia. According to the results, the analysed dolia contained wine, confirming their use as dolia de fossa, typical of the Roman installations devoted to the production of wine.

The above-mentioned data confirm that the original function of the installation was to produce wine, as suggested by Brun and Neyme [1].

From a methodological point of view, it is important to highlight that the results are consistent with the archaeological hypothesis, confirming the reliability of the method to recognize the presence of wine in archaeological samples.

The total lipid extracts of all the dolia displayed abundant dehydroabietic and 7-oxo-dehydroabietic acids, markers of resin from Pinaceae (Fig. 3). Only in dolium G these acids were not abundant. Methyldehydroabietate was present in all extracts, except for dolium G. The latter compound has been used as biomarker for pitch extracted by burning the wood of Pinaceae trees [21]. Significantly, the soil control samples (samples 15 and 17), do not present any resin or pitch biomarkers. This confirms that the pitch/resin does not derive from post-depositional contamination, but from the application of an organic coating in the interior part of the vessels.

The use of Pinaceae products to coat dolia and amphorae is well known for the Roman period and organic residue analysis is able to detect it. This product is usually abundant in dolia used to contain wine. Also several papers based on the organic residue analysis of Roman and Late Roman dolia excavated in Pompeii, Somma Vesuviana, Calabria, Butrint and Barcelona, have highlighted presence of a pitch lining [18-21]. These products probably had a multiple function: waterproofing the vessels, protecting the ceramic matrix during the fermentation process, and giving a special flavour to the wine, that had to be similar to modern Greek *rezina* wine.

In the case of the analysed dolia it is possible to suggest that, besides the above-mentioned function, pitch was also used to glue and waterproof restored vessels, as suggested for ancient potteries at different sites. In fact, dolia A, C, E and F, display metal cramps which are indicative of ancient cracks.

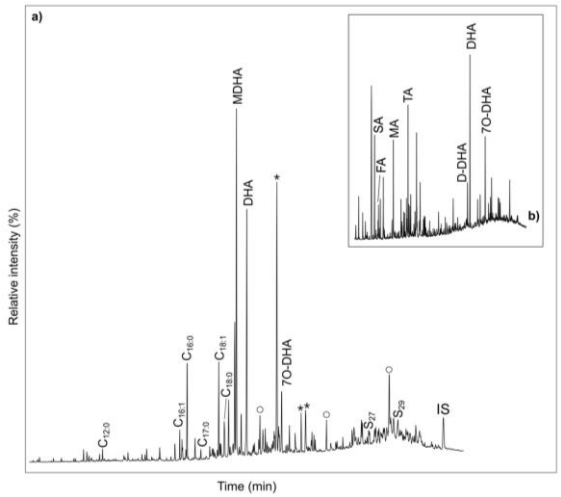

Figure 3. Gas chromatogram of dolium E from extraction a) i. and b) ii. The figure displays: saturated fatty acids ($C_{n:0}$) and unsaturated fatty acids ($C_{n:1}$), being *n* the number of carbons; methyldehydroabietate (MDHA), dehydroabietic acid (DHA), 7oxo-dehydroabietic acid (7-O-DHA), unidentified resin compounds (*); succinic, fumaric, malic and tartaric acids (SA, FA, MA and TA); cholesterol (S_{27}) and β-sitosterol (S_{29}). White dots are n-alcohols. Internal standard (IS) is n-hexatriacontane (C_{36}).

As mentioned before, the building suffered a transformation and in its latest years was used to sell food. In this regard, it is interesting to observe that extraction i. of dolia B, C, E, and H revelated high concentration of palmitic ($C_{16:0}$) and oleic acid ($C_{18:1}$) (Fig. 3). Traces of β-sitosterol were also identified, suggesting a possible plant oil origin of these extracts. The latter might be further strengthened by the identification of C_9 fatty acid, which was the most abundant among the short-chain fatty acids in both extracts (i. and ii.) of dolium H, and extract ii. of dolium C. This acid is abundant when oil is heated. The heat produced by the Vesuvian eruption could be an explanation for this phenomenon[23]. Dolium G displayed abundant palmitic acid and appreciable concentration of oleic acid pointing to a possible plant oil origin of the extract. The presence of palmitoleic acid is less conclusive since it was also found in the corresponding soil sample, and it might derive from contamination. Stearic acid was also abundant suggesting a mixture of different substances, including animal origin fats. Cholesterol is also present in the samples: it can derive either from animal products and/or post-depositional contamination, as recently suggested by Hammann et al. [24]. Extracts from dolium D revealed the presence of abundant palmitic, stearic and oleic acids, also suggesting a mixture of animal and vegetable products.

Extracts i. of dolia A and F did not display other significant compounds, besides pitch markers. This indicates that they were used solely to store wine, also during the last phase of use of the building, suggesting a continuity in the use of some of the investigated dolia.

In general, the results of the analyses indicated that the dolia were originally used for wine production and later, the majority of them were re-used to contain different commodities which is consistent with the fact that, during the last phase of use, the building was used as a caupona, where food and drinks were sold and consumed.

4. CONCLUSIONS

Organic residues analysis confirmed that all the *dolia* located in room F (*cella vinaria*) contained wine, and that room F was a wine cellar. The organic coating of Pinaceae pitch identified in all dolia is consistent with their function as dolia de fossa. Pitching was indeed a common practice in Roman times, widely attested by ancient documents and previous organic residue studies; it was most likely used to waterproof the vessels, and preserve the wine, which flavour was likely similar to modern Greek wine *rezina*, that is still obtained by storing wine in barrels pitched with pine pitch. In addition, the pitch could have also served to repair and waterproof some of the dolia that had broken and were repaired with metal cramps. Finally, the results of the analyses showed that most of the *dolia* also contained other products: a phenomenon that can be related to the re-use of the *dolia*, probably in the last phase of the building, when it most likely acted as a *caupona*, devoted to the sale and the consumption of food and drinks. The latter data confirm that organic residue analysis has a great potential to identify the function of ancient production buildings.

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