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Archaeological Evidence of Medieval Sugar Production in Sicily: A Reassessment

By R Mentesana[1] *and* J Buxeda i Garrigós[2]

SINCE MEDIEVAL TIMES, the impact of sugar production and consumption on European social, cultural, and economic development has been huge. The introduction of sugar cultivation entailed knowledge transfer and new technological requirements, such as the manufacture of sugar pots used to crystallise sugar, which is often the only archaeological evidence of its production and consumption. Sicily was one of the major sugar producers in medieval and post-medieval times, and many studies based on written sources are devoted to this phenomenon. However, the archaeological evidence seems comparatively scarce. This paper reviews the contexts and materials already known in Sicily, as well as research conducted under the EU-funded Marie Skłodowska-Curie SPotEU project. A typological classification based on sugar-pot shape and size is proposed here. This study allows the reconsideration of the archaeological evidence on the island and discusses changes in the design of sugar pots over phases, contexts and sites.

Since medieval times, the production and consumption of sugar had a huge impact on European social, cultural, and economic development. After its 10th-century introduction, in the 14th–16th centuries local and foreign entrepreneurs, supported by the aristocracy in some cases, transformed sugar production into one of the first industries in post-Roman Europe. Sugar production required 'proto-industrial organisation' from its cultivation to its processing, involving major capital and human resources (Galloway 1977; Mintz 1986, 48–52; Ouerfelli 2008, 260–87; cf discussion in Morreale 2006, 283–93). In addition, the introduction and cultivation of sugar cane entailed knowledge transfer and new technological requirements linked with the production of sugar, from the construction

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of specific buildings (*trapetum, -i*, the name used for the sugar production site from the 14th century), to the manufacture of purpose-specific objects, such as cone-shaped ceramic vessels used for crystallising the sugar. Furthermore, sugar not only changed traditional cuisine by introducing sweet flavours, but its consumption changed European society. From being a rare and precious substance used as a symbol of power by royalties and elites, it transformed into a widely affordable luxurious good, able to level social-class differences (Mintz 1986, 96). For these reasons, the impact that sugar production had on the formation of modern Europe has become one of the most discussed topics in literature over the last two centuries up to the recent in-depth work by Ouerfelli (2008).

The well-known works of Carmelo Trasselli (1982), Henri Bresc (1986), Stephan Epstein (1992) and the most recent, by Morreale (2006), have been devoted to Sicily, one of the most productive areas of the western Mediterranean. According to our reconstruction, which we have based on written sources, different sugar production phases are distinguishable. The first recognised traces of sugar production and consumption on the island belong to the mid-10th century: this first phase was probably small-scale, restricted to the area of Palermo, and directed to the royal/higher class consumption and the pharmacopoeia (Morreale 2006, 22–6; Molinari 2018; Nef et al 2021). Sugar production was in crisis by the beginning of the 13th century, as reflected by King Frederick II's instructions to find someone to reinstate it in Palermo (Ouerfelli 2008, 151–5). Only at the beginning of the 14th century is a positive change in sugar production attested: the number of *trapeti* increased considerably within and mainly outside the area of Palermo. Between the end of the 14th and the beginning of the 15th century, large sugar-production sites were installed in Carini, Partinico, Buonfornello, Collesano, Ficarazzi, and other parts of the island, such as Augusta, Acireale and Marsala. At the same time, they decreased drastically in Palermo (Morreale 2006, 93–5). Bresc (1986, 233) explains this change as driven by the need to find economically advantageous large land extensions, wood, and water resources. In any case, the small-scale production of the first phase makes room for a large-scale proto-industrial organisation involving a number of specialised workers, the creation of extensive plantations outside Palermo, and a complex organisation from its production up to the export of Sicilian sugar to the north of Italy and Europe. It is probable that an economic crisis between the end of the 15th and the beginning of the 16th century affected sugar production in Sicily,

though it seemed to reflourish in the mid-16th century until its final collapse in the mid-17th century (Morreale 2006, 225–74).

These studies are mostly based on written resources and draw a picture of impressive sugar production on the island, which is not what is reflected in the archaeological data, above all in comparison to the eastern Mediterranean and the Levant (cf von Wartburg 1983; 2014; LaGro 2002; Jones 2017; Shapiro et al 2020). This evidence relates to sugar pots,[3] often the only archaeological remains of sugar production and consumption. In the 1970s, the pioneering works by Franco D'Angelo (1973) and Gioacchino Falsone (1974), who identified the first sugar cones on the island — found in Palermo, led the way to other such identifications during the excavation of Himera (Bonacasa 1976), of the Castello della Favara at Maredolce (Tullio 1996), and up to the most recent, that of Partinico (Lo Cascio 2002) and Carini (Ardizzone 2011 and Cipriano 2014). This last one having the most abundant material related to sugar production found and studied in detail to date. Therefore, though fragmentary, the archaeological evidence of sugar production in Sicily is noticeable compared to other Mediterranean areas displaying the same phenomenon. Instead, as will be discussed further in detail, the issue of the archaeological evidence of Sicilian sugar production is related to a fluctuating chronology of some of these findings due to the characteristics of the context (reuse, dumps and landfilling), and the lack of dating material associated to the sugar pots. In addition, in most cases these vessels have been studied mainly on their physical attributes, taking the rim diameter to determine the size of the cones. Therefore, there are significant research gaps which still need to be filled. The manufacture of these vessels was introduced in different areas of the Mediterranean as part of the *sugar production package*, but little is known about whether these vessels were imported or produced locally, whether a standard design was reproduced over time and across areas, or if local ceramists adapted their tradition to produce such specialised vessels. The *SPotEU* project,[4] aimed to explore the development and impact of sugar production in western Europe (modern Sicily and Spain) on ceramic manufacture from an interdisciplinary

[3] In this paper we refer to the generic term 'sugar pots', including sugar cone moulds and molasses collecting jars (in brief, sugar cone and molasses jar).

[4] 'Sugar Pot manufacture in western Europe in the medieval and post-medieval period (11th–16th centuries AD)', funded under the Horizon 2020 Marie Skłodowska-Curie actions (grant agreement: 797242).

perspective, integrating archaeological science, conventional archaeology, and written resources. In order to reach these goals, the known archaeological evidence on the island was reviewed, focusing on morphometric and technological details to note some features not considered before. This paper reviews the published Sicilian archaeological contexts and adds the new data developed during this project to provide an overview of the phenomenon on the island.[5] The raw data presented in this study are openly available in the CORA Research Data Repository (Mentesana 2022).

ARCHAEOLOGICAL EVIDENCE OF SUGAR PRODUCTION IN SICILY: PREVIOUS AND RECENT DATA

A re-examination of existing contexts and materials is presented together with the new data obtained as part of the project (Fig 1). When needed to consider specific technical details, some published vessels were restudied and redrawn, photographed and inserted in a database together with the newly studied vessels. Some were sampled to for analytical study, which is part of another publication, where some details about possible forming techniques are described (Mentesana et al 2022). A preliminary typological classification is here attempted based on the rim profiles, as these demonstrated most of the variations across sites. This classification proceeds from Falsone (1974) and names cones progressively with numbers, and molasses jars with letters (variant with a pointed number, ie, type 1.1). Vessel features have been described accordingly to the guide published by the Medieval Pottery Research Group (MPRG 1998), integrating with those terms already in use (Jones 2017). Measurements are always taken considering the vessel's internal portion (rims and holes). The complete list of vessels studied has been published in an open access repository (Mentesana 2022). These data were used to study the change in vessel design over time and across contexts.

SITES AND MATERIALS

Castello della Favara in Maredolce, Palermo (MAR)

The Castello della Favara is located in the south-eastern part of Palermo, in the

[5] The provenance and technology of the sugar pots cited in this paper is published in Mentesana et al 2022.

present-day neighbourhood of Brancaccio, not far from the coast (Fig 1, c = 1). It was excavated for the first time under the direction of Amedeo Tullio in 1992–93 (Tullio 1996; 1997), who excavated both within the chapel and outside of the main building, close to the dam of the artificial lake of Maredolce. This last area is of interest; a two-metre long trench called Trincea I or Saggio I with different strata (according to Tullio's excavation) relating to the filling of the artificial lake. In these layers, fragments of sugar cones and molasses jars were recovered, which Tullio asserted were evidence of local sugar production, along with *noria* (waterwheel) vases, amphorae, and glazed vessels. In his 1997 publication, Tullio dated these layers to the mid-13th century, when a phase of transformation occurred from residential to agricultural/industrial of Maredolce (Tullio 1997, 473). However, in his earlier publication of the previous year, he had dated the evidence to the beginning of 15th century, when written sources refer to the installation of a sugar production area. The 2000–2001 excavation campaign did not reveal any sugar-related remains (Tullio 2002), while the 2014 excavation directed by Emanuele Canzonieri and Stefano Vassallo uncovered a larger quantity of sugar cones and molasses jars. These were found in the superficial layers, but in contact with the four kilns found in the south-western part of the porch of the building. These kilns were built by cutting the pre-existing structures and therefore refer to a later phase of the use of the area, probably not later than the beginning of the 15th century AD (Canzonieri and Vassallo 2014, 275).

We could review the material from Tulio's excavations (Fig 2) as the only available when this study was performed. Both sugar cones and molasses jars were found, some of which had already been published by Tullio (1997). The only entire vessels are the sugar cone MAR005 and the molasses jar MAR008; the others are fragments of the lower parts (MAR001–003, 007) and rims of sugar cones (MAR004, 009–0010) and a rim of a possible molasses jar (MAR006). The complete cone MAR005 has a straight rim, slightly everted; this is labelled type 1. The other cones are characterised by a bevelled rim, like the ones already known from Palermo (Falsone 1974) and labelled here as type 2. The rim diameter of the cones ranges from 24 to 26 cm. The bases of the cones have a hole that varies in diameter (from 1.9 to 1.4 cm) and is often not perfectly centred on the base. The entire molasses jar MAR008 correspond to the type with a cylindrical body slightly bending inwards at the neck and everted rounded rim similar to those of type B published from Palazzo Steri —

Chiaramonte; MAR006 is more similar to the type A from the same site, here named A.1 as later explained, even though the attribution to the molasses jar of this fragment is still uncertain (Falsone 1974). According to the chemical and petrographic analysis results, these vessels were all made in the area of Palermo (Mentesana et al 2022).

A major proportion of the vessels comes from stratum V, except for MAR004 from stratum VI and MAR005 and MAR007 from stratum IV. According to what was already published by Tullio (1997), the few glazed materials found together with the sugar pots were dated between the 12th and the 13th centuries AD. A systematic review of the excavation is needed to attempt a proper definition of the chronological range of these layers, but the end of the 13th century AD could be considered as the possible terminus ante quem for the use of these sugar pots. Regarding the potential sugar production at the site posited by Tullio, the compresence of sugar pots and *noria* vases suggests that agricultural activities were taking undertaken in the vicinity, probably sugar related. This was probably small-scale, as the minor amount and size of cones suggests, and limited to the palace's consumption. This small yield would be in line with the sugar role in this earlier phase, and different from the later development of the (proto-)industrial sugar production in Sicily, which probably also involved the Castello della Favara in a later phase. A first glance at the sugar cones from the Vassallo/Canzonieri excavation, on display at the museum, confirms that they are larger and different in design from those found by Tullio. It could be assumed they belong to a later phase of sugar production/consumption at the place, possibly corresponding to the 15th century, when the presence of the *trapetum* of P Afflitto is noted in the area (Trasselli 1982, 113, endnote 103). Further work is needed to verify this hypothesis.

Convento di San Giovanni di Baida (BAD) and San Giovanni degli Eremiti (PAM), Palermo

In the storeroom of the Archaeological Museum ‘A. Salinas’ of Palermo were found some sugar cones which pertain to the restoration of the vaults of the convent of San Giovanni di Baida (BAD), located on one of the hills west of Palermo (Fig 1, c = 2). Unfortunately, research conducted at the archives of the Soprintendenza dei Beni Culturali e Ambientali of Palermo did not clarify the date or exact location of the restoration: that is, whether it was the church or the convent. It is known that the church was damaged during

the Second World War, and some works were later undertaken, though unauthorised by the Soprintendenza of Palermo that was concerned about the damage on some of the original parts of the building. It is presumed that the cones were extracted from the vaults during these works and eventually given to the Archaeological Museum. This may have happened prior to 1960s to 1970s when all the archaeological finds were stored in the museum rather than in the Soprintendenza.

The seven cones found are of similar size and shape: an elongated conical shape of 53–5 cm height; a rim diameter of 26–30 cm; a slightly everted, rounded rim and cordon below the rim; a slightly flattened base with a 1.8–2 cm hole. On the basis of the rim profile, this is considered here as type 3 (Fig 3). On the exterior, they all show yellow-brown flows, probably traces of the sugar syrup and some traces of the cement used to fit them into the vaults.

The homogeneous features suggest these cones came a single production centre and probably belong to the same chronological range. A terminus ante quem between the ends of the 14th and 15th centuries is estimated. The construction of the church and convent started in 1388 under Manfredi III Chiaramonte, who died in 1391 leaving the convent unfinished. In 1496, the archbishop of Palermo, Giovanni Paternó, obtained the right to restore the structure and modify part of the convent (Caracciolo 1938). It is possible that the cones were included in the vaults during the first phase of construction at the end of the 14th century. However, as it is unknown whether the cones were retrieved from the church or the convent, a longer period up to the end of 15th century could be considered. The analytical study also indicates the vessels were made in the area of Palermo (Mentesana et al 2022).

The reuse of ceramic material, usually large closed vessels, to fill the vaults and ceilings of buildings is a well-documented practice in Sicily from the Middle Ages up to at least the 18th century (Ardizzone 1999). Another sugar cone used in the same way is stored at Galleria Regionale Palazzo Abatellis (PAM). The cone, database entry PAM001, was published by D'Angelo (1973) and Fabiola Ardizzone (2012, 131 and 189), and is extremely similar in shape and size to those from BAD: an elongated conical shape of 56 cm in height; an everted rounded rim (27 cm), with an outer cordon and flattened base with a hole of 1.8

cm.[6] D'Angelo states that the cone was found in the vaults of the San Giovanni degli Eremiti, a 12th-century church in Palermo's city centre.[7] Ardizzone also dates it to the 12th century, though based on a different argument: the cone was found stored at Palazzo Abatellis together with 12th-century amphorae. These came from the restoration of the vaults of some Norman buildings in the early 20th century (Ardizzone 2012, 145: see illus p 131 and fig 49b).

The lack of further contextual information could lead us to assign this cone a terminus ante quem of the 12th century. However, while the construction of the church of San Giovanni degli Eremiti finished in the mid-12th century, the attached cloister and convent were built later and went through subsequent building phases from the 15th century onwards (Torregrossa 2013, 36). If the cone was retrieved from another part of the building rather than the church, a terminus ante quem of the 15th century could be safely proposed, which is more aligned to that of BAD. The similarities with the cones from BAD and their dissimilarities with those from MAR are striking. As discussed later in the paper, cones of larger size are common in a later phase when sugar production on the island intensified. Having said that, this is an argument based on vessel form, and further research based on well-dated material might clarify the chronological placement of this type of cone.

Palazzo Steri — Chiaramonte, Palermo (STE)

Palazzo Steri — Chiaramonte (STE), situated in the present Piazza Marina, near the Palermo's harbour, was completed in the early 14th century and is renowned as the residence of many Sicilian rulers, first among others being Manfredi I Chiaramonte. In 1973, the excavation directed by Vincenzo Tusa during restoration works revealed a conspicuous material culture relating to different phases of the building (Tusa 1973). Further research was undertaken by Falsone, who in early 1974 published a detailed paper on the sugar pots, followed more recently by publication of the chronological sequence and materials (Falsone

[6] These measurements differ slightly from those published by Ardizzone (2012) as they have been retaken for this study using the same procedure as for the other vessels. Clarify what this means and add to main text. Please, leave this comment here.

[7] D'Angelo states the cone was located in that church in the 1970s and that the priests confirmed it was taken with other vessels from vaults and other nearby buildings during restoration works (D'Angelo, pers comm).

1974; 2015). Falsone classified the cones into large and small ones based on rim diameter, and the molasses jar into type A (slightly everted round rim and downward bending collar, like a hook, larger than type B) and type B (rounded splayed rim, cylindrical shape, smaller than type A). He concluded that the three whole vessels found in the trench (Saggio) IV, stratum 4, dated to the 15th century.

During this review of the STE materials, eight fragments of sugar cones and five of molasses jars were found (Fig 4). Of the cones, the two complete ones (STE001 and STE009), one of the bases (STE014), and all the rims were originally published in 1974 by Falsone. The rims are all the same type, everted bevelled rim (type 2), and ranging between 24–7 cm, except for the small cone (STE001), which has a rim diameter of 19 cm. The sole cone base (STE014) probably pertains to one of the rims and has a hole of 1.8 cm as has the large cone STE009. Two molasses jars of Falsone's type A have been found (STE002, STE018) with rims ranging between 8.5 and 9.8 cm and heights of 30–6.5cm. Additionally, two of Falsone's type B (STE007, STE019) were found, with a rim diameter of 9.5–9.7 and a height around 24.5–26 cm. Falsone's type A is here labelled A.1 as further variants in this rim shape have been identified. STE008 diverges from type A.1 as the rim does not bend downwards but straight, forming a disc-like collar; this has been labelled type A.2. As well as these, some vessels distinguished by a flat everted rim, defined by Falsone as '*cantaro*' (1974, 105), were found (STE003, STE004, Fig 4). These have a rim diameter of 21–6 cm, making them unsuitable for use as molasses jars as the cone will fall entirely inside the cantaro, as already indicated by Falsone. In the same layers as the sugar cone, some '*noria*' vases were found (STE005–006, STE015–017), which are clearly distinguished by the squared rim, the upper part of which shows wheel traces and the interior scraping marks created by the inversion of the vessel on the wheel during manufacture and the subsequent removal of the clay excess (Fig 4, STE017). These last two categories, *cantaro* and *noria*, have been examined and included in this list, only to highlight their distinction from sugar cones on the basis of those manufacturing traces highlighted above, but observed only in the context of STE materials. Sugar pots, and *noria* and *cantaro* type vessels were all made in the Palermo area (Mentesana et al 2022).

Thanks to Falsone's 2015 publication of the excavation's chronological sequence, the fragments of sugar pots are attributable to specific phases. The sugar pots come from Saggio IV, stratum 4, a sondage in the basement on the southern part of the palace's court. This excavation revealed a six-metre-deep well filled with different materials; layer 4 was of burnt soil and ceramics dating from the end of the 15th to the beginning of the 16th century (‘phase F2’, Falsone 2015, 428). The molasses jar STE018 originated from Saggio I, layer 3, a sondage below the basement on the eastern part of the court, which revealed a rock-cut tunnel with deep stratification; however, layer 3 pertains to the same chronological phase F2.

The sugar pots from STE all share a similar design, and belong to the period when the building was the residence of the Viceré. The compresence of *noria* vessels and sugar pots, common also at MAR, indicates that agricultural activity occurred within the city wall, as suggested for earlier phases (Nef et al 2021, 182). Carmelo Trasselli (1982, 67) reports that some *trapeti* were located in the same neighbourhood, and Mohamed Ouerfelli (2008, 283) was able to identify some *trapeti* between the Kalsa and the Albergheria neighbourhood in the eastern part of the city.

Underwater cone, Palermo (UND)

Another large sugar cone was found in the Archaeological Museum A. Salinas of Palermo storeroom. According to the museum inventory, it was a maritime find, probably from the Palermo gulf. The cone has an everted, rounded rim and rounded cordon below the rim as seen on type 3 cones; the rim diameter is 32 cm; the wider belly and the bottom are slightly flattened with a hole of 2.4 cm (Fig 5). The cone surfaces are covered with a calcareous encrustation typical of marine findings. The cone design is similar to those found at the BAD, but the diameters of the rim and hole are bigger than any other cone analysed for this study. Unfortunately, the discovery is not linked to any contextual information, and analytical study of the fabric did not clarify its provenance (Mentesana et al 2022).

Partinico (PAR)

Partinico is a small town on a hill above the gulf of Castellammare, in-between the present-day provinces of Palermo and Trapani. Documentary sources referring to sugar cane cultivation in the area date to the end of the 14th century and continue to the beginning of the 17th, indicating that, in those centuries, most of the plains along the coast and the river Nocella were dedicated to sugar cane cultivation and wine plantation (Lo Cascio 2002, 41–2; Morreale 2006, 101–11). Besides the written records, archaeological evidence of such large-scale production is scarce. Filippo Lo Cascio identifies some remains of a *trapetum* in the ruined walls, serving as a defence of the industrial building, surrounding the Torre San Cataldo (Lo Cascio 2002, 44–6). Also, the name of the nearby town of Trappeto recalls the presence of a *trapetum* there. However, no excavation has been performed, and the ceramics presented here have been collected during ground survey. Most of the ceramics stored at the Museo Etno-Antropologico ed Archeologico of Partinico were collected by Lo Cascio on the left side of the Nocella river, within the vicinity of Roman kilns (PAR004–011);[8] while others were found at Cala dei Muletti (PAR001–002, probably the bottom and upper part of the same cone) and Castellaccio (PAR003).

The sugar cones all share similar features and designs (Fig 6). The rim fragments have a bevelled profile (type 2), similar to the cones found at STE, and diameters ranging from 24 to 28 cm (PAR008–009 are too small for the diameter to be determined); only PAR008 has a slightly different profile with a lip going downwards. The bottom parts of the sugar cones are conical and have a hole diameter ranging between 1.8 and 1.9 cm. The thickness of the vessel wall varies considerably from the top rim to the bottom and around the circumference.. Similar traits have been observed in some of the cones from MAR, perhaps due to the forming method used to shape the cones, which might encompass both hand-building and wheel-fashioning techniques at different stages (Mentesana et al 2022). The molasses jars' rim fragments share similarities with those from STE: PAR007 and PAR010 have a rim which would be classified as Falsone's type A.1, and PAR011 is similar to Falsone's type B with the everted rim. While sharing a similar design, half of the sugar pots retrieved in

[8] After a review of the material retrieved from Lo Cascio, the material has been renumbered, as a couple of fragments were stuck together, as for example PAR005a-b. Lo Cascio's publication numbers are included in the museum/publication id.

Partinico were produced in the area of Palermo and the other half probably produced around Partinico (Mentesana et al 2022).

The chronology of these fragments cannot be determined with certainty. They might be later than the end 14th century when the first written sources referring to sugar production in the area begin, but they could be from an earlier phase not recorded by text. Considering their shape and profile, they are similar to those from STE (end of the 15th to beginning of the 16th century). This chronological attribution is, however, only based on typological features.

Himera — Buonfornello, Termini Imerese (HIM)

The site of Himera (HIM) is located on the northern coast of Sicily on a plain crossed by the Imera river. The name Buonfornello, indicative of a structure for cooking/heating, was probably given to the village located in the same area in the 16th to 17th century (D'Angelo 2021; cf Bonacasa 1976, 631). The first archaeological excavation in the late 1920s was directed by Pirro Marconi (1931, 16–18). This documented the presence of a tower and several buildings, among which was a brick workshop related to the village of Buonfornello, which was demolished to reveal the structure of the 5th cent BC Temple of Victory. Later excavations directed by Nicola Bonacasa (1976), in the area south of the temple revealed structures and materials from the 12th to the 16th century, including numerous kiln wasters probably related to the brick workshop. In these layers, were found seven fragments of sugar cones dated to the 12th to 14th centuries (Bonacasa 1976, 640, n 32). These fragments were reviewed by D'Angelo (2021), who divided them into two types based on comparison with the sugar cones found in Palermo: some with a straight profile dated to the 11th to 12th century; others with the double-folded profile dated to the end of 15th to the beginning of 16th century. D'Angelo also found evidence of in situ production of the polychrome glazed Polizzi-style ceramics, suggesting that sugar pots might have been produced in the same place to supply the sugar production in the area. The most recent excavation was to the northern side of the temple occupied by some buildings, named Case Cobisi, contemporary with Buonfornello village and nowadays the location of the Archaeological Museum, 'Pirro Marconi'. During this excavation, under the direction of Stefano Vassallo, some strata belonging to a medieval/modern phase were found linked

with circular structures, probably the base of milling structures, and containing numerous fragments of sugar pots (Vassallo 2017, 195, tav X).

The examination of the material identified 50 fragments of molasses jars and 126 of sugar cones. The fragments of molasses jars are largely from rims and fall into type A.1 (Fig 7, HIM071) and A.2 (Fig 7, HIM029) already described. A few rims show a profile which seems to be a variant of A, named here as A.3, with a straight round rim and a collar of triangular section (Fig 7, HIM036). No rims of type B were found on this site. All rim types have a diameter between 9 and 10–11 cm. Molasses jar's bases are thickly walled, not well-trimmed and ribbed, and ranging in diameter between 13 and 16 cm (Fig 7, HIM060).

The major part of the sugar cone rims is outwardly double folded, creating a curved profile named type 4. Three variants have been identified based on the size of the second fold: variant 4.1 has a small second fold (Fig 8, HIM007); in variant 4.2, the two folds are almost the same size (Fig 8, HIM008); in variant 4.3 there is a larger distance between the first and the second fold (Fig 8, HIM057). A few other cones have a straight, rounded rim with a small exterior cordon named type 5 (Fig 8, HIM148). Unfortunately, no whole vessel could be reconstructed, but the bases and the rims might belong to middle-sized cones. The bases found are rounded with a hole diameter ranging from 1.9 to 2.4 cm. One sherd has a flat base with a hole of 0.6 cm, which probably belonged to a cone of smaller size (Fig 8, HIM176).

Only one vessel shows a type 2 rim, (Fig 8, HIM175), the only complete vessel reconstructed from the several sherds found by Bonacasa (1976, TAVOLA CIV, 6). It differs in design and manufacture from the others, more similar to the cones from Palermo than those from HIM: 38 cm in height, with a rim diameter of 24 cm and a hole of 1.8 cm, thick walls, and traces of both wheel throwing and hand forming techniques . HIM174 share similar characteristics to this last one, even though the rim is missing. Therefore, except for these last two items, the cones found at the excavation of Case Cobisi and from the southern temple area are quite homogeneous in design and probably also size (except for HIM176), and they differ from those found in Palermo and Partinico. The analyses of the fabrics confirmed that the sugar pots were made locally at HIM except for HIM174–175, whose provenance points to Palermo (Mentesana et al 2022).

The few glazed ceramics found with these cones belong to the Polizzi- (D'Angelo 2021) and Robba styles (Bagnera and Neff 2018, pl 29, 301), indirectly dating the layers to the end of the 15th to the beginning of the 16th century AD range. It is uncertain whether the two type-2 cones from the Vicory Temple excavation can be assigned to the same chronological range, as they were in a mixed stratigraphic context. Both Bonacasa and D'Angelo considered these to belong to an earlier phase due to their rim profile, which, however, is not dissimilar from those found at STE. For now, these two will be marked chronologically as the others but with a question mark (Tab 1).

The large number of cones found during the excavation of Case Cobisi, the presence of a watermill near the building, and the several milling stones also found might suggest a sugar production centre at this location. The production of sugar pots for the *trapetum* might have occurred here, as suggested by D'Angelo for the Polizzi ware and some written sources (cf Bresc 1986, 245). Rosario Termotto (2005, 47; 2012) states that the *trapetum* of Buonfornello was active from at least 1433 and that the area between the Himera and Rocella rivers was all devoted to sugar plantation and production up to the mid-17th century, at which time cultivation changed to rice and cereal (Termotto 2005, 47; 2012; cf D'Angelo 2021).

Other sugar production contexts

Sugar pots have been retrieved from other contexts in Sicily and though not part of this study are cited to add to the general overview. Recent papers refer to sugar cones dating to Islamic phases found in excavations at Corso dei Mille and the Gancia in Palermo (Molinari 2018, 158; Nef et al 2021, 192). These have yet to be published and may represent the earliest evidence for sugar production on the island. Sugar cones are also evident on the northern side of Palermo, in the courtyard of the Palazzo Arcivescovile, along with some 11th- to 12th-century archaeological remains excavated in 1999 (Spatafora 2004). However, the cones were not recovered through excavation, but were found in vaults during the restoration works of the Palazzo Arcivescovile after the 1968 earthquake (Diocesi di Palermo, pers comm). The construction of the main building began in the mid-15th century, therefore the cones were probably inserted in this first construction phase. In terms of shape and rim profile theses cones seemed similar to those found at BADaccording to what

could be observed by one of the authors (RM) for this study. In contrast, the conical vessel found in the vaults of Villa Napoli (Ardizzone 2001) does not look like a sugar cone because of the wide opening of ca 10 cm at the bottom, which would not retain the syrup once poured inside.

Outside Palermo, the finds from Villagrazia di Carini are surely the most abundant and systematically studied (Ardizzone 2011; Cipriano 2014). During the excavation of the catacomb, many sugar pot fragments were found in the filling layers of the catacomb. The *trapetum* was built on top of the catacomb, which seems to have been used as both landfill and for some of the production operations, as testified by the milling stones and some structural adaptations (Cipriano 2014, 77). Unfortunately, no dating material has been found, and sugar production is generically dated to the end of the 14th century, when written sources refer to several *trapeti* working in the area (Traselli 1982, 142–5; Bresc 1986, 233; Lo Cascio 2002, 52; Giuffrida 2012). Sugar cones were divided into several types according to variations in profile by Cristina Ardizzone (2011): type F1 has a bevelled rim similar to those of STE, while the other types present a double-folded rim similar to those found at HIM and BAD. Similarly, the rims of molasses jars closely follow the profiles found at HIM.

DESIGN OF SUGAR POTS OVER TIME AND SITES

Acknowledging the chronological uncertainties discussed above, this study of sugar pot morphology seeks patterns in terms of the design of these vessels linked to site and phases. Of the 225 sugar pots examined, 160 could be included in the typology proposed based on the rim profile (Table 2). The statistical data treatment has been performed using 'R' programming language (R Core Team 2021). After initial presentation of the data in contingency table and bar chart (Table 2), correspondence analysis in combination with the chi-square test (χ^2) was used to explore the existing relationship between sites and types. An association between sites and types exists if the *p* value of the chi-square test is lower than (<) 0.05.

As it is clearly shown in Table 2, regarding molasses jars, type A is the most common in all the contexts examined, but variant A.1 is the most represented in all sites. In Palermo and Partinico, type B is attested in the earlier (MAR) and the later sites (STE and PAR). At the

same time, type A appears only in later sites (Fig 9) except for one individual in MAR, (MAR006) which identification as molasses jar is nevertheless doubtful due to the small fragment retrieved.

The distinction between the PAR and Palermo sites, on the one hand, and HIM, on the other hand, is much clearer regarding sugar cones (Table 2). Cone types 1 to 3 are present exclusively in PAR and Palermo sites with the exclusion of one individual (HIM175) found at HIM, although it had been produced in Palermo (Mentesana et al 2022). Type 1 is found only at MAR and might be considered the earlier type among the ones examined, while types 2 and 3 are also found in the later contexts of both Partinico and Palermo (Fig 10). At HIM, different types of cones (4 and 5) prevail with some profile design variants, which also seem to be restricted chronologically to this site.

The correspondence analysis of these ceramic assemblages (Table 2) shows a significant association of BAD, PAM and UND sites from Palermo, at the left side of the first dimension (Fig 11, a), with sugar cones type 3 (χ^2 (60, n 160) = 297.78, $p < 0.001$). Once excluded from those assemblages, it is also clear that HIM, at the left side of the first dimension (Fig 11, b), is significantly associated with molasses jars type A.3 and sugar cone types 4 and 5 (χ^2 (27, n = 151) = 130.03, $p < 0.001$). On the right-hand side of this biplot (Fig 11, b), a difference is visible between PAR and STE, on the one hand, and MAR, on the other. This difference is due to the association between MAR and the sugar cone type 1, only found at this site. However, these three sites cannot be differentiated because this association is based on just one individual being not significant (χ^2 (8, n = 24) = 4.54, $p = 0.805$).

Once the association between types and sites and the possible chronological implications are examined, it is necessary to explore the possible link between types and sizes. With molasses jars, there are rim diameters of 34 jars (HIM = 25; MAR = 1; PAR = 3; STE = 5), mainly related to types A.1 and A.2 (A.1 = 15; A.2 = 10; A.3 = 5; B = 4). The molasses jars show a narrow rim diameter range, usually between 9 and 11 cm, with the HIM vases in the upper part and the other sites in the lower one, except for MAR which reaches the highest value (13 cm) (Fig 12). Type A shows less variation in diameter than type B, but this last one appears in earlier sites, such as in MAR, and more variations could be expected. In

any case, the size variation in rim diameter does not seem strictly correlated to the types and sites examined. The one-way analysis of variance (ANOVA), that compares the means of different groups, confirms that there is no statistically significant difference between the types ($F(3, 30) = [0.453]$, $p = 0.717$, ie $p > 0.05$).

With sugar cones, there are rim diameters of 72 cones (HIM = 51; MAR = 4; PAR = 2; STE = 6; BAD = 7; PAM = 1; UND = 1), mainly related to type 4.1 (1 = 1; 2 = 12; 3 = 9; 4.1 = 39; 4.2 = 8; 4.3 = 1; 5 = 2). Most of the cone rim diameter are in the range of 24–8 cm, which compared to other contexts indicates they were of medium size (von Wartburg 1983; 2014; Fábregas García and García Porras 1998; Jones 2017); and only a few below and above this range, which correspond to smaller and larger cones (Fig 13). The sites in Palermo (BAD, PAM, STE, MAR) and Partinico (PAR) show the whole range of rim diameters: those from MAR are in the lower part of the range, and those cones from BAD are in the higher. The one-way ANOVA confirms significant differences among the means of the different types ($F(6, 65) = [2.974]$, $p = 0.013$, ie, $p < 0.05$). John Tukey's honestly significant difference (HSD) test for multiple comparisons enables the two by two comparison, revealing significant differences between type 3 (mean = 27.89; sd = 2.03) and types 2 (mean = 24.83; sd = 2.29), 4.1 (mean = 25.28; sd = 2.01) and 4.2 (mean = 24.75; sd = 1.49), for which the p-value is lower than 0.05. Types 1, 4.3 and 5 have too few individuals (one or two) to provide any significant result. Thus, regarding rim diameter, type 3 is the only one that exhibits a significant difference in having larger values.

With the hole diameter, very few sugar cones (43) are complete enough to use the rim to assign type. By site, there are six from BAD (all of them complete, type 3), 22 from HIM (only one complete, but whose provenance is from Palermo, type 2), six from MAR (one type 1 and one type 2), one from PAM (type 3), four from PAR (all incomplete), three from STE (two of type 2), and one from UND (type 3). The box plot (Fig 14) shows these available hole diameters. It seems clear that HIM sugar cones have large values but confirmation is needed using the one-way ANOVA, excluding three sugar cones from HIM. HIM174 and HIM175 are excluded because the archaeometric analyses confirmed their production at Palermo. Additionally, HIM176 must correspond to a completely different type of sugar cone, much smaller (hole diameter = 0.6 cm), as confirmed by its outlier position as the smallest value in Fig 14. As expected, one-way ANOVA confirms that there are significant

differences among the means of the holes of different sites ($F(6, 33) = [16.14]$, $p < 0.001$). Tukey's HSD test for multiple comparisons reveals that significant differences occur between HIM (mean = 2.27; sd = 0.18) and BAD (mean = 1.90; sd = 0.06), MAR (mean = 1.58; sd = 0.21), PAR (mean = 1.87; sd = 0.05) and STE (mean = 1.57; sd = 0.40). Moreover, significant differences between UND (2.4 cm) and MAR and STE are also confirmed.

Comparison of rim and hole diameters for those sugar cones with complete profiles (n = 13), is possible with a few considerations. The total number of sugar cones that have provided either rim or hole diameters is 99 (excluding HIM174, 175 and 176, for the reasons explained above). Seven were recovered from BAD, and six of these have a complete profile. In contrast, at HIM, all 69 sugar cones have uncomplete profiles. MAR, PAR and STE exhibit similar frequencies with eight, six and seven sugar cones respectively from which two, zero and two are complete. Finally, PAM and UND are singletons with complete profiles. The differences by site between complete and uncomplete profiles are significant (χ^2 (6, n = 99) = 63.46, $p < 0.001$). If the extreme cases are not considered (BAD and HIM), there are no significant differences (χ^2 (4, n = 23) = 7.81, $p < 0.001$). It is then clear that this cross-examination of rim and hole diameters will be biased by a high weight of BAD observations and the total absence of HIM complete sugar cones. In order to retain data from HIM, the mean of the rim and hole diameters recorded are considered. The plotted data (Fig 15) show that there is a high linear correlation between the rim and hole diameters in the BAD, MAR, STE and PAR individuals (r = 0.91). The regression line for these sites has been drawn in the plot. HIM mean values fall clearly apart from this linear correlation, as reflected by the correlation coefficient when those values are considered (r = 0.78). While having a similar rim diameter range, these last ones have a different hole diameter proving that they correspond to a different design.

DISCUSSION AND CONCLUSION

Seen as a whole, the archaeological evidence of sugar production in Sicily is not as modest as is first superficially apparent. In terms of geography, it is concentrated in the Palermo area, extending west to Partinico and east to Himera — Buonfornello. Written records indicate that this was an area of continuous and intense sugar production across

centuries (Traselli 1982; Bresc 1986; Morreale 2006). However, this concentration of evidence on the northern part of the island might also be due research gaps in other areas, and materials relating to sugar production not recognised during some excavations. Fragments of the sugar cone and molasses jar rims can be easily mistaken for other wares, especially if the rim diameter is not recorded and other features noted. *Noria* vessels, for example, could be distinguished from molasses jars in the cases examined based on the forming traces left on the rim and interior, while the *cantaro* based on its wider rim diameter. One of the purposes of this publication is to illustrate the variability of the sugar pots across phases and offer a reference for their future identification from Sicilian archaeological.

The archaeological evidence of sugar production in Sicily lacks a secure chronology, mainly due to the discard and reuse of these vessels in difficult-to-date contexts, but also due to the lack of an overview of the materials on the island as has been attempted here. Regarding sugar cones, types 1 and probably 3, seem to be linked to the earlier phases of sugar production (11th and 13th centuries), while types 4 and 5 relate more to the later phases (14th and 16th centuries). Type 2 could be found in earlier and later contexts and therefore is lesser indicative in terms of chronology. The first phases of sugar production are still to be better defined, as well as the later phases. The absence of sugar pots from later contexts is striking, even though according to written records Sicily was actively producing sugar up to the 17th century (Morreale 2006). A temporal tendency towards more elongated conical shape is also noted in Sicily. In other sites this has been related to 15th—16th-century sugar production changes (von Wartburg 2014, 237–9), and in our case it might occur at a slightly earlier phase as elongated cones are present at Convent of Baida. Conversely, no clear chronological link can be made for molasses jars, as the two types are present in both earlier and later sites. Only the example from MAR differs clearly from the others of type B in terms of height and body shape, which would need further consideration in future research.

The observed difference in design is correlated not only to chronology but also to the sites: the sugar cones from Himera — Buonfornello (types 4–5) are different from those produced at Palermo and Partinico despite belonging to the same chronological phases.

Potters were employing different design choices, even though taking into consideration the general shape requirements. This is also evident in other technological aspects of the manufacture of sugar pots, such as on paste preparation and firing regimes choices (cf Mentesana et al 2022). Regarding molasses jars, type A is the most common and some of the variants are linked mainly to Himera — Buonfornello. Only a few type-B molasses jars are linked to the sites in Palermo and Partinico and absent at Himera — Buonfornello.

Among the sugar cone types, only type 3 can be associated with slightly larger rim cones, while for the others no clear link could be observed as they fall in the same range. conversely, the hole diameter easily distinguishes the sugar cones produced at Himera — Buonfornello from those produced in the Palermo and Partinico area, which show smaller hole diameters. Could this be due to the use of different tools in making ceramics, or measurement standards, which allow repetition of sizes without the use of moulds. Alternatively, it might be due to a technological choice by Himera's potters to make larger holes in order to increase the discard of the molasses when the sugar is crystallised.

This study has shown that rim diameter can provide a general view of the size of the cones, but also that the height should be considered as it affects the actual volume of the sugar held. Not much is known from written sources about the volume of these vessels: Bresc states (though his source is unknown) each *trapetum* involved between 1,000 and 2,500 sugar cones and that a cone had a capacity of 10–12 ‘quartucci’, between 8.5 and 10.3 litres (Bresc 1986, 247). Unfortunately, volume estimation is only possible with entire vessels and an exploratory study done with some cones of the same rim diameter presented in this paper reveals much variation in the volume, which will be further explored in a future publication.

If the rim and hole diameter could be taken as evidence of the size of sugar cones, the overall picture is that the majority of the cones produced and used from the studied sites belong to the medium-sized category (24–8 cm) and only a few ones to the small-sized category. This evidence has an impact on considering whether only raw sugar (once or twice purified) was produced in Sicily; or also refined sugar (purified three times). This last process entailed a considerable loss of volume of the raw sugar, and therefore smaller sugar cones were used for the crystallisation (Ouerfelli 2008, 275–6). The earliest mention of Sicilian

refined sugar at several markets in Italy dates to the end of the 14th century (Rebora 1968; Trasselli 1982, 102–3; Morreale 2006, 154–64), but then it disappears from written records (Ouerfelli 2008, 246). On the other hand, in the 15th century, raw Sicilian sugar seems to be transported elsewhere for refining, mostly but not exclusively to Venice (Trasselli 1982, 186; on the refining in Venice cf Gambi 1955; Ouerfelli 2008, 246–7). The scarce presence of smaller cones in the sites examined (only two, from the 15th–16th-century contexts of Himera — Buonfornello and Palazzo Steri — Chiaramonte) may accord with the written record indicating that Sicilian sugar was not refined before the end of the 14th century, and not in the island for the majority of its period of production. On the other side of the Mediterranean at Kouklia-Stavros, Cyprus, the 15th-century appearance of smaller cones is interpreted as evidence of a lack of refining before this date (cf von Wartburg 2014, 238–9, 243). The creation of a large Venetian sugar-refining industry in the mid-15th century (Gambi 1955), followed by implementation at other cities, surely involved changes in sugar production and consequently in the cone sizes observed.

It is possible that part of the picture is missing in terms of archaeological remains: while the contexts studied derive from production or consumption places, refining often occurred outside of these, ie, in small spice stores and pharmacies. Ouerfelli refers to the importance that spice grocers and apothecaries had in the development of sugar refining products and their distribution from the middle of the 14th century (Ouerfelli 2008, 573–5). Therefore, closer examination of archaeological contexts from these types of site might show a different picture of refining activities than that understood at present.

In conclusion, this paper proposes a chronological typology, when possible, of sugar pots studied for the SPotEU project on the rim profiles of sugar cones and molasses jars. Newly excavated and better-dated sites might change this proposal, but this new research aims to provide a critical overview of the archaeological evidence in Sicily as a foundation to advance studies on such materials in the Mediterranean area.

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Data Availability Statement: The raw data presented in this study are openly available in the CORA, Research Data Repository: Mentesana, R. B. 2022. Medieval sugar pots from Sicily: archaeological, typological and morphometric data. Repositori de Dades de Recerca. doi:10.34810/data156.

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Figure Captions

FIG 1

The sites discussed in their local, regional and national geographic contexts.

(a) Sicily in relation to mainland Italy; (b) Western Sicily with the sites discussed in black; and, (c) Map of Palermo with the sites discussed in the text: 1. Castello della Favara in Maredolce (MAR); 2. Convento di San Giovanni di Baida (BAD); 3. Palazzo Steri — Chiaramonte (STE); 4. Palazzo Arcivescovile. *Figure by R. Mentesana*

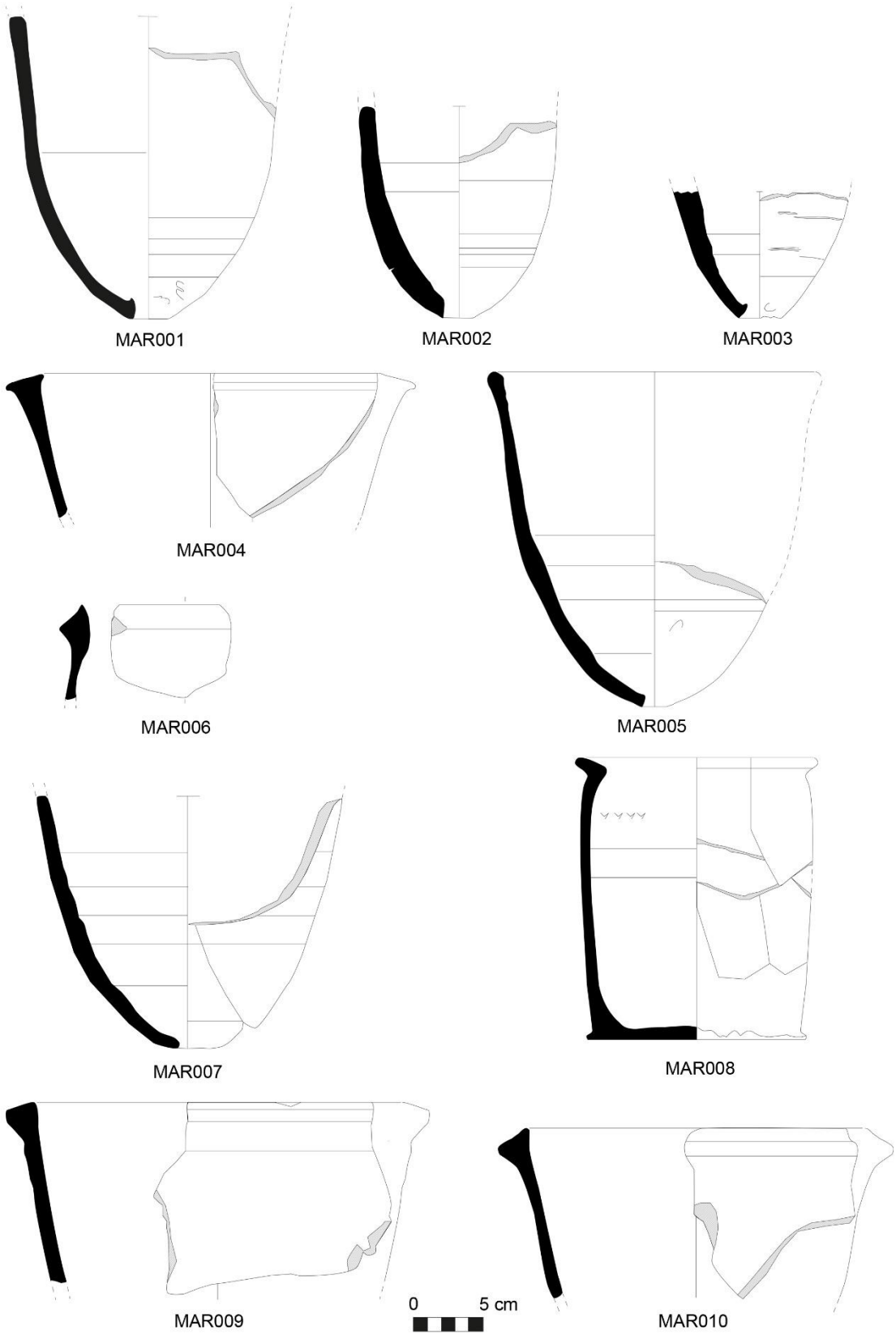


FIG 2

The sugar pots from the Castello della Favara at Maredolce (MAR), Palermo.

Drawings by R Mentesana.

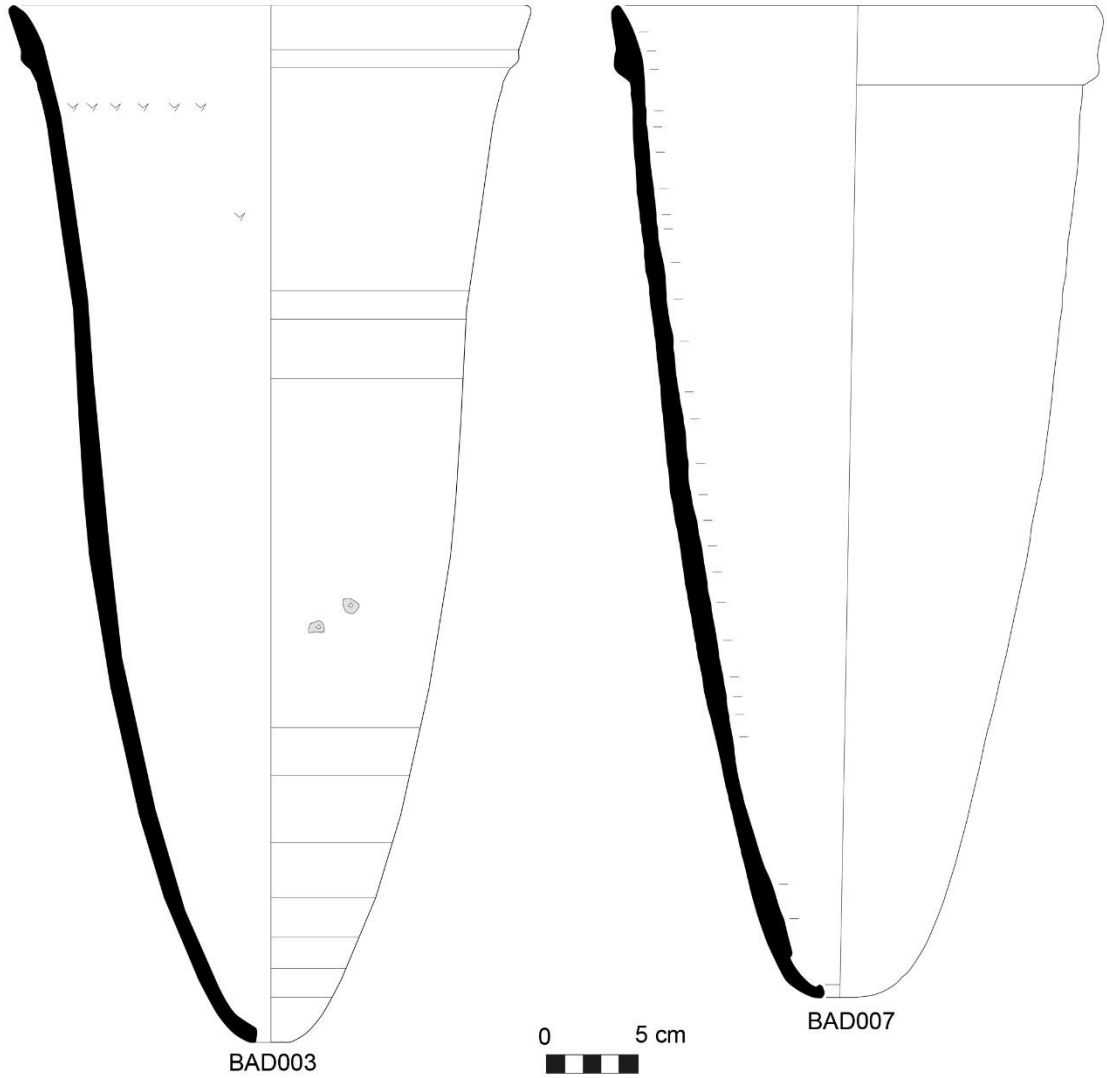
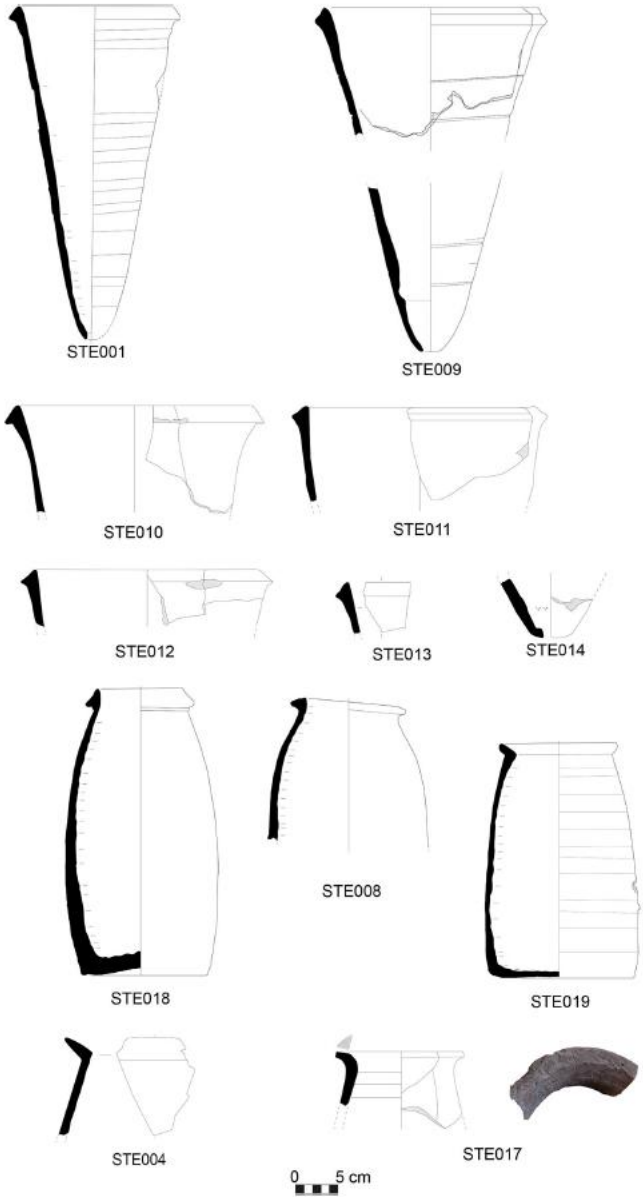


FIG 3

The sugar cones from the Convent of Baida (BAD), Palermo.

Drawings: BAD003 by R Mentesana; BAD007 by S Arrabito.



F

FIG 4

Sugar pots, *cantaro* and *noria* from Palazzo Steri – Chiaramonte (STE), Palermo.

Drawings of sugar pots STE001, 008, 009, 018, 019 by S Arrabito; STE010, 011, 012, 013, 014 by R Mentesana; Drawing of cantaro STE004 and noria STE017 by R Mentesana.

FIG 5

Sugar cone UND001.

Photograph by R Mentesana, courtesy of the Archaeological Museum 'A. Salinas' of Palermo.

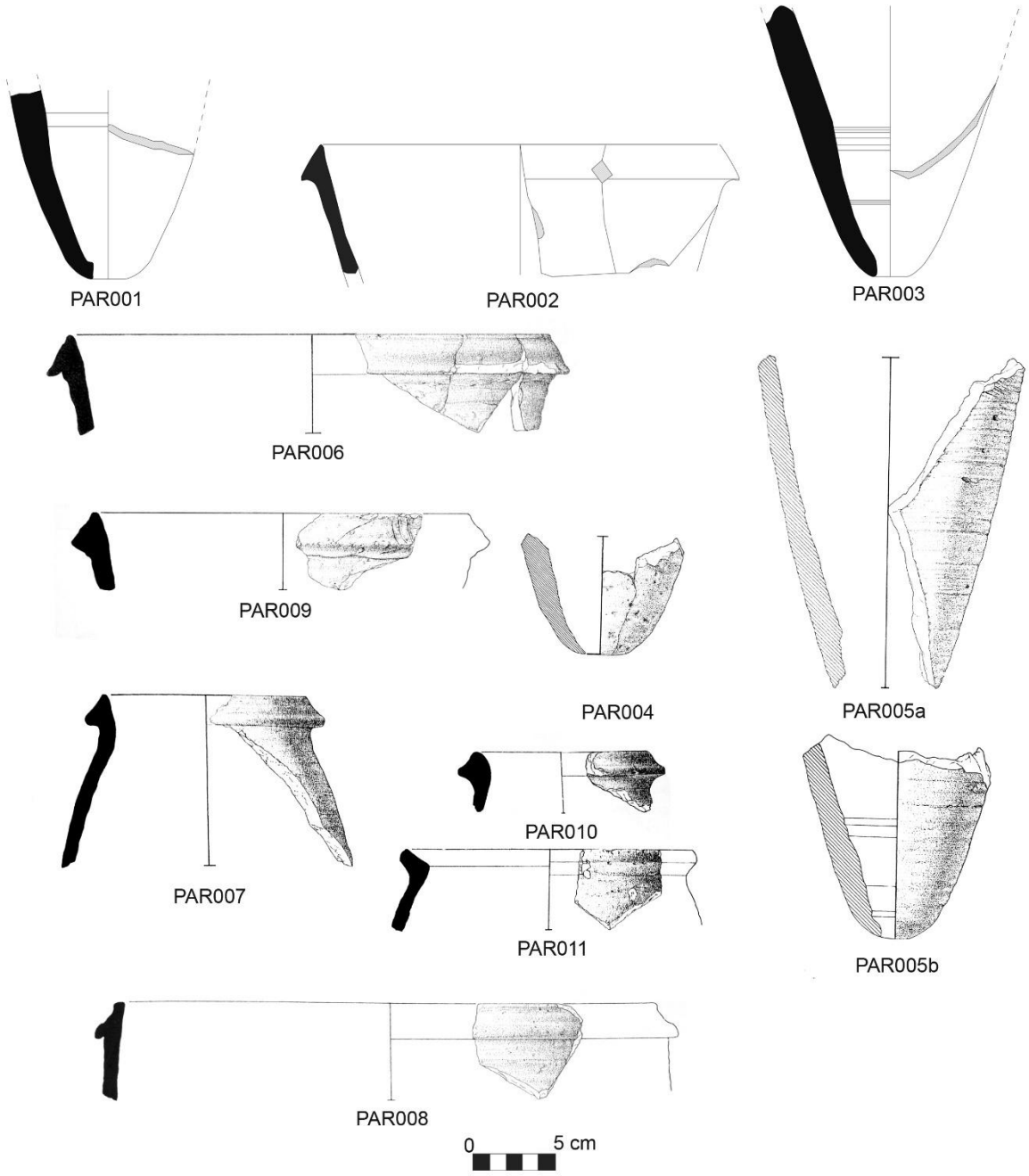


FIG 6

Some of the sugar pots from Partinico (PAR). Please note that after a review of the previously published material from the authors, the profile of PAR008 should be considered slightly bent inwards, and the diameter of PAR008–009 could not be confirmed as the sherds were too smallven though it was drawn in Lo Cascio 2002.

Drawings: PAR001003 by R Mentesana; PAR004–011 by P Lo Cascio, modified after Lo Cascio 2002.

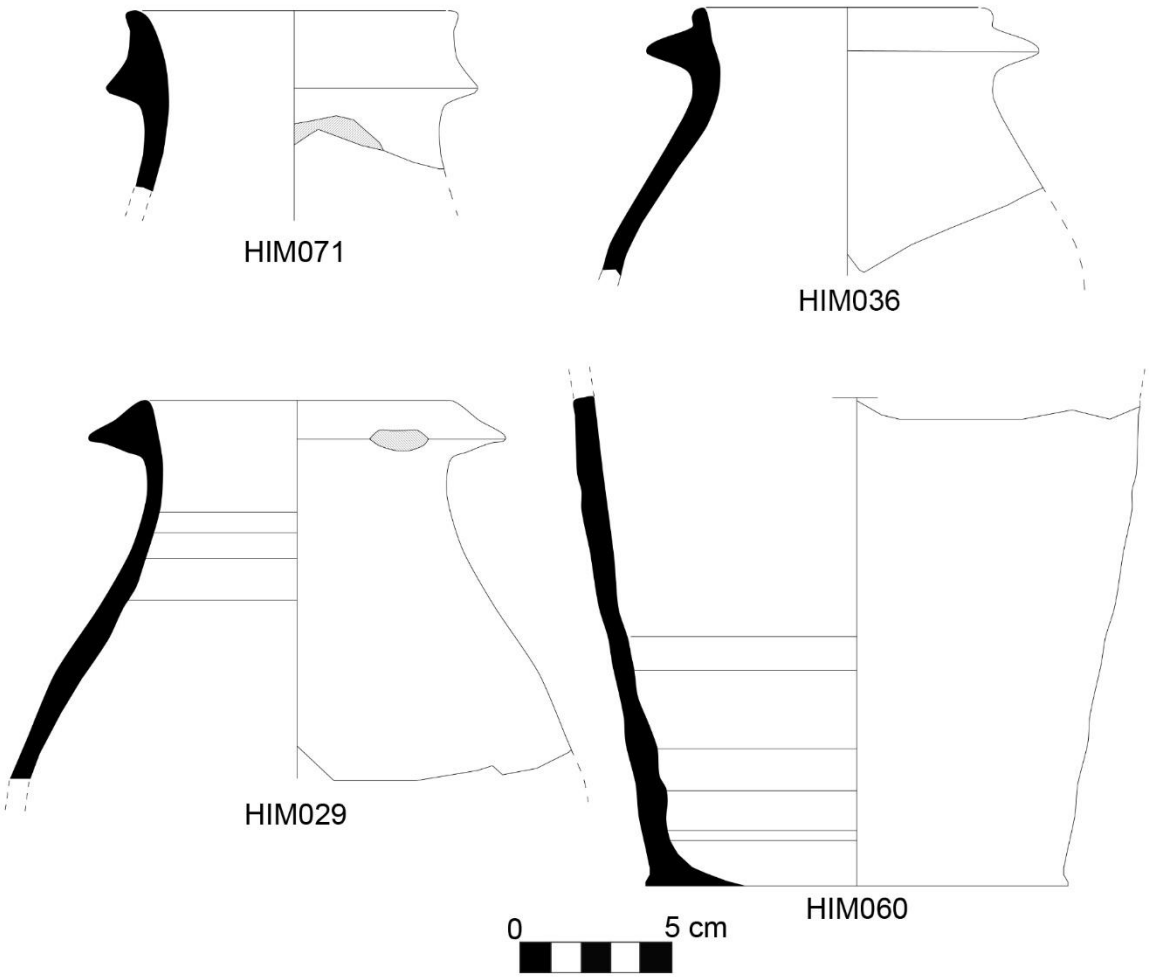


FIG 7

Molasses jar types from Himera — Buonfornello (HIM).

HIM071, type A.1; HIM029, type A.2; HIM036, type A.3. *Drawings by R Mentesana.*

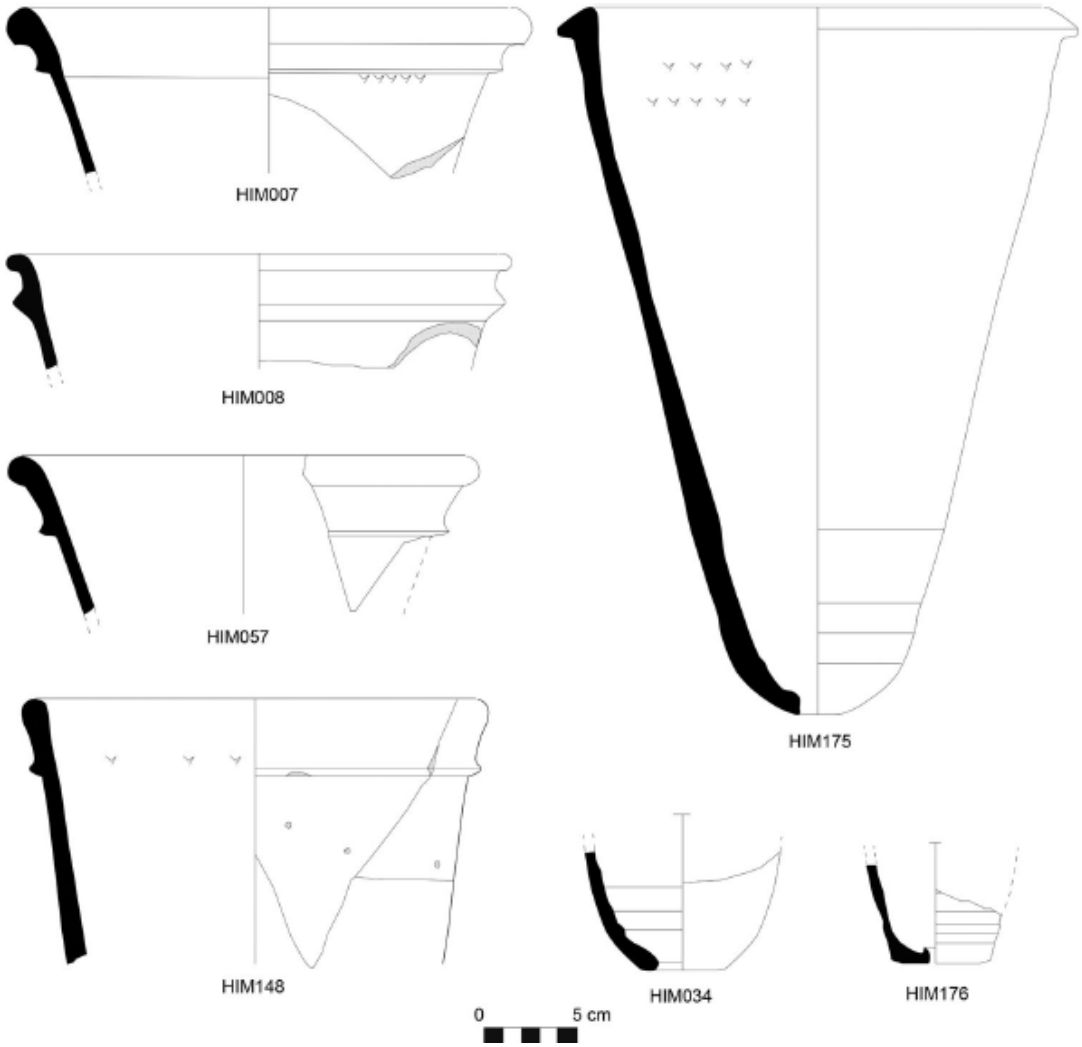


FIG 8

Sugar cone types from Himera — Buonfornello (HIM).

HIM007, type 4.1; HIM008, type 4.2; HIM057, type 4.3; HIM148, type 5; HIM175, type 2; HIM034, the base of a cone; HIM176, the base of a small cone. *Drawings by R Mentesana.*

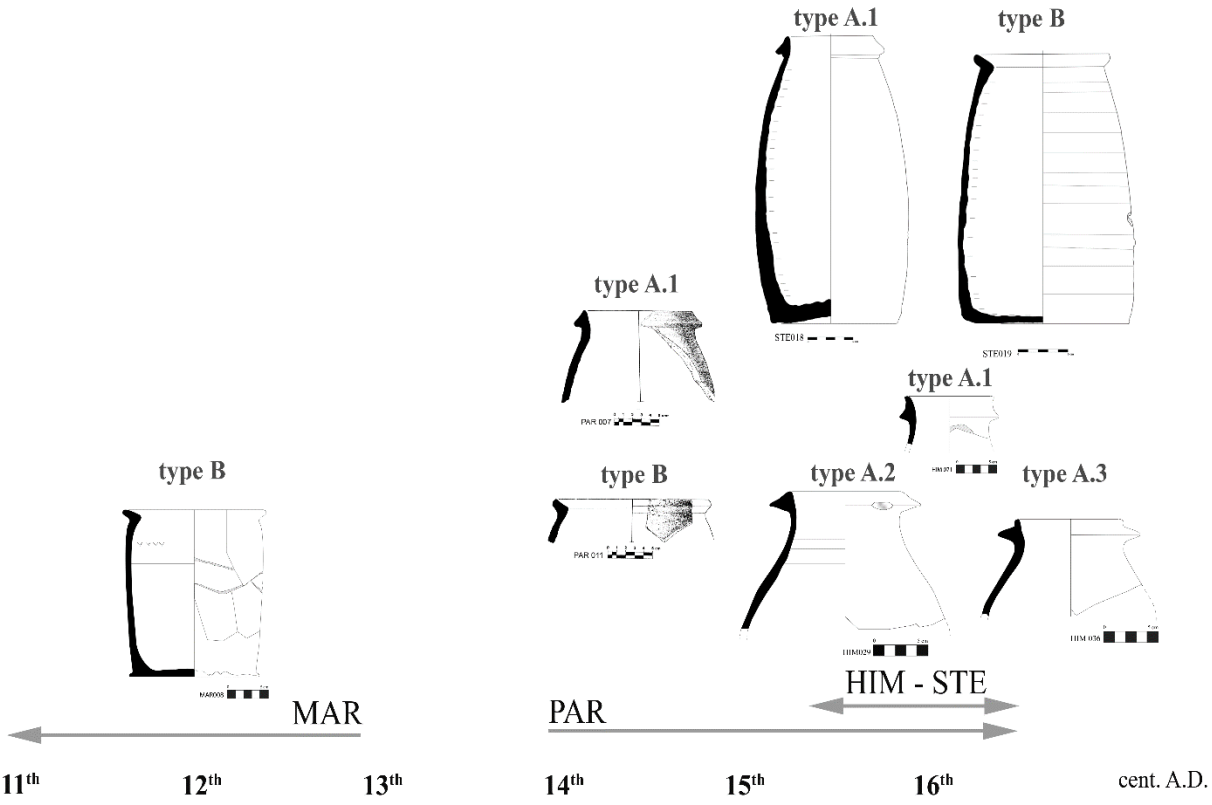


FIG 9

Synoptic picture of the main types of molasses jars across phases and contexts. *Figure by R. Mentesana*

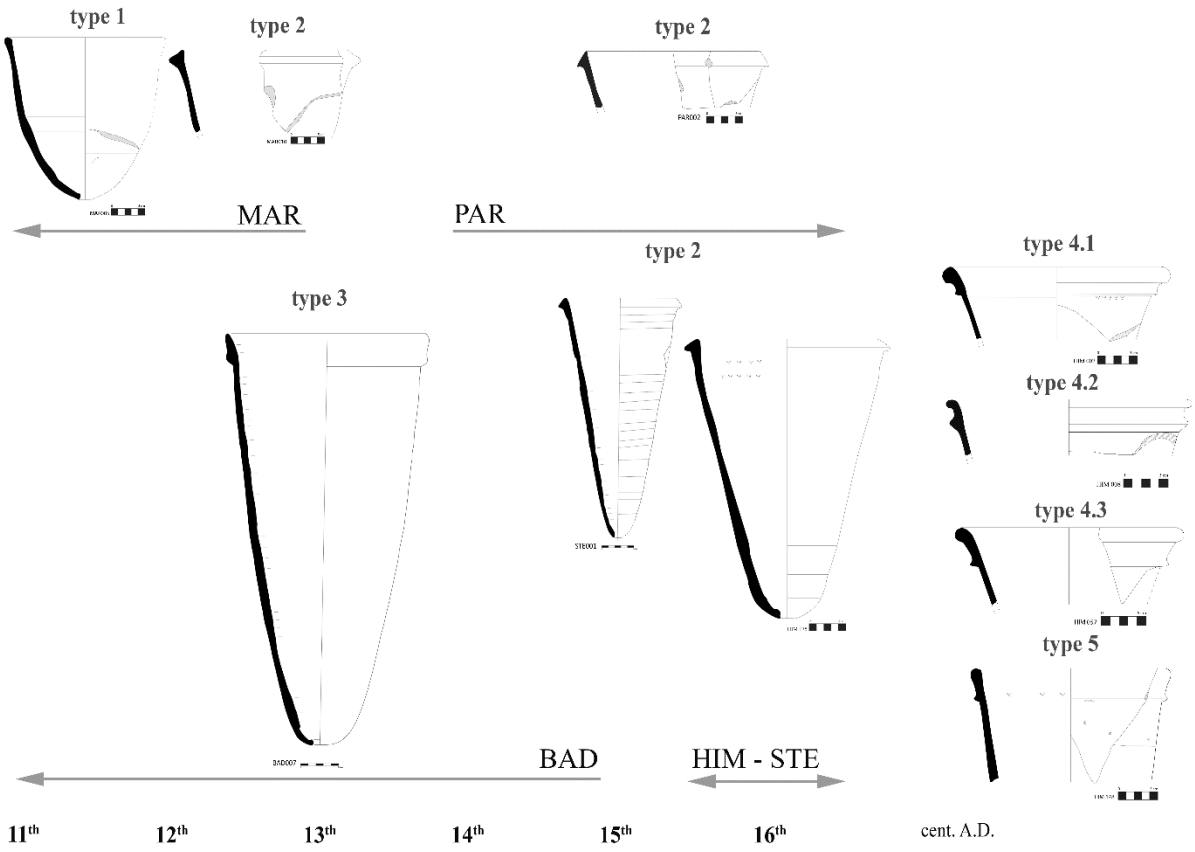


FIG 10

Synoptic picture of the main types of sugar cones across phases and sites. *Figure by R. Mentesana*

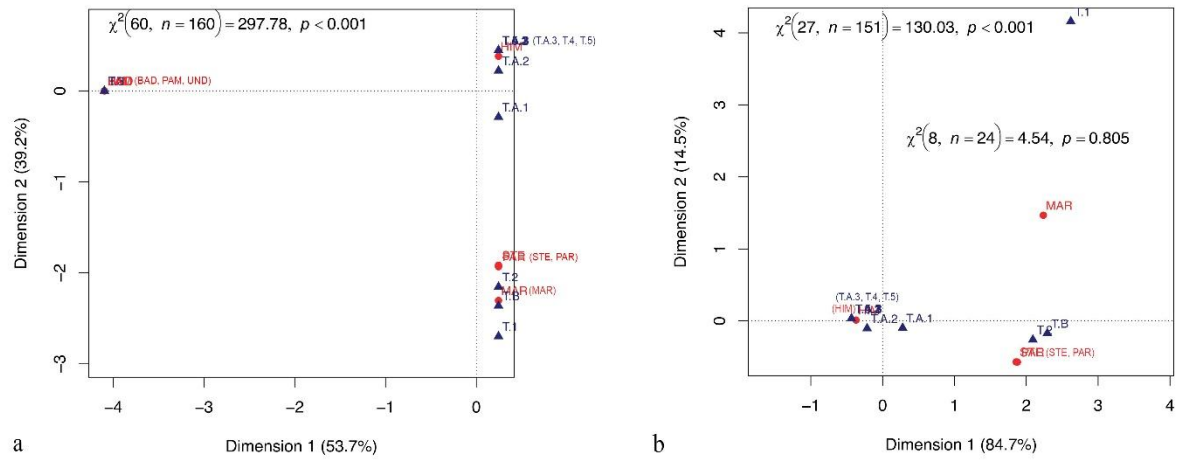


FIG 1

Correspondence analysis.

a: Correspondence analysis of the frequencies in Table 2. b: Correspondence analysis excluding sites with sugar cone type 3. Sites: indicated by acronym (in red). T: type for

molasses jars and sugar cones (in blue). In parenthesis: percentage of inertia. *Figure by J. Buxeda* i Garrigòs

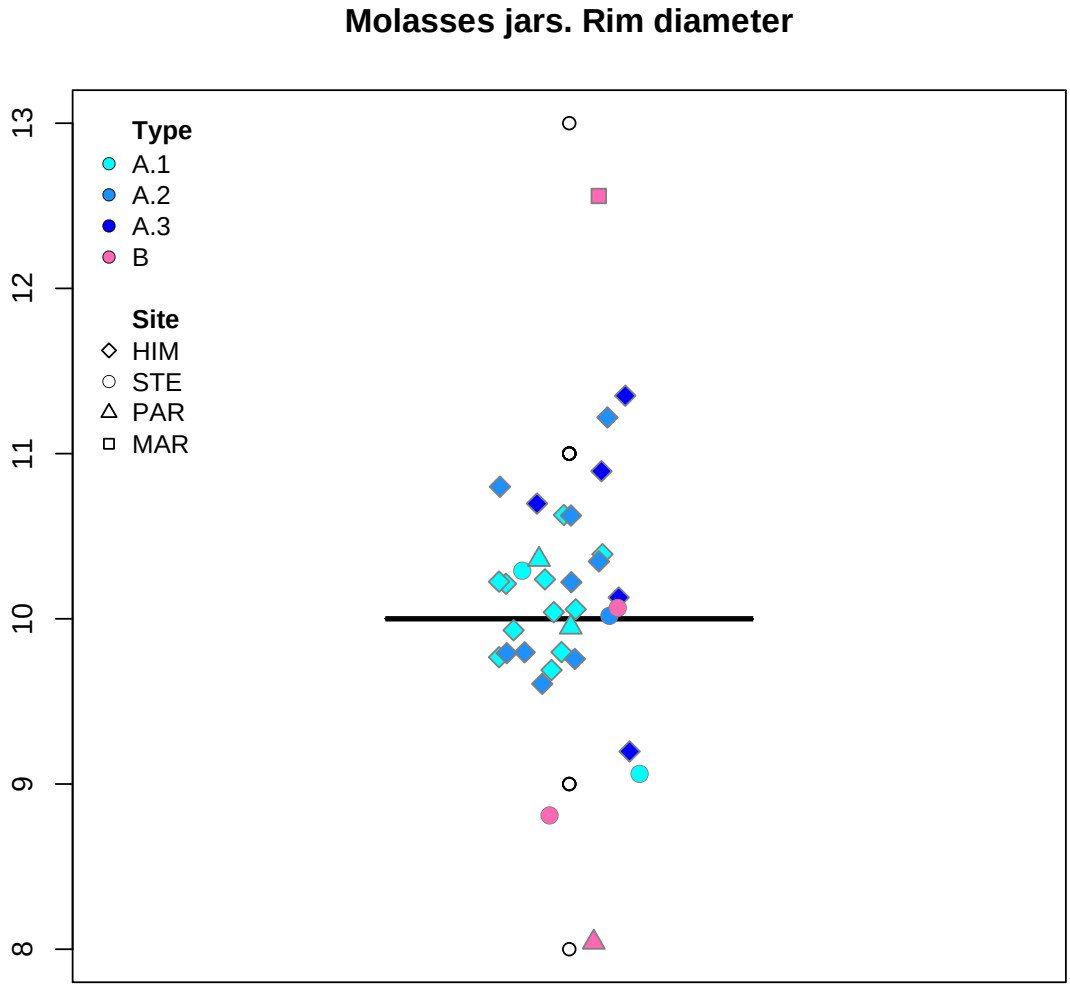


FIG 2

Boxplot of rim diameters of molasses jars by type and site.

The actual values have been jittered to enable the representation. The horizontal line represents the median. White circles represent the actual integer values without differentiation by site. *Figure by J. Buxeda* i Garrigòs

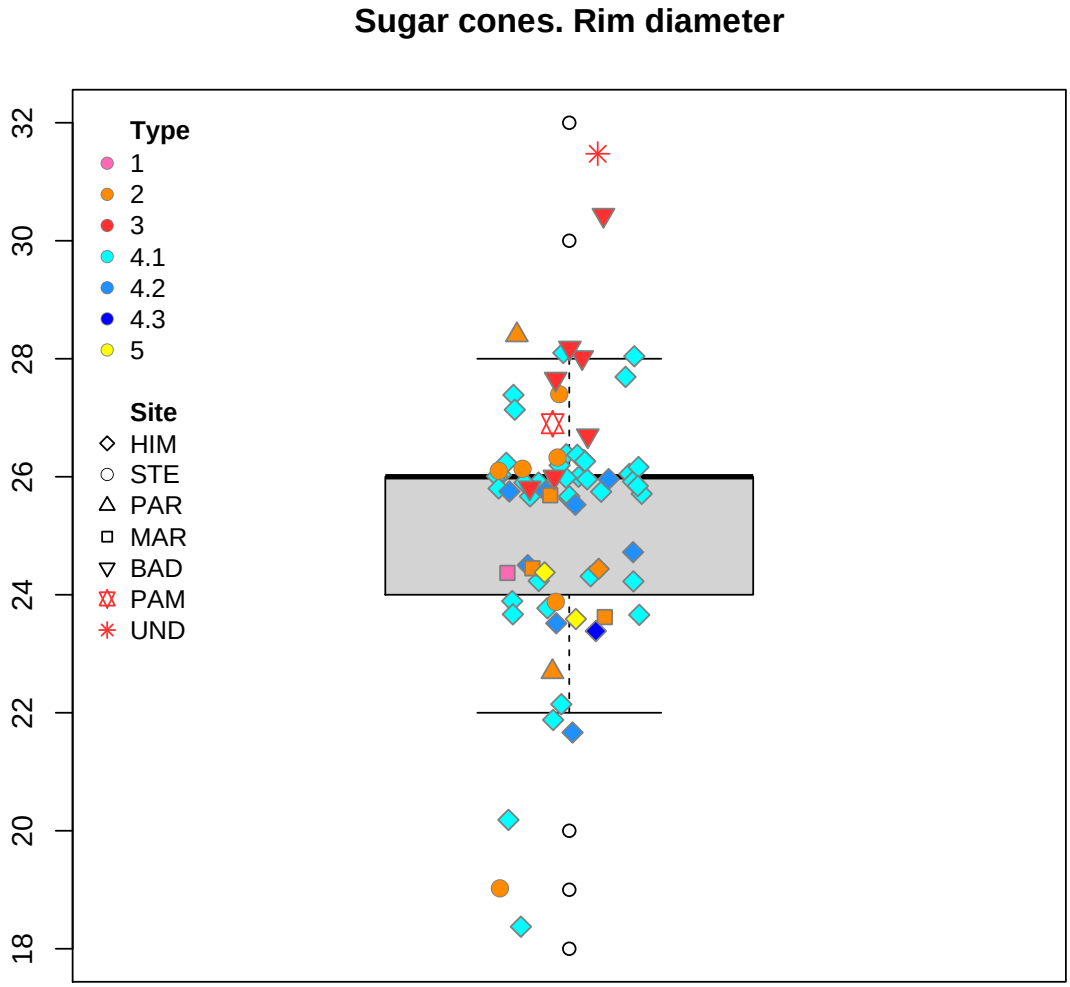


FIG 3

Boxplot of rim diameters (in cm) of sugar cones by type and site.

The actual values have been jittered to enable the representation. White circles represent singleton outliers. *Figure by J. Buxeda* i Garrigòs

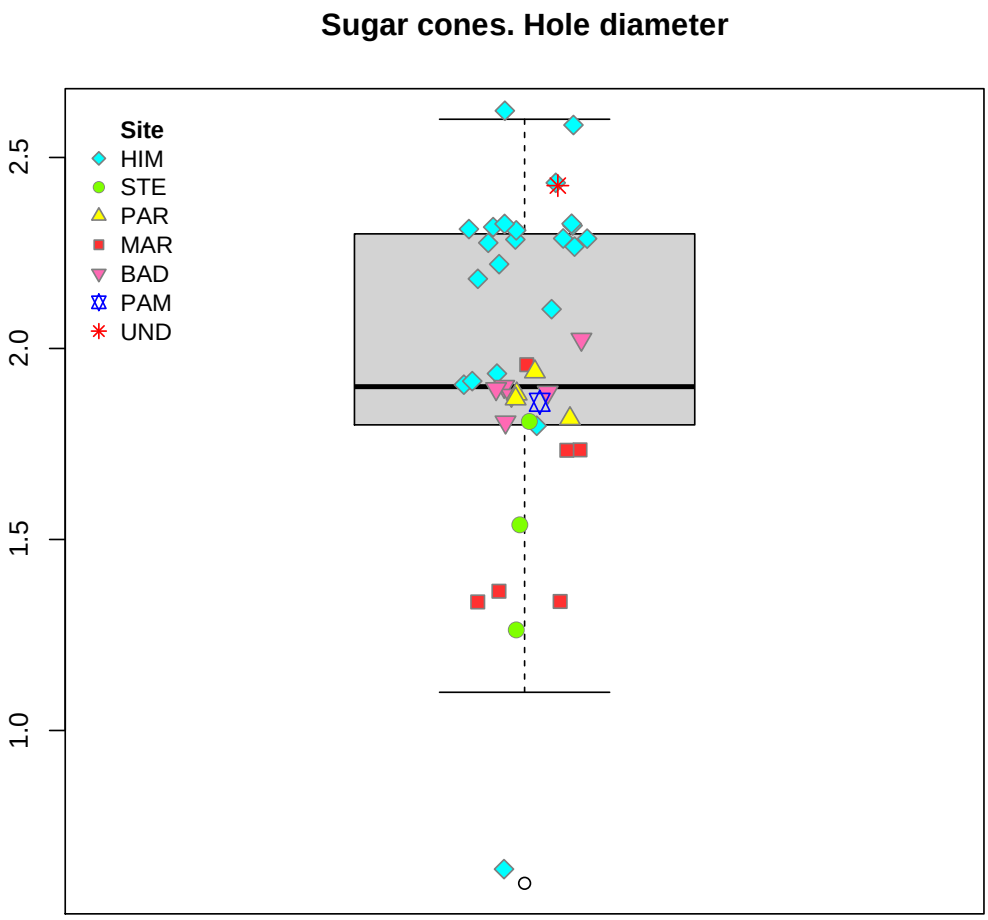


FIG 4

Boxplot of the diameter of the hole (in cm) of the sugar cones by site.

The actual values have been jittered to enable the representation. White circles represent singleton outliers. *Figure by J. Buxeda* i Garrigòs

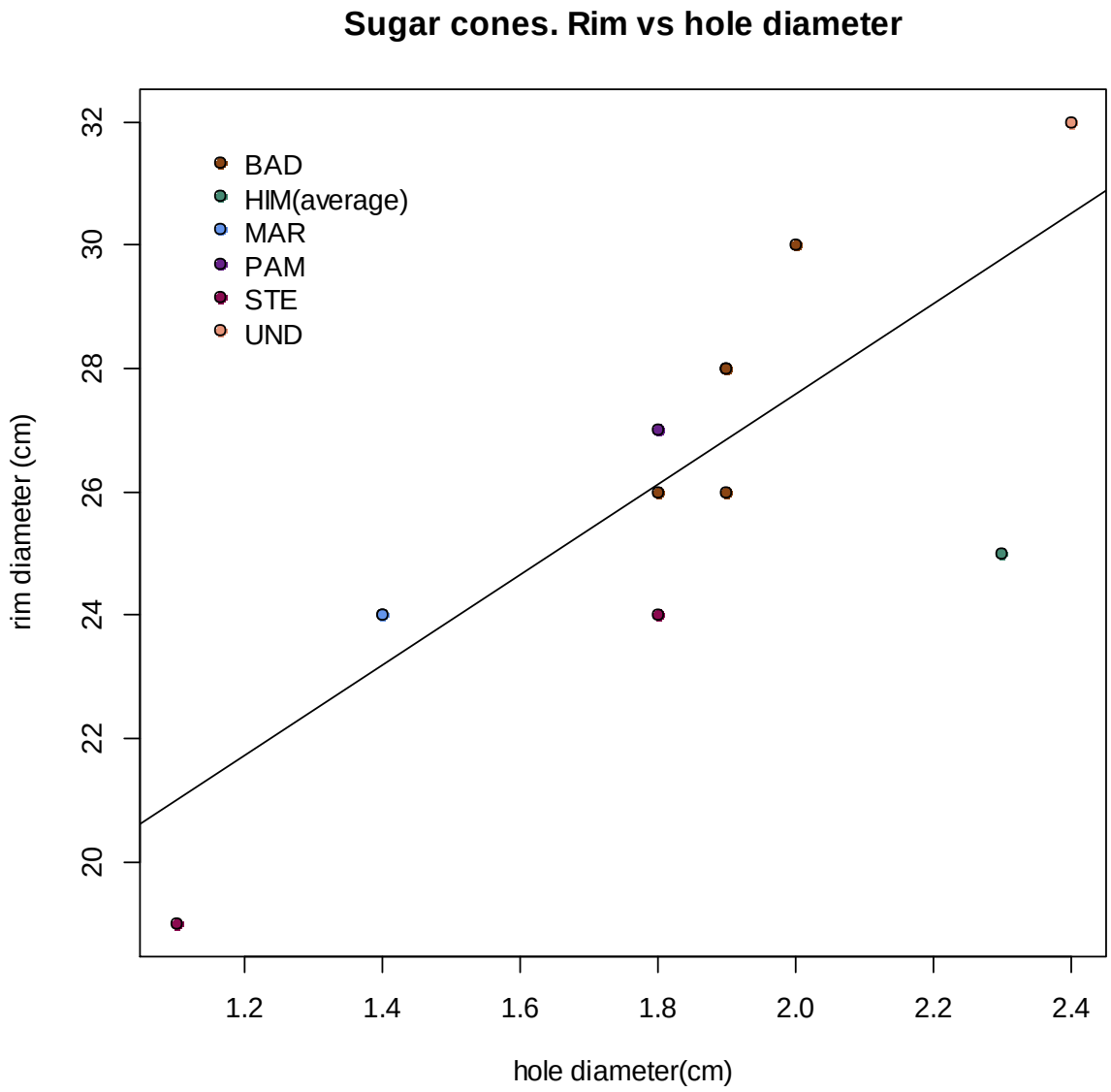


FIG 5

Scatterplot of the rim versus the hole diameter of the few whole sugar cones studied.

The regression line for all the values except HIM is shown. *Figure by J. Buxeda* i Garrigòs

TAB 1

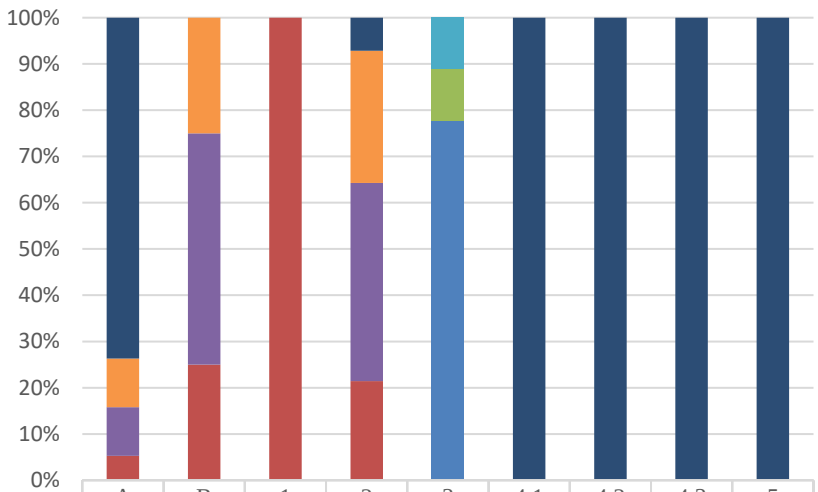
List of materials studied by site, chronology and shape.

Taq = terminus ante quem; tpq = terminus post quem; na = information not available

Site	**molasses jar**	**sugar cone**	***cantaro***	***noria* vase**	**Total**
Castello della Favara a Maredolce (MAR), Palermo	**2**	**8**			**10**
taq end of 13th	2	8			10
Convento di San Giovanni di Baida (BAD), Palermo		**7**			**7**
taq end of 15th		7			7
Palazzo Steri – Chiaramonte (STE), Palermo	**5**	**7**	**2**	**5**	**19**
end 15th - beginning 16th	5	7		2	14
na			2	2	4
tpq 17th				1	1
San Giovanni degli Eremiti (PAM)?		**1**			**1**
taq end of 12th cent or end of 15th?		1			1
Castellaccio (PAR), Partinico		**1**			**1**
tpq end 14th cent.		1			1
Trappeto (PAR), Partinico	**3**	**5**			**8**
tpq end 14th cent.	3	5			8
Cala dei Muletti (PAR), Partinico		**2**			**2**
tpq end 14th cent.		2			2
Himera - Buonfornello (HIM), Termini Imerese	**50**	**126**			**176**
end 15th - beginning 16th	50	124			174
end 15th - beginning 16th?		2			2
Underwater (UND), Palermo		**1**			**1**
na		1			1
Total	**60**	**158**	**2**	**5**	**225**

TAB 2

Contingency table and bar chart of the types of molasses jars and sugar cones by site.



	A	B	1	2	3	4.1	4.2	4.3	5
	molasses jar		sugar cone						
Termini Imerese - Himera - Buonfornello (HIM)	14			1		70	16	2	5
Partinico - Trappeto di Partinico (PAR)	2	1		4					
Palermo - Underwater (UND)					1				
Palermo - Palazzo Steri - Chiaramonte (STE)	2	2		6					
Palermo - San Giovanni degli Eremiti? (PAM)					1				
Palermo - Castello della Favara a Maredolce (MAR)	1	1	1	3					
Palermo - Convento di San Giovanni di Baida (BAD)					7				