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A Note on Archaeological Evidence for Sugar Production in the Middle Islamic Periods in Bilād al-Shām

The role of sugar in medieval Mediterranean trade is well documented in Italian and Arabic sources. The cultivation of sugar cane and the refinement of sugar are also well documented in the archaeological record.[1] Numerous sugar mills and refineries have been discovered in surveys of Israel and Jordan, and four refineries have been the subject of excavation (and publication), providing physical evidence for sugar production, as well as insight into the modes and methods of production,

[1]The textual evidence for production and trade in the Islamic Mediterranean has been discussed most prolifically by Eliahu Ashtor (see especially his ″Levantine Sugar Industry in the Later Middle Ages: A Case of Technological Decline,″ in *The Islamic Middle East: 700–1900,* ed. Abraham Udovitch [Princeton, 1977], 91–132; idem, ″Levantine Sugar Industry in the Later Middle Ages: An Example of Technological Decline,″ *Israel Oriental Studies* 7 (1977): 226–80). It is also discussed by Andrew M. Watson among other agricultural products: Andrew M. Watson, *Agricultural Innovation in the Early Islamic World* (Cambridge, 1983). W. D. Philips discusses the diffusion of sugar throughout the Mediterranean, and its trade through the sixteenth century: W. D. Philips, ″Sugar Production and Trade in the Mediterranean at the Time of the Crusades,″ in Vladimir Goss, ed., *The Meeting of Two Worlds: Cultural Exchange between East and West during the Period of the Crusades,* Studies in Medieval Culture, vol. 21 (Kalamazoo, 1986), 393–406. A. Peled concentrates on Crusader production in Palestine: A. Peled, ″The Local Sugar Industry under the Latin Kingdom,″ in *Knights of the Holy Land: The Crusader Kingdom of Jerusalem*, ed. Silvia Rozenberg (Jerusalem, 1999), 251–57. Anthony Luttrell, Franz Georg Maier and Vassos Karageorghis, and Marie-Louise von Wartburg have all written on the Cypriot sugar industry, with Maier and von Wartburg drawing on excavations of several well-preserved mills on Cyprus: Anthony Luttrell, ″The Sugar Industry and Its Importance for the Economy of Cyprus during the Frankish Period,″ in *The Development of the Cypriot Economy from the Prehistoric Period to the Present Day*, ed. V. Karageorghis and D. Michaelides (Nicosia, 1996), 163–73; Franz Georg Maier and Vassos Karageorghis, *Paphos: History and Archaeology* (Nicosia, 1984); Marie-Louise von Wartburg, ″The Medieval Cane Sugar Industry in Cyprus: Results of Recent Excavations,″ *The Antiquaries Journal* 63 (1983): 298–314; idem, ″Cane Sugar Production Sites in Cyprus, Real and Imagined,″ *Report of the Department of Antiquities, Cyprus* (2000): 381–400. H. Eduard LaGro′s dissertation on Ayyubid-Mamluk ceramics from Tell Abu Sarbut contains a nice summary and description of the sugar industry in the southern Levant, noting al-Nuwayrī′s description of differences between Egyptian and Syrian production methods. See his dissertation (due to be published in 2004): H. Eduard LaGro, ″An Insight into Ayyubid-Mamluk Pottery: Description and Analysis of a Corpus of Mediaeval Pottery from the Cane Sugar Production and Village Occupation at Tell Abu Sarbut in Jordan,″ Ph.D. diss., University of Leiden, 2002.

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throughout the region of Bilād al-Shām. In addition, excellent comparanda come from very well preserved sugar refineries dating to the late thirteenth to sixteenth centuries A.D. excavated in Cyprus, which, having been modeled on the earlier and contemporary Levantine refineries, illustrate how the Levantine installations may have functioned.[2] Other comparanda come from Iran and North Africa: a refinery dating to the twelfth and thirteenth centuries A.D. was excavated at Susa,[3] and several sites, probably sixteenth century and later, have been surveyed in Morocco.[4] Although sources such as al-Qalqashandī and al-Nuwayrī, as well as Geniza letters and other trading documents, indicate Islamic Egypt was awash in sugar cane, there have unfortunately been no published excavations in Egypt to accompany the textual evidence.[5]

In Bilād al-Shām, four sugar factories have been excavated and published, all in the south, in modern Israel and Jordan. Tell Abu Qa'dan/Deir Alla in southern Jordan was excavated by Henk J. Franken and Moawiyah M. Ibrahim in 1977 and 1978, and the nearby Tell Abu Sarbut was excavated by Hubert de Haas, H.

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[2]Marie-Louise von Wartburg, ″Design and Technology of the Medieval Cane Sugar Refineries in Cyprus: A Case Study in Industrial Archaeology,″ in *Paisajes del Azúcar: Actas del Quinto Seminario International Sobre la Caña de Azúcar,* ed. Antonio Malpica (Granada, 1995), 81–116; von Wartburg and Maier, ″Excavations at Kouklia (Palaepaphos): 15th Preliminary Report: Seasons 1987–1988,″ *Report of the Department of Antiquities, Cyprus* (1989): 175–88. Also see Maier, ″Excavations at Kouklia (Palaepaphos): Ninth Preliminary Report: Season 1976,″ *Report of the Department of Antiquities, Cyprus* (1977): 134–40; von Wartburg and Maier, ″Excavations at Kouklia (Palaepaphos): 16th Preliminary Report: Seasons 1989 and 1990,″ *Report of the Department of Antiquities, Cyprus* (1991): 255–62.

[3]Rémy Boucharlat and Audran Labrousse, ″Une sucrerie d'époque islamique sur la rive droite du Chaour à Suse: I: Description et essai d'interprétation des structures,″ *Cahiers de la délégation archéologique française en Iran* 10 (1979): 155–76; Monik Kervran, ″Une sucrerie d'époque islamique sur la rive droite du Chaour à Suse: II: Le matériel archéologique,″ *Cahiers de la délégation archéologique française en Iran* 10 (1979): 177–237.

[4]Paul Berthier, *Les anciennes sucreries du Maroc et leurs réseaux hydrauliques,* 2 vols. (Rabat, 1966).

[5]For example, Ashtor has culled Arab chroniclers such as Ibn Duqmāq and Ibn Mutawwaj for lists of factory owners in both Cairo and Upper Egypt (Eliahu Ashtor, ″Levantine Sugar Industry in the Later Middle Ages: An Example of Technological Decline″). The Cairo Geniza documents, covering a slightly earlier period, also indicate production and sale in Egypt: S. D. Goitein, *A Mediterranean Society: The Jewish Communities of the Arab World as Portrayed in the Documents of the Cairo Geniza,* vol. 1, *Economic Foundations* (Berkeley, 1967); idem, ″Mediterranean Trade in the Eleventh Century: Some Facts and Problems,″ in *Studies in the Economic History of the Middle East: From the Rise of Islam to the Present Day,* ed. M. A. Cook (London, 1970), 51–62. Jean-Claude Garcin has compiled the sources for Qūṣ and Upper Egypt: Jean-Claude Garcin, *Un centre musulman de la Haute-Egypte médiévale, Qūṣ,* Textes arabes et études islamiques no. 6 (Cairo, 1976).

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Eduard LaGro, and Margreet L. Steiner in 1989, 1990, and 1992.[6] In Islamic Beisan (Roman-Byzantine Scythopolis), excavations have revealed a Mamluk sugar factory making use of part of the Crusader citadel there. Brief descriptions are included in Ruth Gertwagen´s report on the Abbasid-Fatimid fortress and surrounding Islamic settlement,[7] and by Jon Seligman in his report on his excavations of the Crusader citadel.[8] Edna J. Stern has excavated a fairly well-preserved sugar refinery and associated mill in northern Israel that dates to the Ayyubid and Mamluk periods.[9]

There are numerous mills extant in Palestine and the Jordan valley, and numerous places are known from the textual sources to have grown sugar cane and manufactured sugar. All of the surveys of the Jordan valley at least mention sites having numerous sugar pots scattered on the surface, and some have described milling sites in detail.[10] Stern´s M.A. thesis provides valuable survey data of the forty-three sites in Israel that have positive evidence of having been sugar factories.[11] She also lists those that may have produced sugar (twenty sites), and those that have been rumored to produce sugar but for which there is no evidence (three

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[6]Henk J. Franken and Mo'awiyah Ibrahim, ″Two Seasons of Excavations at Tell Deir ´Alla, 1976–1978,″ *Annual of the Department of Antiquities of Jordan* 22 (1977–78): 57–80; Henk J. Franken and J. Kalsbeek, *Potters of a Medieval Village in the Jordan Valley: Excavations at Tell Deir 'Allā—a Medieval Tell, Tell Abu Gourdan, Jordan* (Amsterdam, 1975); Hubert de Haas et al., ″First Season of Excavations at Tell Abu Sarbut, 1988: A Preliminary Report,″ *ADAJ* 33 (1989): 323–26; idem, ″Second and Third Seasons of Excavations at Tell Abu Sarbut, Jordan Valley (Preliminary Report),″ *ADAJ* 36 (1992): 333–43.

[7]Ruth Gertwagen, ″The Fortress (of Bet She´an),″ *Excavations and Surveys in Israel* 11 (1989–91): 56–59.

[8]J. Seligman, ″Bet She´an, the Citadel,″ *Excavations and Surveys in Israel* 15 (1996): 43–47.

[9]Edna J. Stern, ″The Excavations at Lower Horbat Manot: A Medieval Sugar-Production Site,″ *´Atiqot* 42 (2001): 277–308.

[10]See especially Mo'awiyah Ibrahim et al., ″The East Jordan Valley Survey, 1975,″ *Bulletin of the American Schools of Oriental Research* 222 (1976): 41–66; idem, ″The East Jordan Valley Survey, 1976 (Part Two),″ in *Archaeology of Jordan: Essays and Reports,* ed. Khair Yassine (Amman, 1988), 203; G. R. D. King, ″Survey of Byzantine and Islamic Sites in Jordan: Third Season Preliminary Report (1982): The Southern Ghôr,″ *ADAJ* 31 (1987): 39–460; idem, ″Survey of Byzantine and Islamic Sites in Jordan: Third preliminary report (1982): The Wadi Arabah (Part 2),″ *ADAJ* 33 (1989): 203; B. MacDonald, *The Wadi el Hasa Archaeological Survey 1979–1983, West-Central Jordan* (Waterloo, Ontario, 1988); idem, ″The Southern Ghors and Northeast ´Arabah Archaeological Survey, 1986, Jordan: A Preliminary Report,″ *ADAJ* 31 (1987): 410; Donald S. Whitcomb, ″The Islamic Period as Seen from Selected Sites,″ in *The Southern Ghors and Northeast ´Arabah Archaeological Survey,* Sheffield Archaeological Monographs, no. 5, ed. B. MacDonald (Sheffield, 1992), 113–18.

[11]Ms. Stern has generously e-mailed me the tables from her M.A. thesis in English.

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sites).[12] Fifty-one possible sugar-producing sites in Palestine have also been collected from survey and textual sources and summarized by Brigitte Porëe-Braitowsky in a long article that also relies on some of her own reconnaissance.[13] This number is mostly a count of milling sites, for which there is no direct archaeological evidence of sugar production, however. Here we are concerned with those sites that have been excavated or surveyed, and found to contain the best proof there is for sugar production, which is the presence of great quantities of sherds of both conical sugar molds and syrup jars.[14] Boiled, reduced cane juice (collected from chopped and crushed sugar cane) was poured into the molds, which were conical, having a wide mouth and narrow base, and had one to three small holes punched in the base. The molds were either set directly on or raised over syrup jars, which collected the liquid slowly draining from the mold. This slow draining, as well as evaporation of liquid, resulted in a cone-shaped cake of sugar. The collected syrup might be re-boiled and poured again into molds, or sold in its own right.[15] The sugar molds were often broken during the removal of the sugar cake, resulting in great quantities of broken pottery remaining at sugar-production sites, and likely on-site production of pottery.[16]

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[12]Edna J. Stern, ″The Sugar Industry in Palestine during the Crusader, Ayyubid, and Mamluk Periods in Light of the Archaeological Finds,″ M.A. thesis, Hebrew University, 1999. There are numerous such sites in this region. For example, the excavators at Caesarea believe they have discovered an Abbasid-period mill used for sugar, which would have been animal-driven. They cite no evidence beyond the mill itself, but Caesarea was known as one of the more important sites of sugar production in the early Islamic period. See Avner Raban, ″Combined Caesarea Excavations (B),″ *Excavations and Surveys in Israel* 17 (1998): 58–76. (I am grateful to Asa Eger for this reference.)

[13]Brigitte Porëe-Braitowsky, ″Les moulins et fabriques à sucre de Palestine et de Chypre: Histoire, geographie et technologie d´une production croisee et medievale,″ in *Kypros kai oi Staurophories/Cyprus and the Crusades: Papers given at the International Conference ´Cyprus and the Crusades,´ Nicosia, 6–9 September, 1994,* ed. Nicholas Coureas and Jonathan Riley-Smith (Nicosia, 1995), 377–510.

[14]Milling sites that are not accompanied by this ceramic evidence could not have been used for sugar, although it has been argued that some of them may have been built for grinding sugar cane and were later used for grain.

[15]The reconstruction of sugar production comes from al-Nuwayrī, and from the above-mentioned excavations at Kouklia, Cyprus. See LaGro´s useful summary of al-Nuwayrī´s description in his dissertation (LaGro, ″An Insight into Ayyubid-Mamluk Pottery,″ 30–31, or al-Nuwayrī, *Nihāyat al-Arab fī Funūn al-Adab,* vol. 7 (Cairo, 1931).

[16]Berthier, *Les anciennes sucreries du Maroc;* Franken and Kalsbeek, *Potters of a Medieval Village*; von Wartburg, ″The Medieval Cane Sugar Industry in Cyprus.″

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Summaries of the excavations known to date illustrate what is known and possible to know from the archaeological evidence:

Tell Deir Alla is a large mound in the east side of the Jordan valley, close to the Zerqa' river. Excavations from 1960 to 1967 by Henk J. Franken of the University of Leiden revealed intensive Late Bronze Age and Iron Age occupation, but in the Islamic periods the site was used as a cemetery, presumably contemporaneous with the adjacent site of Tell Abu Qa'dan.[17] Some of the grave goods include sugar molds and syrup jars.[18] At Tell Abu Qa'dan, northeast of Deir Alla, mills were still visible in the early twentieth century several hundred meters to the east of the tell.[19] Because of its presumed relationship with Tell Deir Alla, it was excavated briefly in 1967 by M. Jamerah of the Department of Antiquities. These excavations and a detailed ceramic study were published by Franken and J. Kalsbeek, providing the most detailed study extant of sugar vessels from this region.[20] Only two 5 m x 5 m trenches were dug, with most of the work concentrating on one trench. The excavators reached a depth of 6.5 m, of material that they dated from the eighth to the fifteenth centuries A.D.[21] In trench DA/AR100 a series of courtyard levels was excavated, each containing pottery, ash, and thick clay deposits from collapsed walls, as well as some pits and thick ash deposits. Bread ovens were also found. The excavators emphasize that the most surprising aspect of the excavation was the very large quantity of ceramic recovered from the courtyards, including several pots smashed *in situ* by a collapsed wall, and thus able to be reconstructed. Partly because of the nature of the deposition, and partly because of the speed of excavation, the excavators were unable to get good stratigraphic differentiation. All the dating is done on the basis of ceramic analysis, not stratigraphy. Thus Franken and Kalsbeek differentiate three phases of occupation, or at least of ceramic production, but they are unable to anchor them to an absolute chronology.

The greatest quantity of sherds from the site is of two types, present only in

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[17]Franken and Ibrahim, ″Two Seasons of Excavations at Tell Deir ′Alla, 1976–1978.″ (Abu Qa'dan is spelled Abu Gourdan in the publications.)

[18]The cemetery was again excavated in 1976–78 by a joint expedition of the University of Leiden and the Jordanian Department of Antiquities, directed by H. J. Franken and M. M. Ibrahim.

[19]Franken and Kalsbeek, *Potters of a Medieval Village*, 219.

[20]Ibid.

[21]James A. Sauer questions the basis for these dates, as Franken and Kalsbeek make only a few general comparisons of their pottery with other sites, and make no attempt to sort through the nineteen layers of stratigraphy. James A. Sauer, ″Pottery Techniques at Tell Deir ′Alla,″ *Bulletin of the American Schools of Oriental Research* 222 (1976): 91–94. LaGro′s dissertation is meant to follow up on and perhaps improve upon Franken and Kalsbeek′s ceramic study: LaGro, ″An Insight into Ayyubid-Mamluk Pottery.″

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the latter two phases of the site. Thousands of body sherds were found belonging to the above-described sugar-pots: conical molds (these having a single small hole in the base) and syrup jars, which are generally described as ″bag-shaped,″ and are handle-less and almost rimless. Both types of sugar pot are usually of somewhat coarse red- or white-firing wares, thickly potted. Only the interiors of the molds are smoothed. According to Franken and Kalsbeek´s study of those at Deir Alla and Abu Qa'dan, they are made with a combination of coil-built and wheel-thrown techniques. The molds come in various heights, keeping a generally standard rim diameter. They seem to be roughly standardized to three different capacities. The same rim variations occur in each phase, making rim changes useless for chronology. Syrup jars are likewise consistent in shape and capacity throughout the periods. The vast majority of both molds and jars are plain, but there are rare examples of decorated sugar molds, having combed decoration or even a dark green glaze.[22] The sheer quantity of ceramics related to the sugar industry, along with the presence of some vitrified sherds, indicates that they may have been produced on site to meet the high demands of sugar production.[23] The courtyards themselves may represent the remains of a refinery, used over a long period of time.

Tell Abu Sarbut, only about 1.5 km west-northwest of Tell Deir Alla and Tell Abu Qa'dan, was excavated by Hubert de Haas, H. Eduard LaGro and Margreet L. Steiner in 1989, 1990, and 1992. Although no remains of either a mill or a press were found, the excavators did find part of a large building that may have been used as a refinery, with two main phases of use some time apart. In its second phase there were benches with sugar molds embedded in them, ready to hold other sugar molds into which the boiled sugar cane juice would be poured. Many fragments of sugar molds and jars were also found here. Another part of the tell revealed a domestic area containing four phases of Ayyubid-Mamluk occupation built directly over unexcavated Byzantine remains. Material culture included numerous ceramics, but also fragments of glass bracelets and pieces of iron and bronze. The dating of this area and the factory was based on calibrated ^{14}C dates.[24] They date the last phase of the domestic area, which is evidence of the village, to A.D. 1434–1510 or 1598–1620, and the phase succeeding the last phase of the factory to 1292–1448. Thus the factories could have been late Ayyubid or early

[22]Franken and Kalsbeek, *Potters of a Medieval Village*, 143–46.

[23]For comparison, the fourteenth–fifteenth-century sugar mill at Kouklia on Cyprus included a simple round kiln for manufacturing the molds and jars on site (von Wartburg, ″The Medieval Cane Sugar Industry in Cyprus″). Generally the quantity of specialized vessels for sugar production is so high at each site that it only seems reasonable to assume that they were manufactured on-site.

[24]The reports do not disclose what material was used for the ^{14}C samples or how many samples were taken.

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Mamluk. We may infer that the village was not completely dependent upon the success of the factories, for it remained occupied for at least a century after the last use of the factory.[25]

Beisan or Bet She'an, Byzantine Scythopolis, also possesses evidence of sugar production in its later periods. It has been excavated by numerous institutions, but we are concerned with two projects: the Bet She'an Excavation Project in cooperation with the Department of Archaeology of Haifa University excavated the area of interest to us in August–October 1989 and May–November 1990 under the direction of Ruth Gertwagen and Adrian Boaz; and the Israel Antiquities Authority excavated in the summers of 1992, 1993, and 1994 under the direction of Jon Seligman. In the lower town, in an area about 400 m west of the center of the Roman-Byzantine town, there is an area of occupation dating from the Byzantine through the Ottoman periods, centered around the Crusader citadel. The citadel appears to have been built over an earlier fortress from the Abbasid-Fatimid periods. In the early Mamluk period a complex of installations for the manufacture of sugar was built inside the citadel′s inner rooms, keep, and part of the moat, as well as over the basalt buildings to the north of the citadel, which may be interpreted as houses built around a courtyard. The principal evidence for sugar manufacture is the presence of thousands of sherds of sugar pots lying on a lime floor. Seligman also noted ″compartments built along the walls to support vessels used in the sugar industry,″ presumably sugar molds.[26] Unfortunately neither Gertwagen nor Seligman describe the finds in detail, although Seligman notes they found no installations for processing the cane itself (i.e., a press). In any case the industry appears to have been short-lived in this location, and by the late Ottoman period the citadel′s upper story was rebuilt and used as a school.

Excavations at Yesud HaMa'ala in the Galilee have revealed the interesting building sequence of a possible synagogue cum sugar factory.[27] Yesud HaMa'ala is in eastern Galilee, on the east bank of the Jordan, about 15 km north of Safed. Excavations were carried out there in 1883, 1970, and 1974–83 by Y. Shoram,

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[25]De Haas et al., ″First Season of Excavations at Tell Abu Sarbut″; idem, ″Second and Third Seasons of Excavations at Tell Abu Sarbut″; LaGro, ″An Insight into Ayyubid-Mamluk Pottery. ″

[26]Seligman, ″Bet She′an, the Citadel.″

[27]Although there are four short publications by the excavators in Hebrew, I have relied most heavily on the summary in French by Porëe-Braitowsky. A. Biran, ″Yesud HaMa′ala,″ in *The New Encyclopedia of Archaeological Excavations in the Holy Land* (Jerusalem, 1993), 4:1510; Biran and Shoram, ″Remains of a Synagogue and of a Sugar Installation at Yesud HaMa′alah″ (in Hebrew), *Eretz-Israel, Archaeological, Historical and Geographical Studies* 19 (1987); A. Biran and Dan Urman, ″Yesud HaMa′ala, Synagogue—1982–1983″ (in Hebrew), *Excavations and Surveys in Israel* 2 (1983): 110–11; Porëe-Braitowsky, ″Les moulins et fabriques à sucre de Palestine et de Chypre.″

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Avraham Biran, and Dan Urman. The building housing the sugar factory seems to be undated. The entire twenty-one meter length of the south wall was uncovered to a height of 1.5 m. The interior space of the building was divided with two rows of columns. In its latest phase the three spaces provided by the rows of columns each held a plastered basin in and around which numerous fragments of sugar molds and jars were discovered. The basins each incorporated a column base. Further evidence of sugar refining was the presence of a five-meter-long stone canal, providing the water necessary for the process of sugar refining.

The ceramics, including those of the sugar pots, were dated on the basis of one Crusader coin minted in Cyprus to the thirteenth century, to which the excavators date the last phase of use of the building. The excavators claim that there were no ceramics later than the medieval period, and also that there were no Roman or Byzantine sherds. The colonnaded building is nevertheless identified as a synagogue based on an Aramean inscription found on the site, along with architectural similarities with those at Gush Halav and Capernaum, which date to the fourth through sixth centuries A.D.

Excavations at Lower Horbat Manot provide the final example of an excavated sugar refinery in Bilād al-Shām. This was a salvage excavation conducted by the Israel Antiquities Authority in 1995. At this site, on the Acre plain about 12 km northeast of Acre, a refinery and aqueduct were built by Godfrey le Tor in the thirteenth century A.D. (who sold it to the Hospitallers, who in turn leased it to the Teutonic Knights of Montfort) and remained in operation under Mamluk and then Ottoman governance.[28] A screw-press nearby was likely the site of sugar cane crushing, before it was taken to the refinery to be boiled. The excavation of the site was incomplete, but the excavators did establish the location of the building that would have housed the fire pits over which cauldrons of cane juice would have been boiled, and they fully excavated the courtyard where the cakes of sugar were dried. The large quantities of sugar pots dating from the thirteenth, fourteenth, and fifteenth centuries indicated that the production of sugar did not slacken during or after the transition to Mamluk rule.[29] The nature of the Ottoman sugar production is far more fragmentary, however. One transformation is apparent, and that is in the manufacture of the sugar vessels themselves. In the Crusader period they are made of a cleaned clay, with added temper, and fired at a high temperature to a hard finish. The Mamluk and Ottoman vessels were, however, made of clay that had not been cleaned or had any added temper, and were fired at a lower temperature to a softer finished product. Stern suggests this difference in production may reflect the change in ownership between the Crusader and Mamluk periods,

[28]Stern, ″The Excavations at Lower Horbat Manot.″

[29]Ibid.

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even though the workers at the plant are likely to have remained the same, coming from the nearby village of Manueth.[30] In addition, the capacity of the molds became greater over time, with the Crusader sugar molds having an average volume of 3.8 liters, the Mamluk sugar molds having volumes of 4, 4.5, or 6 liters, and the Ottoman sugar molds being too fragmentary to determine their volume.[31]

As mentioned above, comparanda for the functioning of sugar mills and refineries can be found at several sites on Cyprus, which are said to be modeled on the Crusader refineries found on the Levantine coast.[32] The sugar factory at Kouklia-Paphos is the most complete factory extant, containing a press, mill, boiling and refining installations, and a workshop and storage area, built within the remains of Roman temples. It was thoroughly excavated by a Swiss-German expedition in the late 1980s, and dates from the thirteenth century with possible use into the seventeenth century.[33] The layout of the factory is logical and efficient for the production of sugar, and represents a refinement of mill planning from those known in the Levant, the layouts of which do not seem planned. Water, so important in both the growing of cane and the production of sugar, was brought to the site from a spring 3 mi. away by means of an aqueduct. Two mills operated at the site, the smaller perhaps an addition to increase the milling capacity of the factory. The larger stone-built mill, grinding hall, and refinery are adjoined, sitting at the bottom of a slope on the main aqueduct line. In the mill proper, the cane was crushed on a large mill-base, still *in situ,* on which a large animal-driven runner stone rotated. The mash thus produced was then taken to a water-driven mill north of the hall and pressed, as described by al-Nuwayrī. The adjoining vaulted refinery hall contained basins for collecting the freshly-squeezed cane juice, and hearths for boiling it in large copper cauldrons, as well as a water conduit in the center of the room, compartments for molds of sugar juice to rest on beams for evaporation, and rooms with water basins for the soaking and cleaning of sugar jars and molds.[34] The stone and mud-brick hearths are constructed so that their stoking chambers are on the outside of the building, to prevent ash and soot from entering

[30]Ibid.

[31]Ibid.

[32]Von Wartburg, ″The Medieval Cane Sugar Industry in Cyprus″; idem, ″Cane Sugar Production Sites in Cyprus.″ Until the mid-fifteenth century, the master of the royal refinery at Kouklia was always a Syrian (Maier and Karageorghis, *Paphos: History and Archaeology*).

[33]Von Wartburg, ″The Medieval Cane Sugar Industry in Cyprus″; von Wartburg and Maier, ″Excavations at Kouklia (Palaepaphos): 15th Preliminary Report″; idem, ″Excavations at Kouklia (Palaepaphos): 16th Preliminary Report.″

[34]Von Wartburg, ″The Medieval Cane Sugar Industry in Cyprus.″

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the refining area.[35] A storage and workshop area was found adjoining this complex at the north, which may have served as a place to store and repair the cauldrons and other implements used in refining. An additional mill or crushing installation was found here as well.[36]

This review of the excavations of sugar-production sites reveals that the archaeological evidence corroborates the textual evidence of both the processes by which sugar was produced in the Mamluk period and the implements with which it was done.[37] The numerous sugar mills that have been surveyed (twenty positively-identified sites in modern Israel alone) also seem to corroborate the story of large quantities of sugar being produced for the international and probably local markets in this period. On the other hand, these excavations and surveys cannot yet flesh out the picture of production in rural Bilād al-Shām, placing sugar in its agricultural and economic contexts. This is not due to the inherent limitations of archaeological investigation, but rather to the failure on the part of excavators to determine the relationship of the sugar refineries with their supporting settlements. This element is missing from all excavations discussed above but that of Tell Abu Sarbut, where the excavators determined that the existence of the village was not contingent upon the success of the sugar refinery, as it was occupied long after the refinery was defunct.[38] Careful excavation of additional sugar factories and their attendant settlements will help address such debated issues as rural population fluctuation in Mamluk Bilād al-Shām, and the degree to which populations of various regions depended on cash crops and associated industries.

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[35]Von Wartburg and Maier, ″Excavations at Kouklia (Palaepaphos): 15th Preliminary Report.″

[36]Von Wartburg and Maier, ″Excavations at Kouklia (Palaepaphos): 16th Preliminary Report.″

[37]For example, al-Nuwayrī describes the sugar pots and molds, noting that the molds were of different volumes.

[38]This may soon be remedied by the ongoing research at Tall Hisban in southern Jordan, where excavators have unearthed a storeroom containing sugar storage jars. The surrounding area is likely to have held numerous sugar mills, and several mill sites have tentatively been identified in archaeological field surveys as being Mamluk. See Bethany J. Walker, ″Mamluk Investment in Southern Bilad al-Sham in the Eighth/Fourteenth Century: The Case of Hisban,″ *Journal of Near Eastern Studies* 62 no. 4 (2003): 241–61. As she notes in this article on p. 259, n. 81, research on the possible sugar industry at Hisban will integrate the field research and textual study of *waqf* and other documents and is published in her article entitled ″Mamluk Investment in Transjordan: A ′Boom and Bust′ Economy″ in this volume.

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