Economic use of threshing remains as temper in mud-bricks in Karanis, Roman Egypt.

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# Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Abstract</strong></td>
<td>6</td>
</tr>
<tr>
<td><strong>1. Introduction</strong></td>
<td>7</td>
</tr>
<tr>
<td>1.1. Archaeological context</td>
<td>7</td>
</tr>
<tr>
<td>1.1.1. Grain selection from the Neolithic until the Roman period</td>
<td>7</td>
</tr>
<tr>
<td>1.1.2. Economic importance of threshing remains</td>
<td>9</td>
</tr>
<tr>
<td>1.1.3. Mud-brick architecture</td>
<td>12</td>
</tr>
<tr>
<td>1.1.4. Roman Karanis</td>
<td>16</td>
</tr>
<tr>
<td>1.2. Research problem and research questions</td>
<td>18</td>
</tr>
<tr>
<td><strong>2. Method</strong></td>
<td>20</td>
</tr>
<tr>
<td><strong>3. Results</strong></td>
<td>23</td>
</tr>
<tr>
<td>3.1. Samples from Roman Karanis</td>
<td>23</td>
</tr>
<tr>
<td>3.2. Recent samples</td>
<td>30</td>
</tr>
<tr>
<td>3.3. Spatial distribution of samples in Roman Karanis</td>
<td>33</td>
</tr>
<tr>
<td><strong>4. Discussions and conclusions</strong></td>
<td>36</td>
</tr>
<tr>
<td>4.1. Comparison between Roman and recent threshing remains</td>
<td>36</td>
</tr>
<tr>
<td>4.2. Traces of working on threshing remains from Roman Karanis</td>
<td>36</td>
</tr>
<tr>
<td>4.3. Explanations and recommendations</td>
<td>44</td>
</tr>
<tr>
<td><strong>Bibliography</strong></td>
<td>46</td>
</tr>
<tr>
<td><strong>List of figures and tables</strong></td>
<td>50</td>
</tr>
</tbody>
</table>
Abstract

Emmer-wheat (*Triticum turgidum* ssp. *dicoccon*) was the dominant crop cultivated in ancient Egypt, but was gradually replaced by hard-wheat (*Triticum turgidum* ssp. *durum*) during the Ptolemaic period (later the Roman period). Hard-wheat was in contrast to emmer-wheat a free-threshing cereal. Threshing hard-wheat resulted in large numbers of threshing remains. This provided the opportunity to use threshing remains, among others, as temper in the fabrication of mud-bricks in construction. However, archaeobotanical research of threshing remains (rachis fragments in particular) in mud-bricks from Roman Karanis showed that they were not directly used in the production of bricks. Instead, after threshing the material was treated a second time, what resulted in higher expenses and extra time.

This is an interesting observation in the study of the dynamics of the agricultural economy in the town of Karanis. This thesis focusses upon the economic use of threshing remains in Roman Karanis. The following text will explore the link between the available threshing remains on the one hand and their use as temper in the production of mud-bricks on the other hand. The aim of this research is to reconstruct the logistic of the construction of houses in Karanis. Central to this study are several questions: How many threshing remains were on average needed for the production of a single brick? Which processes were applied to the material before adding them as temper in mud-bricks and why?
1. Introduction

1.1. Archaeological context

1.1.1. Grain selection from the Neolithic until the Roman period

The agricultural economy of ancient Egypt encompassed the entire framework of the Egyptian civilization. For thousands of years the Nile supplied the land with rich sediments from the highlands of east central Africa deposited by annual floodings.¹ This annual cycle was of substantial importance for the production of crops (fig. 1) and became the basis of the Egyptian economy, culture and religion.

The Neolithic period in Egypt started in the sixth millennium B.C in Upper (southern part of the Nile Valley) and Lower Egypt (northern area of the Nile Valley). The agricultural communities of Upper Egypt were based upon herding cattle, sheep and goat, while in Lower Egypt this comprised herding and the cultivation of six-row barley (Hordeum vulgare ssp. vulgare) and emmer-wheat (Triticum turgidum ssp. dicoccon).² Evidence of two-row barley (Horedeum vulgare ssp. distichon) is known from the Predynastic period from the site of Tell el-Fara’ in the Nile Delta. Evidence of the cultivation of this crop is also known from the Pharaonic period (Middle Kingdom/Second Intermediate Period) in Tell el-Dab’a in the Nile Delta and Umm Mawagir (Second Intermediate Period) in the Kharga oasis.³

Six-row barley was the dominant crop in the Old and Middle Kingdom. Although this crop is a hulled grain, evidence from Northern Syria shows that bread can be made of hulled barley without removing the husks first. Therefore, this grain was probably preferred for the production of bread until the New Kingdom, after it was replaced by emmer-wheat. Emmer-wheat became the dominant crop in the course of the New Kingdom and was especially important during the Late Period in Egypt.⁴

A major shift took place in the Graeco-Roman period due to the replacement of emmer-wheat by hard-wheat (Triticum turgidum ssp. durum). Hard-wheat had been an important source of food in the Mediterranean region for the preparation of pasta and bread.⁵ The Egyptians had contacts with peoples who grew free-threshing wheats since the Neolithic period,⁶ but finds of free-threshing grains from before the Graeco-Roman period are

¹ Stokes & Gorman 2008, 198.
² Cappers & Neef 2012, 405.
⁵ Nesbitt 2005, 52.
⁶ Cappers & Flohr 2008, 128.
sporadic. Therefore, it is unlikely that these cereals played a significant role in the diet of Pharaonic Egypt. However, once Egypt came under the rule of Greeks (Ptolemaic dynasty) and later the Romans, the agricultural economy was directed by political choices and outside circumstances. The Romans took an interest in establishing powerful internal affairs with this rich and strategically located country. Egypt was dubbed a Roman province a year after the defeat of Cleopatra VII (the last of the Ptolemies) and Mark Anthony in 31 B.C. at the Battle of Actium. The disappearance of emmer-wheat is visible in the archaeobotanical assemblage of most Roman period sites in Egypt. These sites often show a predominance of hard-wheat, which was preferred due to its favorable characteristics in relation to the high demand of grain by Rome.

Fig. 1. Introduction and replacement of cereals in Egypt from the Neolithic (6000 B.C.) until modern times.

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7 Jans & Cappers 2002-2003, 84.  
8 Homsey 2003, 39.  
9 Bagnall & Rathbone 2004, 16.  
10 Van der Veen 2011, 141.  
11 Cappers & Neef 2012, 408.
1.1.2. Economic importance of threshing remains

Hard-wheat is a free-threshing cereal, which means that the grains separate from the ear during threshing. This process of threshing is easy and produces considerable quantities of material including huge numbers of threshing remains all at once. However, after the upper spikelets of free-threshing wheat’s become ripe grain kernels start to scatter already. The entire plant needs harvesting and this means that if harvest takes place after the lower spikelets become ripe a considerable number of grains are already lost. The naked grain kernels are more vulnerable to vermin, because the chaff does not protect them. However, naked grains require less volume/weight for storage and transport.

This all is in contrast to emmer-wheat, since after threshing of this cereal the chaff remains attached to the grain. Of hulled wheat’s the entire ears are harvested and threshing remains only become available after the second threshing. This second process ‘dehusking’ aims to remove the husks, and takes place prior to the preparation of a meal. The fact that emmer-wheat is a hulled cereal has advantages when it comes to the harvest, because this can be done without too much yield loss, since the spikelets remain attached to the rachis. The chaff also protects the grain against bacteria. The hulled nature of emmer-wheat does mean a larger volume/weight for storage and transport in contrast to naked cereal. For all these reasons, emmer-wheat was ideal for use by small villages or a family.

The above clarifies that both hulled and naked cereals have advantages as well as disadvantages, but this differs per stage of crop processing and the aim and use of a particular cereal type (table 1). For the Romans, the use of hard-wheat had several economic advantages, since it required less storage space, one process of threshing and could be produced on a large scale resulting in a surplus of grain and a huge surplus of threshing remains due to the free-threshing nature of this cereal. Besides the surplus of grain, this by-product of hard-wheat also became an important economic factor in the Roman period in Egypt.

Van der Veen (1999) gives a good example of the archaeological site Mons Claudianus, which was a Roman quarry in the eastern desert in Egypt. In Mons Claudianus rachis fragments of hard-wheat and small amounts of bread-wheat and barley (Hordeum vulgare) were found and represent approximately 40% of the total plant assemblage uncovered at the

15 Sidebotham 2008, 77.
The presence of these remains proves local production of wheat, however, this is not very likely since the site is located in a desert area about 120 km from the Nile Valley. In this region dry climatic circumstances have occurred since 3000 BP and there is no evidence (archaeological or textual) to support the occurrence of arable farming. Therefore, threshing remains at the site were probably imported, which stresses the value of trade in this by-product of wheat. Archeological research proved that in Mons Claudianus, threshing remains were used as fodder, in dungcakes and in building material. This is also the case in the settlement of Roman Karanis.

Cappers (2008) explains that the economic importance of threshing remains of hard-wheat (Triticum turgidum ssp. durum) in Roman Egypt, can be illustrated on the basis of the present-day use of bread-wheat (Triticum aestivum L.). Bread-wheat is cultivated in Egypt today, and is intertwined in a complex mechanism of market dynamics in the agricultural system of the country. Bread-wheat has in common with hard-wheat, that it is a free-threshing wheat, and therefore yields substantial numbers of threshing remains. The harvest and threshing of bread-wheat in Egypt occurs in April, but until November threshing remains can still be seen in huge piles located at barnyards and on the edge of agricultural fields. Farmers wait as long as possible to sell for a good price. These threshing remains even play a part in international trade to countries such as Jordan and Libya. This shows that threshing remains in present-day Egypt still have economic value.

Table 1. Advantages and disadvantages of hulled and naked cereals per stage of crop processing.

<table>
<thead>
<tr>
<th>Cereal Type</th>
<th>Harvesting</th>
<th>Threshing</th>
<th>Transport</th>
<th>Storage</th>
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<tbody>
<tr>
<td>Hulled</td>
<td>When last spikelets are ripe; negligible yield losses</td>
<td>Difficult; low quantities of threshing remains produced prior to cooking</td>
<td>Large volume/weight</td>
<td>Grain kernels protected in chaff</td>
</tr>
<tr>
<td>Negative</td>
<td>–</td>
<td>Large volume/weight</td>
<td>Large volume/weight</td>
<td></td>
</tr>
<tr>
<td>Naked</td>
<td>When first spikelets start ripening; substantial yield losses may occur</td>
<td>Easy, huge quantities of threshing remains that can be used as fuel, fodder and temper</td>
<td>Small volume/weight</td>
<td>Small volume/weight</td>
</tr>
</tbody>
</table>

16 Meijer 2010, 23.
17 Van der Veen 1999, 211-12.
18 Van der Veen 1999, 213. Mud-bricks were found, but the majority of the buildings were constructed of stone.
Fig. 2. Morphology of a grain plant.\textsuperscript{22}

\textsuperscript{22} Edited by the author, but based on Hillman 1984, 2.

Fig. 3. Morphology of a rachis fragment.\textsuperscript{23}

\textsuperscript{23} Hillman et al. 1996, 202.


1.1.3. Mud-brick architecture

The study of mud-brick architecture has received relatively little attention in contrast to stone architecture, which is not surprising considering the fact that impressive monumental stone structures made Egypt famous and alluring for the first explorers and researchers. However, of the two the mud-brick was the more common construction medium in ancient Egypt. In archaeology, the study of mud as building material has been researched extensively in the past century. The emphasis is mostly on the technological and architectural properties of the material, but in recent years this research has expanded to the investigation of mud-bricks as part of broader socio-economic mechanisms.\(^{24}\)

Mud-bricks as building material was used for many centuries in regions such as the Mediterranean, Africa, the Near East and Asia.\(^{25}\) The mud-brick was used as building material in dry areas where wood was and is scarce.\(^{26}\) It was used especially in the Near East for the construction of small, private structures as well as large public architecture, its availability in large quantities and due to the simple technique to produce the bricks. Egypt was a favorable area for the production of mud-bricks. Therefore, it is not surprising that mud-brick architecture was immensely popular in Egypt from an early period until recently.\(^{27}\)

One of the great advantages of mud-bricks in comparison to the use of stone in Egypt was and is its accessibility, easy construction and its workability. Unlike stone, mud-bricks are easily manufactured from Nile alluvium, desert clays/sediment, sand and water, which were resources everyone could obtain in different quantities and quality.\(^{28}\) A specific quality could be obtained due to the use of different types of sediments or clay, of which some might provide a stronger brick and thereby a more durable construction. The same is true for the amount and quality of temper that was used. The construction of mud-bricks was an easy, but labor-intensive process (fig. 4). First, a basic mixture of clay, sand and organic material was poured into molds of similar size.\(^{29}\) After that, the bricks were sundried slowly.\(^{30}\) A dried mud-brick is, however, quite easy to break by bending it, since bending puts a lot of tension and force on the edges.\(^{31}\) Bending material the right way, does make a good strong wall when all

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\(^{24}\) Emery 2011, 1.
\(^{25}\) Ormeling 2011, 12.
\(^{26}\) King & Stager 2001, 28.
\(^{27}\) The use of threshing remains of free-threshing hard-wheat as temper in mud-bricks was introduced in the Graeco-Roman period in Egypt. This tradition lasted until several decades ago (Cappers 2008, 10).
\(^{28}\) Emery 2011, 1-2.
\(^{29}\) Kemp 2000, 83-84. Nubian structures only contained equally sized mud-bricks: 37 x 18 x 12cm (Vogel & Delf 2010, 8).
\(^{30}\) Downton unknown year, 151.
\(^{31}\) Vogel & Delf 2010, 8.
the forces are compressive. Pieces of straw or other organic materials have a lot of strength if one tries to stretch them, but when this material is crumbled it has no strength whatsoever. If organic material is added to the mixture of mud and left to dry hard it results in a mud-brick which is resistant to both squeezing and tearing and makes an excellent strong building material.\(^{32}\) Threshing remains can be added to prevent the brick from premature cracking. By using this technique, the mud-brick has both a good compressive strength as well as tensile strength.\(^{33}\) This technique enabled people to build strong and high structures.

After the fabrication of the brick, a foundation was laid by a first level of mud-bricks to form the layout of the structure.\(^{34}\) Walls were built by connecting bricks with mortar and plaster layers filled with all sorts of rubble. After the structure was completed, the walls were covered with a layer of plaster to protect the bricks from weathering and wear.\(^{35}\)

Mud-bricks were often preferred, because of their easy construction in contrast to the quarrying and the reworking of stone.\(^{36}\) It was also easy to use, because of the standardized rectangular sizes of the bricks in contrast to the variety of stone shapes. Besides that, mud-brick constructions offered favorable living conditions, since in summer the heat was left out of the building, while in winter the heat was accumulated between the walls.\(^{37}\) The material was also flexible in a practical sense, because of the workable size and its easy manufacture. Additional spaces or alterations to the layout were easily made.\(^{38}\) Mud-brick buildings were strong, because of the simple constructions, but not as strong and durable as stone. Mud-bricks required constant upkeep, restorations and reparations. Mud-brick walls can last long, but do need protection from extreme weather, such as driving rain and exposure to continuous high moisture.\(^{39}\) Mud-brick constructions covered with plaster usually need replacing after the raining season, but the regions where this building material was commonly used have dry summers that enable the restoration of damage caused by rain.\(^{40}\) Despite that, mud-brick constructions are not capable to last for centuries, hence many monumental structures, tombs and statues were made of stone.\(^{41}\)

\(^{32}\) Vogel & Delf 2010, 8.
\(^{33}\) Vogel & Delf 2010, 8.
\(^{34}\) Kemp 2000, 88.
\(^{35}\) Vogel & Delf 2010, 18.
\(^{37}\) Meijer 2010, 29.
\(^{38}\) Emery 2011, 2.
\(^{39}\) Downton unknown year, 152.
\(^{40}\) Dunham 2005, 268-270.
\(^{41}\) Emery 2011, 1.
Mud-bricks were used in temple constructions, tombs, palaces, houses, sheds and all sorts of other objects such as kilns, hearts and ovens.\textsuperscript{42} Mud-bricks were a universal building material as it was incorporated in complex religious structures as well as in simple dwellings. The use of mud-bricks was not restricted to the lower classes, but instead for structures of all sizes and different socio-economic levels.\textsuperscript{43} An example of the use of mud-bricks is a tomb excavated in Saqqara. This tomb belonged to the first ruler of the first dynasty (2920-2575 B.C.), a Thinite, who was named Aha (Hor-Aha, Menes).\textsuperscript{44} His tomb was a pit cut into the natural rock, which contained 27 magazines and five subterranean chambers all made of mud-brick and decorated in the ‘palace facade’ style.\textsuperscript{45}

Mud-bricks preserve excellent and their botanical content remains unharmed without contamination. In other words, a mud-brick provides a closed context for the study of their archaeobotanical content.\textsuperscript{46} This has obviously led to thorough research of agricultural processes in archaeology in ancient Egypt. Mud-bricks consist of clay and supplements, which are interesting for archaeobotanical specialists: chaff of grain, middle high and long weeds harvested with the grain and the seed bank from the fields from which the clay originates.\textsuperscript{47} This is interesting for the reconstruction of early agricultural practices, the use of land and irrigation techniques and for the investigation of differences in the quality of mud-bricks and the possible preference of certain clay. The identification of organic temper used in mud-bricks is important for the reconstruction of the ancient agricultural economy.

Throughout the history of the use of mud-brick constructions, the material was used for domestic, funerary and religious structures.\textsuperscript{48} Egyptian villages were generally built completely out of mud-bricks, which increased their flexibility when family structures changed.\textsuperscript{49} This traditional building method continued into the Roman period in Egypt. Roman Karanis is an excellent example of a settlement build of mud-bricks, with the exception of two stone temples.\textsuperscript{50} In Karanis, houses and other mud-brick constructions such as granaries were excavated.\textsuperscript{51}

\textsuperscript{42} Staubach 2005, 19.  
\textsuperscript{43} Emery 2011, 1.  
\textsuperscript{44} Bunson 2002, 14.  
\textsuperscript{45} Bunson 2002, 14-15.  
\textsuperscript{46} Cappers 2011, personal communication. Ormeling 2011, 23.  
\textsuperscript{47} Cappers 2006, 12.  
\textsuperscript{48} Emery 2011, 1.  
\textsuperscript{49} Wickham 2006, 459.  
\textsuperscript{50} Bowman 1996, 171.  
\textsuperscript{51} Oleson 2008, 274.
Fig. 4. Illustrations of the process of mud-brick manufacture in present-day Egypt. 
a. Mixing of mud and organic material. The standing man holds a supply of extra sand and ready.
b. Sometimes extra organic material is added to get the consistency of the brick right. On the right, some newly fabricated bricks lay. The brick-maker adds some straw on top and underneath the wed bricks to prevent them from sticking to the earth.
c. The brick-maker pours the mixture in a mold.
d. He levels the surface of the mold after filling it and removes the mold.
e. The fabricated bricks are left to dry and are turned over every couple of days.
f. The finished product.52

52 Illustrations and supporting texts belong to the Brooklyn Museum, and is accessible at: http://www.flickr.com/photos/brooklyn_museum/sets/72157594275159545/with/237788938/.
1.1.4. Roman Karanis

The province of El-Fayoum is located approximately 70 km southwest of Cairo and is rich in archaeological sites (fig. 5). The Fayum is known as an oasis, but is not an oasis such as Egypt’s Farafra, Siwa, Kharga and Dakhla oases, but a natural depression in the Egyptian desert. The ‘Bahr Yusuf’, a canalized branch of the Nile, links the Fayum to the Nile. This connection was and is crucial for the development and the existence of the Fayum, because agriculture depended on the winter flooding of the Nile and the nutritious silt the water brought.\(^5^3\)

Egypt’s Fayum was known for its rich agricultural production in Ptolemaic times and saw in this period the introduction of an irrigation system, but this region was economically exploited and flourished in the Roman period.\(^5^4\) Several settlements were established or came under Roman rule to stimulate the production of grain and the coordination of the exchange of goods to Rome. Augustus started a major restoration campaign in the Fayum: the neglected irrigation systems were repaired and the land was reclaimed as state domain. Some land was given to veterans of the Roman empire to give cities such as Karanis a more ‘Roman’ character and population than other smaller Fayum villages.\(^5^5\)

During the late fourth until the third century B.C. irrigation techniques improved to increase Egypt’s agricultural production, what enabled to harvest twice a year.\(^5^6\) Canals and dikes were built to increase the amount of agricultural land in the Fayum.\(^5^7\) The available agricultural land tripled in this period.\(^5^8\)

The town of ancient Karanis in the Fayum, which today is known as Kom Aushim or Kom Ushim, was occupied for a period of about seven centuries and endured many changes after the end of dynastic rule in Egypt.\(^5^9\) Ptolemy II Philadelphus (285-247 BC) founded Karanis in the mid-third century B.C. to station part of his troops in Egypt\(^6^0\), but Karanis became more than just a garrison, since it developed, grew and prospered into a large settlement. Karanis remained occupied throughout the sixth century A.D. or possibly until slightly later.\(^6^1\)

The town of ancient Karanis was discovered at the end of the nineteenth century, but in 1924 the first actual excavation begun organized by the University of Michigan. These

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\(^5^3\) Heinrich 2011, 7.
\(^5^4\) Hewison 2008, 21.
\(^5^5\) Van Minnen 1994, 224.
\(^5^6\) Boserup 1993, 15.
\(^5^7\) Cappers & Flohr 2008, 127.
\(^5^8\) Cappers & Flohr 2008, 127.
\(^5^9\) Ptolemy II Philadelphus (285-247 BC).
\(^6^0\) Gazda 2004, 8.
\(^6^1\) Bagnall & Rathbone 2004, 131.
excavations lasted until 1935. Artifacts were divided between the University of Michigan and the Egyptian government. Many are on display in the Kelsey museum in Ann Arbor.

In 2002 the University of Groningen (RUG) and the University of California, Los Angeles (UCLA) started to work together on the so called ‘RUG-UCLA Fayum-project’ both with specialists and students. The Fayum-project has brought new information to light on the Neolithic and the Graeco-Roman periods in Karanis. Archaeobotanical research in Karanis has recovered data on the subsistence economy and the development of early agriculture in the Graeco-Roman period of the town. The reconstruction of past agricultural activities include evidence of land-use strategies/methods (ploughing, weeding, irrigation) and reconstructions of different stages of crop processing (reaping methods, threshing).

Roman Karanis continues to decay, but is still one of the best-preserved sites in the Fayum. The site is slightly smaller than the city of Pompeii, but still enormous with its 60-hectares. Most of the visible ruins in the settlement are of the early Roman period, which is partly due to the fact that the first century A.D. was a prosperous period for Karanis, but also since later remains were largely destroyed before the start of excavations. Earlier layers, such as those from the first century A.D. were not reached during excavations and therefore remain intact.

Fig. 5. The Fayum.

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63 Bagnall & Rathbone 2004, 131.
64 Cappers 2005, 89.
65 Cappers 2011 et al., 176.
68 Bagnall & Rathbone 2004, 128.
1.2. Research problem and research questions

To reconstruct former agricultural practices a good quality of plant remains is needed. Therefore, it is important to consider the sampling method that was used and the representativeness of the data.\textsuperscript{69} A problem with sampling botanical remains is, however, that the majority of past activities occured outside the settlement while excavation work and sampling is done \textit{on-site} within settlement areas.\textsuperscript{70} A solution for this is a model created by Cappers (fig. 6). This model presents the study of the cultivation of free-threshing wheats in Roman Egypt and is based on judgemental sampling.\textsuperscript{71} In this model the relationship between cereal fields and archaeological settlements in Roman Egypt was mapped with the aid of ethnological observations in modern-day Egypt\textsuperscript{72} and illustrated with samples taken at Roman Medinet Watfa in the western Fayum. With this information, routes of seeds and fruits from their biotopes to settlements were reconstructed and translated in this model. Cappers showed that the best solution to the sampling problem is a combined analysis of samples from different archaeological contexts as ash layers, storage facilities and building materials.\textsuperscript{73}

![Fig. 6. The relationship between cereal fields and archaeological settlements in Roman Egypt.\textsuperscript{74}](image)

The primary aim to cultivate hard-wheat was to produce a surplus of grain, but due to the free-threshing nature of this cereal, huge numbers of a by-product (threshing remains) became available as well. One could use this by-product as fodder, fuel and in construction. The presence of rachis fragments in mud-bricks from Roman Karanis proves that this by-product was suitable as temper in bricks for construction.

\textsuperscript{69} Van der Veen 1984, 193.
\textsuperscript{70} Cappers 2008, 125.
\textsuperscript{71} Cappers 2011 et al., 176.
\textsuperscript{72} This included analyses of threshing remains from cereal fields in the Fayum (Cappers 2011, 176).
\textsuperscript{73} Cappers & Flohr 2008, 125.
\textsuperscript{74} Cappers & Flohr 2008, 125.
This seems a logic cause of events: a large number of threshing remains become available and one uses them in the production of mud-bricks. However, the results of this research revealed traces of working on the rachis fragments (fig. 8a/b). Threshing remains from Karanis that were not used in the production of bricks do not bear such marks (fig. 8c). The rachis fragments from mud-bricks in Karanis are heavily fragmented and do show marks/traces of working (fig. 8 a/b). Apparently, temper had to fulfill certain demands and was crucially accessed before it was used. The material got extra treatment after threshing, what resulted in more time, labor and costs. This invokes important questions related to threshing techniques and extra treatment of threshing remains: How did the fragmentation of rachis fragments came by and which processes were used to treat the material? Why did the material need fragmentation?

The aim of this research is to reconstruct the logistic of construction in Karanis. Quantifying the number of threshing remains by mud-brick is interesting in relation to the production and economic use of threshing remains in construction and raises another question: How many threshing remains are on average needed as temper in a mud-brick and how is this related to the composition of the brick? If the results of this research show significant differences in the number of rachis fragments in the mud-bricks, the quality of the clay might have played a role. Such differences are possibly connected to mechanisms such as supply and the demand for threshing remains, since threshing remains have economic significance (paragraph 1.1.2.). This is interesting in relation to the role of agriculture in the economy of Roman Egypt.

The importance of cereal processing by-products as construction material needs assessment in a wider economic context. Therefore, this graduate research focusses upon the economic use of threshing remains as temper in mud-bricks in Roman Karanis.
2. Method

Forty-one samples\(^{75}\) were investigated to reconstruct the economic importance of threshing remains as by-product of hard-wheat in the settlement of Roman Karanis (table 2). Each sample represents a single mud-brick. The mud-bricks were measured, weighed and photographed and of each brick, a small section was preserved for future research. The remainder was dissolved in water. The resulting residue was dried, sieved and studied under a stereomicroscope in the palaeobotany laboratory of the Groninger Institute for Archaeology (GIA) in Groningen.

Twenty-eight samples contained rachis fragments (table 3). Only rachis fragments of hard-wheat (*Triticum turgidum* ssp. *durum*) were sorted out from these samples. Thirteen samples contained no threshing remains and were not included in table 3. The lack of threshing remains in these samples is due to the use of different types of temper in the mud-bricks, such as gravel, stones, clay and kitchen waste (fig. 7). The use of different types/qualities of clay also influences both the amount and composition of temper.

Besides these samples from Karanis, two recent samples of threshing remains of common wheat (*Triticum aestivum*) from Tunis (Egypt)\(^ {76}\) and a sample of recent wheat from La Fuliola (Barcelona)\(^ {77}\) were incorporated in the investigations (table 3 & 4). This was done to make comparisons between the quality, use and treatment of the material from these recent contexts and Roman Karanis.

Rachis fragments consist of nodes and internodes (fig. 3). The nodes were counted to get a picture of the fragmentary state of the threshing remains of hard-wheat and to estimate the number of threshing remains used for the fabrication of a single mud-brick from Roman Karanis (table 3). This information is archaeologically relevant for the investigation of the economic importance of this by-product and the reconstruction of the construction of houses in Roman Karanis.

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\(^{75}\) These samples were chosen, because F. Fantone and F.B.J. Heinrich registered them as ‘archaeobotanical’. Due to the lack of time for this thesis it was impossible to investigate all sampled (over 200) mud-bricks from Karanis.

\(^{76}\) This material was collected during threshing by prof. dr. R.T.J. Cappers in Tunis, Egypt.

\(^{77}\) Dr. W.A. Out gathered this material after threshing in La Fuliola, Spain.
Fig. 7. Four examples of the variety in the amount and composition of temper in samples from Roman Karanis. These are samples before the microscope investigation. All samples were photographed in a large petri dish (app. 13 cm x 13 cm) by the same camera from the same distance. a. Almost exclusively threshing remains, some shell, stones and gravel (GIA-24602/19473). b. Large numbers of threshing remains mixed with shell (GIA-24755/19824). c. Almost exclusively gravel, grit, stones and shell. Hardly any organic remains were observed (GIA-24603/19474). d. A small number of temper of gravel, organic remains and shell (GIA-24742/19809).78

78 Photographed by the author.
3. Results

3.1. Samples from Roman Karanis

The rachis fragments in samples from Roman Karanis are badly preserved. The material is very fragile and breaks easy. The rachis fragments look chopped into pieces, cut of irregularly and are highly fragmentary (fig. 8a/b). The rachis fragments have a fibrous character, since some pieces have little hairs and are rather woolly. Pieces are dark colored, but some look bleached, which might be due to exposure to sunlight. In the region of Egypt, darker remains of wheat are probably closest to their original color. These different colors might be the result of the conservation of the bricks and their organic component or the use of cereals from different fields, but it might also be due to the characteristics of a mud-brick such as the composition of the clay and the amount of moisture.

The majority of rachis fragments found in the mud-bricks from Roman Karanis are of hard-wheat, fragments of bread-wheat (*Triticum aestivum* L.) (fig. 14) and some fragments of barley (*Hordeum vulgare*) were also found in the samples (fig. 9b). The presence of barley is an interesting indication for the variety of crops in a field. Bread-wheat is the dominant crop for the production of cereals in present-day Egypt.

The rachis nodes from Roman Karanis are badly preserved, but some variety in conservation can be observed. Two samples (table 3: GIA-24683/19684, GIA-24604/19475) contained rachis nodes with the glume still attached (fig. 9a). Fragments from this sample consist of large pieces. One sample (table 3: GIA-24755/19824) contained rachis fragments and a charred piece, while another sample (GIA-24752/19821) yielded no organic remains except a single poorly preserved stem fragment. These examples proof to different conservation of the material: samples containing well-preserved rachis nodes with glumes attached and badly preserved samples.

Ones the temper is inside the brick its composition and conservation remains stable and will not change. Concentrations of threshing remains that were not used for the production of mud-bricks are also known from Roman Karanis (fig. 8c), and do not show a lot of fragmentation and are much bigger and firmer in comparison to the threshing remains that were used as temper in mud-bricks (fig. 8a/b). Therefore, the fragmentary state and poor conservation of rachis fragments from Karanis proofs that the material got extra treatment after threshing and prior to their use as temper in mud-bricks.

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79 Cappers 2011, personal communication.
Fig. 8. a. A rachis fragment (two nodes) of hard-wheat (*Triticum turgidum* ssp. *durum*) used as temper in a mud-brick from Roman Karanis (table 3; GIA-24604/19475). b. Highly fragmented rachis fragments (GIA-24743/19810). c. Threshing remains of *Triticum turgidum* ssp. *durum* (GIA-24613-A/19495) from Roman Karanis. These were not used as temper in mud-bricks.

80 Photograph by the author.
81 Photograph by prof. dr. R.T.J. Cappers.
By counting nodes, it is possible to calculate the number of ears translated to the number of threshing remains in a mud-brick. Such calculations are useful for a reconstruction of the relations between architecture and cereal fields.  

In table 3 the number of rachis nodes per sample from Karanis is shown. Each sample, with the exception of one (table 3: 19809), is represented with rachis fragments of one node. Rachis fragments consisting of two nodes occur in high numbers too, but less frequent as fragments of one node. Three and four nodes occur regularly, but that number is often half the number of fragments of one and two nodes. Some samples contain rachis fragments of five, six and seven nodes, but this occurs even less often than the presence of three and four nodes. In most samples, rachis fragments of one, two, three and four nodes occur, but fragments of more than ten nodes hardly ever occur. The maximum number of nodes is 17, which is only present in a single sample (table 3: 19476).

The microscopic research clarified that the degree of fragmentized rachis fragments in mud-bricks from Roman Karanis is very high, but the results of counting the nodes of each fragment from each sample verifies this. To validate these results additional calculations of rachis nodes in standardized volume and weight were done for 10 kilogram and 10 liter. To calculate the number of rachis fragments in 10 kilogram certain information is required: the

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82 Photograph by the author.
84 From some samples not enough information was available to make calculations for 10 kilogram and 10 liter. The calculations of rachis nodes per sample in 10kg and 10l too demonstrates and proof that the degree of fragmentation in these samples is high.
weight (kg) of the mud-brick excluding the part cut-off for future research. A conversion factor (kg) was calculated by dividing 10 kg with the investigated part of the brick in kilogram (table 3). The number of rachis nodes in 10 kg per sample was calculated with this conversion factor.\textsuperscript{85} For example: sample 19471 contains 59 rachis fragments of one node and its conversion factor is 2.3 kg (table 3). The number of rachis fragments of one node in 10 kg for this sample is: $59 \times 2.3\, \text{kg} = 153$. The same calculations were performed on all numbers of nodes of each sample. These results too show a dominant presence of one node and a frequent appearance of two and three nodes (fig. 11).

\textbf{Fig. 10.} Number of rachis nodes in each sample: 28 samples from Roman Karanis, two samples from Tunis in Egypt (20030395, 200308758) and one from La Fuliola in Spain.

Information about the volume (cm$^3$) is required to calculate the number of rachis nodes in 10 liter. The conversion factor (l) for volume (cm$^3$) was calculated by dividing 10 l with the volume (cm$^3$) of the brick (table 3). Sample 19471 contains 59 rachis fragments of one node and has a conversion factor of 0.0031 l. The number of rachis nodes in 10 l of one node in this sample is: $59 \times 0.0031\, \text{l} = 0.184$ (table 3). Again, rachis fragments of one node clearly dominate, followed by two and three nodes.

\textsuperscript{85} For each sample a conversion factor (kg) was calculated.
The emphasis clearly lies on the presence of rachis fragments of one and two nodes, which confirms that the bulk of the threshing remains are highly fragmentized (fig. 10).

Fig. 11. Rachis nodes per sample in 10 kilogram from Roman Karanis.

Fig. 12. Rachis nodes per sample in 10 liter from Roman Karanis.
Table 2. Documentation of 41 investigated mud-brick excavated and sampled in Roman Karanis.  
Abbreviations: mb (mud-brick), mo (mortar), p (plaster).

<table>
<thead>
<tr>
<th>sampling date</th>
<th>DB no.</th>
<th>Unit no.</th>
<th>GPS ID</th>
<th>Co. no.</th>
<th>Trench no.</th>
<th>Mudbrick</th>
<th>Mortar</th>
<th>Plaster</th>
<th>Dimensions (cm)</th>
<th>Brick weight</th>
<th>Geologic outcrops</th>
<th>Mo/PI (in gr)</th>
<th>Mantle code</th>
<th>Remake</th>
<th>Sh</th>
<th></th>
</tr>
</thead>
</table>
| 14-10-10      | FV19-3417-gp | 5955 | 1 | FF1 | 39 | mb | - | - | 2.36 | none | 40 | Two small mudbricks of irregular shape assumed used to fill gaps in the wall
| 14-10-10      | FV19-3417-gp | 5955 | 2 | FF2 | 39 | mb | 26 | 13 | 9.5 | 4.26 | 0.460 | 170 |
| 16-10-10      | FV19-3417-gp | 5955 | 3 | FF3 | 39 | mo | - | - | 0.38 | none | 100 |
| 16-10-10      | FV19-3417-gp | 5955 | 4 | FF4 | 21 | mb | 26.5 | 15.5 | 3 | 3.6 | 1.35 | 350 |
| 16-10-10      | FV19-3417-gp | 5955 | 5 | FF5 | 23 | mb | 26.5 | 17.5 | 6.5 | 5.36 | 0.560 | 65 |
| 16-10-10      | FV19-3417-gp | 5955 | 6 | FF6 | 39 | mb | 27 | 13 | 9.5 | 4.26 | 0.360 | 70 |
| 16-10-10      | FV19-3417-gp | 5955 | 7 | FF7 | 39 | mb | 27 | 12 | 10 | 5.6 | 1.95 | 250 |
| 16-10-10      | FV19-3417-gp | 5955 | 8 | FF8 | 39 | mb | 27 | 12 | 11.5 | 5.16 | 0.860 | 250 |
| 16-10-10      | FV19-3417-gp | 5955 | 9 | FF9 | 59 | mb, mo | 24.5 | 16.5 | 13 | 5.46 | 0.860 | 700 |
| 16-10-10      | FV19-3417-gp | 5955 | 10 | FF10 | 39 | mb, mo | 23 | 18 | 10 | 5.7 | 1.860 | 40 |
| 16-10-10      | FV19-3417-gp | 5955 | 11 | FF11 | 39 | p | - | - | 0.76 | none | 260 |
| 16-10-10      | FV19-3417-gp | 5955 | 12 | FF12 | 39 | mb | 26.5 | 15.5 | 11.5 | 7.26 | 0.860 | 198 |
| 16-10-10      | FV19-3417-gp | 5955 | 13 | FF14 | 25 | mb | 22 | 14 | 8.5 | 5.06 | 1.95 | 75 |
| 16-10-10      | FV19-3417-gp | 5955 | 14 | FF15 | 39 | mb | 26 | 12.5 | 6.5 | 3.6 | 0.960 | 30 |
| 16-10-10      | FV19-3417-gp | 5955 | 15 | FF16 | 26 | mb | 26.5 | 15.5 | 11.5 | 6.16 | 1.860 | 40 |
| 16-10-10      | FV19-3417-gp | 5955 | 16 | FF17 | 24 | mb | 27 | 14 | 10 | 5.96 | 0.860 | 198 |
| 16-10-10      | FV19-3417-gp | 5955 | 17 | FF18 | 26 | mb | 27.5 | 12.5 | 6.5 | 5.36 | 0.760 | 60 |
| 16-10-10      | FV19-3417-gp | 5955 | 18 | FF19 | 26 | mb | 27.5 | 14 | 9.5 | 5.36 | 0.760 | 60 |
| 16-10-10      | FV19-3417-gp | 5955 | 19 | FF20 | 24 | mb | 27.5 | 14 | 9.5 | 5.36 | 0.760 | 60 |
| 16-10-10      | FV19-3417-gp | 5955 | 20 | FF21 | 24 | mb | 27.5 | 14 | 9.5 | 5.36 | 0.760 | 60 |
| 16-10-10      | FV19-3417-gp | 5955 | 21 | FF22 | 24 | mb | 27.5 | 14 | 9.5 | 5.36 | 0.760 | 60 |
| 16-10-10      | FV19-3417-gp | 5955 | 22 | FF23 | 24 | mb | 27.5 | 14 | 9.5 | 5.36 | 0.760 | 60 |
| 16-10-10      | FV19-3417-gp | 5955 | 23 | FF24 | 24 | mb | 27.5 | 14 | 9.5 | 5.36 | 0.760 | 60 |
| 16-10-10      | FV19-3417-gp | 5955 | 24 | FF25 | 24 | mb | 27.5 | 14 | 9.5 | 5.36 | 0.760 | 60 |
| 16-10-10      | FV19-3417-gp | 5955 | 25 | FF26 | 24 | mb | 27.5 | 14 | 9.5 | 5.36 | 0.760 | 60 |
| 16-10-10      | FV19-3417-gp | 5955 | 26 | FF27 | 24 | mb | 27.5 | 14 | 9.5 | 5.36 | 0.760 | 60 |
| 16-10-10      | FV19-3417-gp | 5955 | 27 | FF28 | 24 | mb | 27.5 | 14 | 9.5 | 5.36 | 0.760 | 60 |
| 16-10-10      | FV19-3417-gp | 5955 | 28 | FF29 | 24 | mb | 27.5 | 14 | 9.5 | 5.36 | 0.760 | 60 |
| 16-10-10      | FV19-3417-gp | 5955 | 29 | FF30 | 24 | mb | 27.5 | 14 | 9.5 | 5.36 | 0.760 | 60 |

86 This table was created by F. Fantone and F.B.J. Heinrich.
### Table 3. Calculations of rachis nodes in mud-bricks from Roman Karamis.

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<td>4</td>
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<td>Number of nodes per 10 kg</td>
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<td>92</td>
<td>82</td>
<td>82</td>
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<td>Total</td>
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</tbody>
</table>
3.2. Recent samples

Three recent samples were investigated: two from Tunis in the Egyptian Fayum and one from La Fuliola near Barcelona in the Spanish province of Catalonia (table 4).87

The sample from La Fuliola (no number) was collected on a threshing floor during a demonstration day of traditional threshing techniques. This threshing floor is approximately 10-20 m in diameter and had been covered by a layer of organic material for protection a year before samples were taken.88 Two processes of threshing were applied to this material: a wooden threshing sledge with metal parts drawn by a horse and a dented sandstone tumble that was drawn by a tractor.89 These threshing techniques are traditional to the region. So, threshing remains in this sample from La Fuliola were not threshed and treated by using modern threshing techniques, which grind the material in fine pieces and would make a comparison with ancient remains invalid. The rachis fragments from this sample are strong, long, firm pieces and show little fragmentation (table 4, fig. 13). The emphasis lies on rachis fragments of two nodes, but fragments of one and three nodes occur frequently too as is the case with five nodes. This sample yielded many fragments of more nodes than three (fig. 10).

Practices of farmers in Tunis and samples were collected for the study of ethnographic research in relation to the interpretation of past agricultural activities. Two samples (table 4: 20030395, 200308758) from Tunis are investigated and contain threshing remains intended for the production of mud-bricks (fig. 14a).90 These samples contained threshing remains of bread-wheat (*Triticum aestivum* L.) and some barley (*Hordeum vulgare*). The rachis fragments from both samples are large, firm and hard fragments and show little fragmentation (fig. 14b/c). The emphasis in these samples is clearly on rachis fragments of one, two and three nodes (fig. 10). Fragments of two nodes clearly dominate (table 4: 200308758). Large fragments occur sporadically. The threshing remains from Tunis preserve well and show a minimum degree of fragmentation. These threshing remains were not further treated after threshing.

87 Dr. W.A. Out took this sample in 2011.
88 Dr. W.A. Out, written communication.
89 According to dr. W.A. Out, a tumble is a large cylindrical piece of stone with pointed elevations at the longer side of the tool. These points give the tumble a stars-shaped side view.
90 Prof. dr. R.T.J. Cappers took these samples in October 2003.
Table 4. Rachis nodes in samples from Tunis (20030395 / 200308758) and La Fuliola.\textsuperscript{91}

<table>
<thead>
<tr>
<th>Rachis node</th>
<th>20030395</th>
<th>200308758</th>
<th>La Fuliola</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>8</td>
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<td>12</td>
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<td>11</td>
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<td>1</td>
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<tr>
<td>12</td>
<td>1</td>
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<td>1</td>
</tr>
</tbody>
</table>

Due to the lack of information about these three recent samples, it was impossible to calculate the number of rachis nodes in 10 kg and 10 l.

Photographed by the author.

\textsuperscript{91} Due to the lack of information about these three recent samples, it was impossible to calculate the number of rachis nodes in 10 kg and 10 l.

\textsuperscript{92} Photographed by the author.
Fig. 14. a. Threshing remains of bread-wheat (*Triticum aestivum* L.) from Tunis (200308750) prior to the microscopic research. b. Rachis fragments from Tunis (200308750). c. Detail of a rachis fragment from Tunis (200308750).93

93 Photographed by the author.
3.3. Spatial distribution

The spatial distribution of samples from Karanis is placed in three maps. The first is a map of Karanis east, in which twenty samples were excavated (fig. 15). The second and third maps depict adjacent parts of the settlement. Trenches of the second map (fig. 16) yielded four samples and those from the third map (fig. 17) seventeen samples. Each of these three images contain two identical maps of which the left one depicts the average number of rachis nodes per sample per area, while on the right map the average number of rachis fragments in 10 kg and 10 l per sample is compared. The average number of rachis nodes per sample is n= 154, and the average number per sample in 10 kg is n= 432 and n= 0.5 in 10 l.

The maps show that ten samples contain rachis nodes below the average, while seventeen contain more than the average number. This is because some samples contain a few large pieces with more than ten rachis nodes (table 3). It is interesting that these seventeen samples only occur in combination with samples that score below average and samples without rachis nodes (e.g. trench 21, 24 and 99). This means that there is variation in the number and quality of temper in the mud-bricks within the trenches. Therefore, it might be interesting to look at the location of the bricks in relation to the quality and the amount of temper in each mud-brick within a structure. Perhaps the composition of a mud-brick (amount of temper, type of temper, quality of clay) is related to construction methods (inner and outer walls). Another solution of why variation occurs within structures might be related to the function of a building.

When a combination is made between the number of rachis nodes in 10 kg and in 10 l, the most common combination is numbers of rachis nodes below the average (e.g. trench 23 and 25). Trench 99 yielded relatively a lot of samples with rachis nodes above the average in both 10 kg and in 10 l in comparison to the other trenches.

A study of the total number of mud-bricks might provide additional insights and a clear picture of the spatial distribution of mud-bricks in Karanis. The number of threshing remains, the quality of the clay and the absence of threshing remains in relation to the spatial distribution of mud-bricks is interesting for the study of the economic importance and use of threshing remains in Roman Karanis.
Fig. 15. Spatial distribution of samples in Karanis east.\textsuperscript{94} a. Distribution of the number of rachis nodes. b. Distribution of rachis nodes in 10 kg and in 10 l.

\textsuperscript{94} Wendrich 2011, written communication. Edited by the author.
Fig. 16. Spatial distribution of samples in Karanis.  

- a. Distribution of the number of rachis nodes.  
- b. Distribution of rachis nodes in 10 kg and in 10 l.

Recent investigations in Roman Karanis resulted in heaps of documentation. A lot of information is not accessible for students yet including a map of trench 99. The author drew this trench.

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Wendrich 2011, written communication. Edited by the author.

Fig. 17. Samples in trench 99 in the settlement of Roman Karanis.  

- a. Distribution of the number of rachis nodes.  
- b. Distribution of rachis nodes in 10 kg and in 10 l.
4. Discussions and conclusions

4.1. Comparison between Roman and recent threshing remains

The results of this research show some interesting things: threshing remains in mud-bricks from Roman Karanis bear traces of working and have a high degree of fragmentation (extreme dominance of rachis fragments of one node). The concentration of threshing remains (fig. 8c), that were not used in the production of mud-bricks, proves that threshing took place in the settlement of Roman Karanis. The high fragmentation of threshing remains in mud-bricks from Roman Karanis compared with recent samples (figs. 13 and 14) shows that this did not result from threshing. The material inside mud-bricks remains unchanged after the production of a brick is completed. So, all of this proves that extra labor was inserted into the fragmentation/processing of threshing remains to temper for the production of mud-bricks in Roman Karanis. The process of fragmentation was conducted after threshing and prior to the mud-brick production.

The cultivation of hard-wheat requires a minimum amount of work. The cultivation of this crop was a conscious choice, but the fact that threshing remains were worked extra instead of using them directly as temper in bricks, was a conscious choice too. So the question is: Why was this done and what sorts of tools were used for this?

4.2. Traces of working on threshing remains from Roman Karanis

Threshing results in loosening the grain kernels from the chaff and fragmentation. The fragmentation of threshing remains depends on the tools that are used. Although, it is unclear which tools were used for threshing and extra fragmentation of threshing remains in Roman Karanis a study of ethnography will provide some insights into this.

Prior to threshing, the grain is harvested. This is done by several different techniques: a basket, seed beaters, uprooting, reaping and hand stripping.97 Hand stripping and the use of a swinging basket are commonly used for the harvest of wild plants. By using the uprooting technique, whole plants are pulled out of the ground. This technique is used to harvest all sorts of crops, including cereals if they grow in low densities.98 A technique, which is suitable for cutting short and long crops is reaping with a sickle or a scythe. In the case of free-threshing cereals, such as hard-wheat, the dispersal unit of the plant is a grain kernel rather than a spikelet (hulled cereals). Ripe grain kernels easily disperse during harvesting.

98 Cappers & 2012, 64.
Therefore, harvesting is preferred before the total ripening has finished.\textsuperscript{99} In present-day Egypt harvesting bread-wheat (\textit{Triticum aestivum} \textit{L.}) is done with a sickle and close to the soil to prevent substantial numbers of yield loss due to after-ripening.\textsuperscript{100}

The sickle was popular for harvesting in Roman Egypt too, however, from the earliest phase of settled agriculture in the Roman period a variety of other techniques were also used, such as Roman reaping-boards (\textit{mergae}) and reaping-combs (\textit{pectines}). The latter only removed the heads of the grain, leaving the straw of the plant in the ground.\textsuperscript{101}

Threshing is the first act after the harvest of cereals and requires a repeated and powerful pounding of the cereal in order to separate the parts of the plant without damaging the seed itself.\textsuperscript{102} Threshing takes place in periods when less labor is required on the agricultural lands. If threshing occurs on-site, it is possible to store the yield directly.\textsuperscript{103} Ethnographic observations in Egypt indicate that harvested wheat’s are often left to dry in the fields before they are taken to the threshing floor and before the grains are released due to after ripening. The transportation of the wheat’s to the threshing floor occurs at night or in the early morning, when the sheaves are still damp. The dampness of the spikes prevents grain loss.\textsuperscript{104} It is unclear whether this custom was also common in ancient Egypt. Iconographic sources show that harvested emmer-wheat was carried to the threshing floor by hand, a donkey, in containers, nets or baskets. It may have been stored in the field until it was required and preferred to thresh the cereals as has been observed in present-day Egypt.\textsuperscript{105}

The threshing floor is preferably a clean, solid and flat surface. The sizes and quality of threshing floors vary and depend on the tools and techniques used for threshing. In order to allow drainage of the threshing area, the central part of the threshing floor should be slightly elevated.\textsuperscript{106} Threshing cereals usually takes place at the hottest hour of the day, when the cereals are at their driest.\textsuperscript{107} The loosened sheaves or ears lie across the threshing floor, after which one of the following methods are used to separate the grain kernels from the threshing remains: beating with a stick, trampling by animals or threshing with a sledge.

\textsuperscript{99} Cappers & Neef 2012, 64.
\textsuperscript{100} Cappers & Neef 2012, 64-65.
\textsuperscript{101} White 1970, 448.
\textsuperscript{102} McNeil 2002, 784.
\textsuperscript{103} Cappers & Neef 2012, 73.
\textsuperscript{104} Murray 2000, 524.
\textsuperscript{105} Murray 2000, 524.
\textsuperscript{106} Cappers & Neef 2012, 73.
\textsuperscript{107} Murray 2000, 524.
Threshing by beating with wooden objects produces certain vegetative parts depending on the type of wheat, such as culm and straw in the case of emmer-wheat. Lashing is a method similar to this and involves beating the crop against a hard surface or a lashing frame. This method was probably not used in Karanis or at least not on a large scale. This is because the method of beating crops, is used to process small quantities of material. This custom is known from traditional agricultural communities, such as Egypt, and is especially used by poorer families, who have no access to cattle or a threshing floor and other implements. In Roman Karanis the production of grain and use of threshing remains was central to the economy. Therefore, it is unlikely that this threshing method was dominantly used here.

Animals used in threshing are required to have certain qualities and abilities. Cattle is very suitable, because of its cloven hooves that enable them to walk over the material easily, without getting material stuck to the surface of their feet and to crush the grain stems. The animal should be able to handle a lot of workload and should stay on its feed during the process. In addition, the speed and controllability of an animal by humans is important. For all those reasons cattle (horses, cows, oxen and donkeys) are suitable.

Cattle are forced to walk over the thick-layered harvest on the threshing floor. The animals trample the cereals to tread the spikelets from the ears and the seed. During this process, the cereals are repeatedly turned with a fork. Sheaves are added at the same time until the whole harvest is threshed. This method of threshing was used in ancient Egypt (fig. 18a) and is common in Egypt and other regions in the Mediterranean and was still in use in this century (fig. 18b). Animals can also draw a threshing sledge. The use of a threshing sledge was common in the Mediterranean region and the Near East until recently. Modern examples of such sledges are found in Cyprus, Syria, Turkey and possibly elsewhere. In the early 20th century, sledges were used in threshing in most countries in the Mediterranean.

A threshing sledge is a wooden frame with stones, metal parts, rollers and wheels inserted in the frame (fig. 19). Flint is often used for this, because of its hardness and durability. The sledge is drawn across the threshing floor by an animal in a circular movement. This method

108 The beating technique is mentioned in Ruth 2: ‘she (Ruth) gleaned in the field until evening, and beat out what she had gleaned’ (Kohlenberger 2005, 313).
109 Murray 2000, 524.
110 McNeil 2002, 784.
111 Murray 2000, 524.
112 Murray 2000, 524.
113 Cappers & Neef 2012, 74.
114 Ataman 1999, 212.
115 Murray 2000, 524.
of threshing produces spikelets and chopped straw.\textsuperscript{116} The material remains after threshing with a sledge look chopped into pieces, because of the hard objects inserted in the frame of the sledge. This is similar to the traces of cutting marks on the threshing remains from mud-bricks in Roman Karanis. These threshing remains were highly fragmented, cut-off and had irregular fractures. It is possible that a threshing sledge was used here, since it is an effective way of working the material and to fragmentize it as much as needed.

In Egypt a somewhat different type of threshing sledge, the \textit{nurag}, had evolved and was used until this century (fig. 20). This threshing sledge consists of a wooden frame, which carries two sets of four small wheels or disks (usually metal) and a set of three disks.\textsuperscript{117} The three wheels in the middle are positioned to cover the interval gaps of the two sets of four wheels at each end of the sledge.\textsuperscript{118} These disks are about 45 cm in diameter and are located about 15 cm apart from each other.\textsuperscript{119} Harvested crops are spread across the threshing floor or a flat surface in layers of 30 to 50 cm deep. During threshing with a \textit{nurag} the crops are turned over with forks. The vegetative remains of free-threshing grain after threshing are not clean and needs to be separated from dust and dirt. It can also be broken, is sometimes not even threshed or is eaten by animals. The broken pieces of free-threshing grain are, however, characteristic for the use of a \textit{nurag}.\textsuperscript{120} Threshing by \textit{nurag} is slow, but thorough, since it bruises the ears of cereal and extracts the grain, while the straw of the plant is cut into small pieces.\textsuperscript{121} The \textit{nurag} has a seat on top and is drawn by a pair of animals during the process of threshing (fig. 20b).\textsuperscript{122} The driver of this sledge is seated athwart the machine. This has the advantage that due to his weight the sledge remains pushed to the threshing floor (fig. 25b).\textsuperscript{123} The outlook of the crops after threshing by \textit{nurag} are similar to the fragmented state of the temper from the investigated mud-bricks from Karanis. The broken-off pieces bruised ears, crushed and cut-off threshing remains indicate to the use of such an implement in Roman Karanis for the treatment of temper for mud-bricks.

\textsuperscript{116} Murray 2000, 524.  
\textsuperscript{117} Cappers & Neef 2012, 75.  
\textsuperscript{118} White 2010, 191.  
\textsuperscript{119} Hopfen 124.  
\textsuperscript{120} Hopfen 1981, 125.  
\textsuperscript{121} Edgar 1903, 39.  
\textsuperscript{122} Hopfen 124.  
\textsuperscript{123} White 2010, 191.
Fig. 18. Animals are often used in threshing. a. This image depicts the use of oxen in the process of threshing wheat. The oxen are forced to walk in pairs through the harvested cereals, which are packed together in a heap. While the oxen walk, other men rake heaps of cereal in the circular path the animals walk. By walking over the harvested parts, the animals crush the material and separate the chaff from the grain kernel. The bulk of iconographic imagery of ancient Egypt, indicates that trampling threshing remains with animals was the primary method used to thresh cereals. b. This photograph was taken in 19th century Israel, and depicts a similar process as fig. 23a. Here, horses pull a threshing sledge, and walk over the threshing floor, while the woman rakes the cereals under the horses’ feet. The sledge crushes the cereals.

124 Photographed by prof. dr. R.T.J. Cappers.
125 Murray 2000, 524.
126 http://www.bible-archaeology.info/agriculture.htm
Fig. 19. A type of threshing sledge from modern Turkey. The photograph depicts a wooden threshing sledge, and a close-up that shows small flint inserts. Such sledges were used in Turkey until the 1950’s.¹²⁹

Fig. 20. a. A nurag from Salehia in Egypt.¹²⁷ b. A man and a child seated on a nurag in the past century in Egypt.¹²⁸

¹²⁷ Cappers & Neef 2012, 76.
¹²⁸ Ibrahim & Ibrahim 2003, 38.
¹²⁹ http://ancientcraft.co.uk/Flintknapping/flint.html
Other traditional techniques used for threshing are flails, sticks, forks, rakes and rollers.\textsuperscript{130} It is assumed that threshing sticks, were also used in ancient Egypt for threshing, but in contrast to the \textit{murag} and the threshing sledge did not underwent much technological innovation.\textsuperscript{131} A roller is used to roll over harvested material on a flat surface. This piece of equipment consists of a heavy cylindrical piece such as hard stone (fig. 21). Rolling is, however, not the same as threshing, since it does not separate the edible from the non-edible parts of a plant, but only crushes the material. A second treatment with for example a reel causes a final separation.

![Fig. 21. This photograph was taken in August 2010 in Murtazakoy in Turkey and depicts a man using a roller to thresh fruits of chickpea (\textit{Cicer arietinum}). Rolling is done on the roof of a building.\textsuperscript{132}](image)

Winnowing is applied to separate light particles from the (hulled) grain kernels and spikelets (by-product). This can be achieved by benefitting from the differences in weight of the crop-parts. The threshed crop is thrown into the air with forks or winnowing fans, allowing the wind to blow away the lighter parts (light straw waste, fragments of weedy plants and light seeds).\textsuperscript{133} The heavy parts (spikelets, straw nodes and large seeds) fall to the ground.\textsuperscript{134} Another way of winnowing is to scatter the threshed crop in a basket, fan or sieve. The latter is used to separate the seeds from the chaff and weeds by differences in size and weight as well.\textsuperscript{135} Iconographic evidence from ancient Egyptian tombs tells that winnowing took place on or near the threshing floor.\textsuperscript{136} Ethnographic studies confirm this (fig. 22). Sieving is the final stage by which the heavy parts are separated from the (hulled) grain kernels based on differences in size.

\textsuperscript{130} Murray 2000, 524.
\textsuperscript{131} Cappers 2011, personal communication.
\textsuperscript{132} Cappers & Neef 2012, 75.
\textsuperscript{133} Cappers & Neef 2012, 76.
\textsuperscript{134} Murray 2000, 525.
\textsuperscript{135} Cappers & Neef 2012, 76-77.
\textsuperscript{136} Murray 2000, 525.
Fig. 22. A threshing floor near modern Memphis. Heaps of threshed cereals are visible on the photograph, while on the right the process of winnowing is seen.\textsuperscript{137}

In present-day Egypt and the Mediterranean, threshing machines are often used and combine threshing, winnowing and sieving (fig. 23). The disadvantages of this for ethnographic studies is that these machines treat and crush the material very fine, which makes it impossible to compare it with ancient threshing remains. It is, however, interesting to observe technological innovations in the field of threshing, which are highly influenced by socio-economic changes. Innovation aims to thresh faster and more efficient such as the \textit{nurag} and the threshing sledge.

Fig. 23. A modern threshing machine in present-day Egypt. Cereals are pushed into the machine at the rear. The machine separates the chaff, which is blown out of the machine and forms a heap of threshing remains (at the right of the picture). The grain kernels, which fall out from underneath the machine and are collected into bags.\textsuperscript{138}

\textsuperscript{137} http://www.flickr.com/photos/8430129@N06/1338627829/in/photostream/
\textsuperscript{138} Photographed by prof. dr. R.T.J. Cappers.
4.3. Explanations and recommendations

The fragmentation of rachis fragments in mud-bricks from Karanis shows that the material was treated. Extra treatment resulted in extra time, but apparently, a high quality mud-brick was desired and needed. How can this extra work be justified?

Mud-bricks were produced on a large scale (fig. 4), which is effective and less expensive as small-scale production. If thousands of bricks are easily produced all at once, it seems illogical to set high demands on the temper, especially since huge numbers of threshing remains were available in Karanis. However, threshing remains are economically significant. This is exemplified by ethnographic studies of present-day Egypt were threshing remains of bread-wheat (Triticum aestivum L.) are auctioned off to the highest bidder and illustrates that threshing remains contain an element of supply and demand.

Most inhabitants of Karanis owned cerealfields and were self-sufficient. Farmers probably used threshing remains from their own field for the production of bricks, since in present day Egypt farmers are reluctant to buy them from other fields. The cultivation and production of hard-wheat and its by-product threshing remains was central to the economy and subsistence of the inhabitants in Roman Karanis. Knowing that, the use of threshing remains in construction meant a great investment to the farmers. The refinement (fragmentation) of threshing remains to temper ensured a more compact, solid and stronger brick. Although, more time and expenses had to be invested, eventually a higher quality mud-brick meant a more durable construction which could last for up to two generations and did not constantly required replacement of bricks and extra investment of valuable threshing remains, which could be used in merchandise instead.

The traces of working on these threshing remains are very interesting. A suggesting for future research is to pay much more attention to such traces in relation to threshing and possible tools used for fragmentation. The tools discussed in the previous paragraph are suggestions of equipment that might have been used to fragmentize threshing remains, but for now, no equipment for such practice has been found in Roman Karanis. A total investigation of temper of all mud-bricks from Karanis will possibly shed light upon the relation between number, quality and type of temper in the mud-bricks and their spatial distribution across the settlement.

139 Heinrich 2011, 44-45.
140 Cappers 2011, personal communication.
141 Van Minnen 1994, 231.
Bibliography


List of figures and tables

Page
8  Fig. 1. Introduction and replacement of cereals in Egypt from the Neolithic (6000 B.C.) until modern times (Cappers & Neef 2012, 408).
11 Fig. 2. Morphology of a grain plant (based on Hillman 1984, 2).
11 Fig. 3. Morphology of a rachis fragment (Hillman et al. 1996, 202).
15 Fig. 4. Illustrations of the process of mud-brick manufacture in present-day Egypt (Error! Hyperlink reference not valid.).
17 Fig. 5. The Fayum (Bagnall & Rathbone 2004, 128).
18 Fig. 6. The relationship between cereal fields and archaeological settlements in Roman Egypt (Cappers & Flohr 2008, 125).
21/22 Fig. 7. Four examples of the variety in the amount and composition of temper in samples from Roman Karanis.
24 Fig. 8. a. A rachis fragment (two nodes) of hard-wheat (*Triticum turgidum* ssp. *durum*) used as temper in a mud-brick from Roman Karanis (table 3: GIA-24604/19475), b. Highly fragmented rachis fragments (GIA-24743/19810), c. Threshing remains of *Triticum turgidum* ssp. *durum* (GIA-24613-A/19495) from Roman Karanis (Photograph by prof. dr. R.T.J. Cappers). These were not used as temper in mud-bricks.
25 Fig. 9. a. Rachis fragments with glumes still attached to it (GIA-24683/19684). b. Some rachis fragments of barley (*Hordeum vulgare*) (GIA-24600/19471).
26 Fig. 10. Number of rachis nodes in each sample: 28 samples from Roman Karanis, two samples from Tunis in Egypt (20030395, 200308758) and one from La Fuliola in Spain.
27 Fig. 11. Rachis nodes per sample in 10 kilogram from Roman Karanis.
27 Fig. 12. Rachis nodes per sample in 10 liter from Roman Karanis.
31 Fig. 13. a. Rachis fragments from La Fuliola. b. Detail of a single rachis fragment from La Fuliola.
32 Fig. 14. a. Threshing remains of bread-wheat (*Triticum aestivum* L.) from Tunis (200308750) prior to the microscopic research. b. Rachis fragments from Tunis (200308750). c. Detail of a rachis fragment from Tunis (200308750).
34 Fig. 15. Spatial distribution of samples in Karanis east (Wendrich 2011, written communication. Edited by the author).
35 Fig. 16. Spatial distribution of samples in Karanis (Wendrich 2011, written communication. Edited by the author).
35 Fig. 17. Samples in trench 99 in the settlement of Roman Karanis.
40 Fig. 18. Animals used in threshing (Photographed by prof. dr. R.T.J. Cappers/ http://www.bible-archaeology.info/agriculture.htm).
41 Fig. 19. A type of threshing sledge from modern Turkey.
41 Fig. 20. a. A nurag from Salehia in Egypt (Cappers & Neef 2012, 76). b. A man and a child seated on a nurag in the past century in Egypt (Ibrahim & Ibrahim 2003, 38).
Fig. 21. This photograph was taken in August 2010 in Murtazakoy in Turkey and depicts a man using a roller to thresh fruits of chickpea (Cicer arietinum). Rolling is done on the roof of a building (Cappers & Neef 2012, 54).

Fig. 22. A threshing floor near modern Memphis. Heaps of threshed cereals are visible on the photograph, while on the right the process of winnowing is seen (http://www.flickr.com/photos/8430129@N06/1338627829/in/photostream/).

Fig. 23. A modern threshing machine used in present-day Egypt (Photographed by prof. dr. R.T.J. Cappers).

Table 1. Advantages and disadvantages of hulled and naked cereals per stage of crop processing (Cappers & Raemaekers 2008, 389).

Table 2. Documentation of 41 investigated mud-brick excavted and sampled in Roman Karanis (based on F. Fantone and F.B.J. Heinrich).

Table 3. Calculations of rachis nodes in mud-bricks from Roman Karanis.

Table 4. Rachis nodes in samples from Tunis (20030395 / 200308758) and La Fuliola.