EXARC Journal
2019/2
23 Articles | Open Access

Reviewed Article:

Experimental Bonfirings of Pottery with Camel Dung Fuel, Jordan, July 2018

Persistent Identifier: https://exarc.net/ark:/88735/10427

EXARC Journal Issue 2019/2 | **Publication Date:** 2019-05-21

Author(s): Maria-Louise Sidoroff [1]

[1] Independent researcher, PO box 967 Hobe Sound 33475 FL, USA.

The objective of this series of experimental pottery firings with camel dung fuel was to isolate the function of this fuel type within the context of a simple mode of pottery firing for data applicable to studies of ancient pottery manufacture.

Introduction

> Dung fuel is most widely used for bonfirings because of certain advantages. The light weight of dung creates only slight pressure on the vessels, retains its shape during and after combustion, and provides insulation against temperature fluctuations. During the firing, dung forms a dome shaped blanket of ash to uniformly heat and slowly cool the vessels. This prevents damage from thermal shock, as is common in wood fueled bonfirings, and there are no wasters (pottery with firing defects) in areas surrounding dung fueled firings.

The experiments generated new quantitative and temporal data. This allowed the author to formulate inferences about the role of camel dung fuel in pottery production and contributed new data to how the archaeological record is developed.

Our materials, methodology, documentation, and evaluation follow standards of Experimental Archaeology: defined by John Coles (1979), applied by Errett Callahan in ceramic manufacture (Callahan et al.,1998), and the foundation for a phase within a broader study by William Schindler III (2006). For our experimental bonfirings we used local clay, camel dung from the arid region of southern Jordan, and set up a field laboratory in central Jordan. The written record and photographs of each firing facilitate replication of our results.

As Fire Master, Katherine Higgins, M.A. candidate in Archaeology, Florida Atlantic University, perfected the *chaîne opératoire* for a dome-shaped blanket of hot camel dung, which produced sufficient heat to bring clay vessels to functional hardness.

The lead author has been engaged in ceramic studies for over 30 years. Currently she is ceramic technology advisor for the Nabataean Early Roman Villa Complex within the Mudayna ath-Thamad Regional Survey Project directed by P. M. Michèle Daviau, Wilfrid Laurier University, Canada. Over the years she has also developed a network of collaborators in Jordan who contributed to the success of this research, with special thanks to Marwan Shwaihat and the Salahat Family.

Methods

Experimental Archaeology

Experimental archaeology is the branch of archaeology that seeks to interpret technology of the past by means of structured, scientific experimentation. Standards proposed by Coles (1979, pp.37-39) defined the processes of scientific experimental archaeology, which Sidoroff first applied working with Errett Callahan on the Pamunkey Indian Reservation, Virginia. During the summer of 1978 we formed large experimental vessels with coils and fired them in Callahan's tipi style wood fueled bonfirings (Callahan et al., 1998).

Experimental standards define materials and methods. All materials used in experiments must be similar to those locally available during time of the ancient society under study, the methods for processing materials must be within the skill levels known to ancient people, and no modern technology should interfere with the experimental processes (Coles, 1979). As in all scientific experiments, methodology should be documented and assessed as the work progresses. When results are published the experiment can be repeated by others using the same materials and methodology.

A regional focus drawn from archaeological evidence provides direction for resource selection. To identify a range of resource choices for the experiments, this study was set in an environmental context, which is the current scholarly focus of Sidoroff. Materials in this study represent choices that could have been made by a household potter living a few thousand years ago in the arid area surrounding a Nabataean- Roman Villa Complex in the Wadi ath-Thamad Region, Central Jordan (Daviau, et al., 2012, pp.291-297).

Materials in this study were all local and of a type available to ancient potters in the region. Recent analysis of clay from the Wadi ath-Thamad indicate suitability for ceramic production although there is no archaeological evidence of a pottery workshop or a household hearth from antiquity. An experimental program of replication with Wadi clay confirmed the clay could be formed into vessels and fired in an electric kiln at Orton cone 06 (995°C) (Sidoroff, 2013, pp.78-79). Comparative petrographic analysis hints at similarities between thin sections of clay from the Wadi and vessels excavated in the nearby Nabataean Roman Villa (Sidoroff and Ownby, 2016, p.210).

The archaeological record indicates fuel supplies for pottery firing were present in antiquity. Abundant grain harvests provided agricultural waste (Daviau, et al., 2012, p.296) and there is secondary evidence of sheep dung as fuel because of wool textile production in the Iron Age town at nearby Tell Mudayna (Daviau and Chadwick, 2007, p.311). There is no archaeological evidence of camels in the region but historians in antiquity commented on camel caravans of 1000 animals (Graf and Sidebotham, 2003), which were a major mode of transport across desert lands, including central Jordan where a route passes from Petra to Damascus.

We purchased camel and sheep dung supplies from Bedouin in southern Jordan where we discussed types of dung fuel to achieve the best results for our experimental firings.

Because experimental data is too valuable to be used only once (Schindler, 2006, pp.136-137), we insured that our experiments can be replicated, which is important in all scientific experiments. We documented and assessed our methodology with written records and photographs of the sequences in each firing (See accounts of each firing in Appendix 1).

Location

We secured a location for the pottery firings on an undeveloped private lot in the small town of al Fasalia, central Jordan, about a half hour from our base in Madaba (See Figure 1). Situated on the road to Mount Nebo and the Dead Sea, the property was surrounded on three sides by earthen cliffs, so the firing hearth was protected from the wind and could be left undisturbed to cool overnight. We had a small tent for protection from the sun and to protect supplies and equipment from evening moisture. Twenty plastic crates were stacked for tables and a few plastic chairs were easily moved around to keep the team out of the sun and the smoke of burning camel dung.

We cleared the hearth area of stones and other material that might interfere with firing. We quickly used up all fire-starters of dried grasses and shrubs in the immediate area and expanded our search into a nearby valley where we gathered pine twigs, needles, and cones.

Bonfiring

The firing strategy for this study was bonfiring, a type of non kiln firing, also called open firing, or clamp firing where vessels come in direct contact with surrounding fuel. (Rye and Evans, 1976; Rice, 1987; Callahan et al., 1998; Ali, 2005; Sidoroff and Higgins, 2017).

With the absence of firm archaeological evidence of pottery bonfirings, contributions from ethnography and experimental archaeology provide data to understand this firing strategy, which is so basic that it can be accomplished in a domestic hearth.

Relevant to this study is the wide range of adaptation to locally available fuel documented in pottery bonfirings. For example, wood in north and south Africa (Gosselain, 1992; Steele, 2012), agricultural waste in the Middle East (Balfet, 1965; Matson, 1971), donkey dung in Pakistan (Rye and Evans 1976), olive pressing waste in Mediterranean regions (Rowan, 2015), cow dung in Mexico (Sidoroff, 2004), llama dung in the highlands of Peru and Bolivia (Sillar, 2000), and in the American Southwest cow and sheep dung (Hyde, 1983; Peterson, 1984; Sidoroff, 1991). For this series of experiments, we chose the bonfiring strategy because it is a well- documented method of non-kiln pottery firing with dung fuel especially in arid regions where wood resources are rare.

Non-kiln bonfirings are well suited to the individual household potter (Peacock 1982) who manufactures hand-made vessels for her family. The vessels are fired in the domestic heart, which is archaeologically indistinguishable from cooking fires. There are women potters in villages in northern Jordan who manufacture pottery in a household setting (Ali, 2005; 2010). Throughout their *chaîne opératoire* for hand built cooking pots, there would be no evidence of clay preparation, organic tools, or pit and bonfiring strategies. Both firing methods would leave only quantities of ash in and around a slight depression in the ground with characteristics similar to either a domestic hearth or a pottery firing site (Ali, 2015, p.85).

The most striking aspect of pottery bonfirings is the rapid rise in heat. The maximum temperature is achieved within an average of 20 minutes with a variety of fuels (Gosselain, 1992, Table 1; Rice, 1987, Figure 5.19) and in Shepard (1965, Figure 4) after 5 minutes in an unspecified type of dung fueled firing the temperature registered 850°C.

Temperatures recorded in non-kiln bonfirings range between 600°C and 900°C (Matson, 1971, p.77; Rice, 1987, p.386). In a firing fueled with unspecified type of dung, Rye reports a temperature of 755°C (1981, Table 3) and Shepard (1965, Figure 4) recorded 900°C. Gosselain (See Table1) specifies the range of sheep dung temperatures 675°C - 862°C.

Methods to Document Temperatures, Measure and Weigh Fuel, and Fired Vessels

Temperatures in all firings were measured with a laser thermometer and Orton standard size cones were placed in most firings. The laser was EXTECH, 30" Dual Laser Thermometer to provide non-contact Infra-Red temperature measurements to maximum temperatures 1832°C (1000°F) with a fifteen second response time.

Orton pyrometric cones are a blend of clay designed to bend at certain temperatures when placed within a kiln but are rarely used in bonfirings. We used 016 cones (794°C) placed next to the vessels in two early firings and cones 018 (732°C) placed in the last eight firings. Cones 016 showed no change and cones 018 were blistered but did not present the bent cone that indicates temperature achieved that melts the cone (see Rice, 1987, p.82).

A battery powered electric scale was brought to the firing site to weigh each bucket of fuel. The scale was set to compensate for the weight of the empty bucket (See Figure 2).

For all ten firings we used 2 full bags (*shawl*) of camel dung from range fed animals and about one half a *shawl* of sheep dung. This excluded the earliest supplies of one year old camel dung that were too hard and dry to catch on fire easily as did soft 6 month old camel dung.

A *shawl* is the feed sack made with white woven plastic strips used throughout the Levant. Measurements when the *shawl* was empty: length 160 cm width 40 cm and when full of camel dung each *shawl* weighed about 18 kg (40 lb).

Large individual pieces of camel dung measured 7 cm x 5 cm, the weight of 6 pieces was 0.175 kg. Smaller pieces measured 3cm x 2 cm, the weight of 6 pieces was 0.020 kg. Large slabs of sheep dung were broken into pieces of average size 5 cm x 7 cm x 3 cm.

The standard unit of measurement of dung during the firings was a round plastic bucket (24 cm diameter x 11 cm height). The empty weight of bucket was 0.185 kg and the scale was set to compensate for this.

The first few firings were an exploration of the properties of camel dung fuel, which was a type of fuel new to both Sidoroff and Higgins. By the fourth firing Fire Master Higgins was in control of the process. This firing using only camel dung fuel, recorded the highest temperature in this series of experimental firings.

There were small adjustments in the following six firings. Small amounts of sheep dung were included with the camel dung based on discussions about sheep dung with Bedouin women in Jordan and an Acoma potter in New Mexico. They suggested that sheep dung would raise the temperature and increase oxygen in the firings.
As the series of 10 experimental firings continued, the ashy hearth expanded, and changes were recorded in the diameter of the hearth.

This study delivers qualitative data for archaeological inferences regarding ceramic manufacture of bonfirings with camel dung fuel. This was achieved through application of Munsell Color Codes and Mohs' Hardness Scale. In experimental examples there is no possibility of color alteration or hardness due to use or from a depositional setting.

Munsell Color readings were taken on fresh-cut samples from fired experimental vessels, all made from the same clay body and fired in dung fueled bonfirings. The properties of color were measured on the interiors, exteriors, and cores of cross-sections.

Mohs' hardness scale can verify an objective degree of hardness of fired clay. Non kiln fired pottery commonly ranges between 3 and 5 in hardness but values of 2 and 7 are not unknown (Rice, 1987, p.356).

Materials

Clay

For the integrity of our study it was important to fire vessels made with local clay.

Because of time constraints we were unable to clean and process clay from Wadi ath-Thamad for our vessels therefore we purchased twenty-five kg (55lb) of prepared clay from a local pottery factory. The Zizia Pottery Factory clay is dug by the owner who travels a short distance to Amman when clay is exposed at a building site (Sidoroff, 2015, p.94). Petrographic analysis suggested that clay from central Jordan today has the same mineralogical profile as clay selected by earlier potters since at least 900 B.C. Thin sections of clay in a modern jar from Zizia factory compared favorably with Iron Age II pottery from Tell El Umeiri, a site in central Jordan (London, 1991, p.405). For the experiments we used this local clay to hand model twenty-six vessels using pinch, mold, and coil techniques.

This was the fourth year the lead author visited the Zizia Pottery Factory. Beginning in 2012 the factory has been part of a long range ethnoarchaeological study of change and continuity at this industrialized system of production (Sidoroff, 2015). The factory activities are centered in a compound few miles outside the town of Jizza, in central Jordan. In the main covered building, there are four potter's wheel stations, masses of prepared clay, and indoor areas to slowly dry the main production of water jars. Nearby are three large circular updraft kilns which were formerly fueled with garbage collected in nearby Amman. In 2018, because of pollution caused by burning garbage, the government forced replacement of the old kilns with new structures fueled with recycled oil.

Our team visited the Zizia Factory in 2018 to ask the potters to make several dozen small vessels, which we would purchase unfired, to use in our experiments. The three employees, all Egyptian migrant workers, refused to allow unfired pottery to leave the premises. All agreed it would bring "bad luck" on the factory, its products, and the personnel. This was news to our interpreter, who suggested it was a type of "Egyptian black magic". Finally the potters agreed to sell us a bag of factory clay body (25 kg / 55 lb) to make our own vessels. As we left, we picked up wasters (i.e. pottery damaged in firing) strewn on the ground outside the main building to support vessels in our firings.

Dung fuel

The primary question here is whether camel dung fuel, a previously unstudied waste product for this purpose, can achieve temperatures to harden clay vessels in a bonfiring setting. Once we achieved successful firings with only camel dung fuel we explored the effect of adding small amounts of sheep dung in some firings. This step was included because sheep dung was available as fuel in antiquity and we has an opportunity to discuss details of sheep dung with Bedouin ladies.

The dromedary camel, a native to desert regions of North Africa and the Middle East, is the main beast of burden in desert transport. Secondary products provide food, skin for containers, and wool for weaving. Here we investigate another secondary product, camel dung. Along trade routes, especially in areas around caravansaries and oases, there would be supplies of camel dung for fuel and fertilizer. Historians in antiquity remarked on thousands of camels in a single long distance caravan (Graf and Sidebotham, 2003, p.68).

Sheep are among the earliest domesticated animals and were first valued as meat. In the fourth millennium B.C the secondary products revolution changed the focus of husbandry (Sherratt, 1983) to dairy products, wool, transport, and dung.

Sheep dung is one of the primary pottery firing fuels among modern American Southwest potters (Rice, 1987, p.164). Maria Martinez, San Ildefonso, uses only sheep dung to create a reduced atmosphere in bonfirings to finish her vessels with distinctive matt designs on shiny black surfaces (Hyde, 1983, p.20).

In regions where cattle are raised, cow dung fuel has been well documented in pottery firings in South America (Litto, 1976), the American Southwest (Peterson, 1984); Pakistan (Rye and Evans, 1976), and Mexico (Parks,1995). Acoma potter Lucy Lewis fires with cow dung using sheep dung very sparingly in her bonfirings. She believes it is hotter than cow dung and could discolor or damage her white surfaces painted with a white kaolin wash and decorated with black fine line designs (Sidoroff, 1991, p.56).

Agricultural waste products are primary sources for renewable, and often free, fuel for fertilizer, heating, and pottery firing. Among most common sources are crop processing debris (Matson, 1971, p.77; Rye, 1981, p.102; Arnold, 1985), and in the Mediterranean region, olive pressing waste (‘Amr, 1991, p.321; Rowan, 2015, p.467).
The environmentally efficient and renewable resource of dung has a long history in human settlements where livestock is raised. The animals feed on dispersed organics that are turned into compact easily gathered sources of fuel and fertilizer. The amount of dung produced by an animal each year is more than four times its weight (Sillar, 2000, p.46).

Dung as fuel is also documented in archaeological accounts. In an archaeological setting, ash samples are collected for botanical analysis to identify carbonized seeds that represent animal fodder as dung in the ash. Archaeobotanical data from sites in antiquity (Miller, 1984; Ramsey and Parker, 2016; Smith, et al., 2018) strongly suggest dung fuel was a response to an arid environment where wood was rare.

Dung minerals are present in carbonized seeds from an Ubaid Period site (5000-5100 BC) in Syria (Smith, et al., 2018). Analysis of carbonized seeds in ash from Mayalan, an urban center in arid southern Iran during 3rd millennia BC, suggests that cakes of donkey dung and straw were used as fuel in hearths (Miller, 1984, p.74). The archaeological suggestion of this fuel type in antiquity is corroborated in modern Pakistan where donkey dung and straw are formed into fuel cakes (Rye and Evans, 1976, p.24). At Aila, the ancient port city on the Gulf of Aqaba, pottery production existed throughout the history of the site from the 1st century thorough the 8th century A.D. Carbonized seeds representing possible fodder for camel, sheep, donkey, and goat (Ramsay and Parker, 2016, p.104) strongly suggest dung was used to fuel pottery kilns at Aila. In later millennia, when widespread deforestation was encouraged by marketing secondary products (such as oil, wine, and dried fruits) with intensive cultivation of orchard crops (Fall, Falconer and Lines, 2002), dung was an available fuel resource.

We submitted ash samples from several camel and sheep dung firings to Dr. Alexia Smith, University of Connecticut, for a study collection and for macro-botanical characterization to compare with ash from archaeological sites.

Dung fuel is most widely used for bonfirings because of certain advantages. The light weight of dung creates only slight pressure on the vessels, retains its shape during and after combustion, and provides insulation against temperature fluctuations. During the firing, dung forms a dome shaped blanket of ash to uniformly heat and slowly cool the vessels. This prevents damage from thermal shock, as is common in wood fueled bonfirings, and there are no wasters (pottery with firing defects) in areas surrounding dung fueled firings.

Temperature graphs of bonfirings do not mention camel dung fuel: Gosselain, 1992 (See Table 1a); Shepard, 1965 (See Figure 4). A range of bonfire temperatures reported in the desert region of Palestine of 500-755°C was fueled with twigs and unspecified 'dung', which may have been produced by camels (Rye, 1981, Table 3).

Bedouin Ethnography

When dung is embedded in their society, people spend much time discussing management of the vital resource for fertilizer and fuel, heating and pottery firing (Sillar, 2000). We had good conversations regarding dung with some Bedouin of Jordan who provided us with advice about camel and sheep dung for our firings. Mifleh gathered the best quality soft camel dung for us and Um Hamid Dalal and Khrawla explained how sheep dung is part of their daily lives and demonstrated cooking in dung fueled clay ovens.

Traditionally the workers at Jordan's major tourist site, Petra, are Bedouin who live in villages south of Wadi Rum. We began our firings with one year old camel dung collected in Wadi Rum by a "friend of a friend' and delivered to our firing site.

As we continued experimental work, we learned that the most efficient camel dung for fuel is collected in summer from animals that are range fed on spring grasses several months earlier. The animals are not fed grain supplied by a breeder who confines the animals. This soft dung crumbles easily, catches fire quickly, and is superior to one year old camel dung, which is dried and hardened by the elements.

To insure we received the best camel dung for our remaining firings, Bedouin Mifleh was recommended to us. We travelled to Al Twasi, a village south of the Bedouin center Ad Desi in Wadi Rum. At Mifleh's compound (See Figure 3) he showed us his new baby camel (See Figure 4) and brought out bags of dung. We examined and appreciated the best quality dung he gathered for us and paid for two *shawl*.

Ethnography, Khrawla

We spent several days with Bedouin women, Um Hamid Dalal, age 48, and Khrawla, age 42 (See Figure 5). Once we were joined by Jordanian friends who wanted to learn about Bedouin cooking (See Figure 6). The women live on opposite sides of the Desert Highway. Khrawla has two tents: one for daytime work and for sleeping at night (See Figure 7) and another for cooking (See Figure 8 and Figure 9).

In preparation for cooking bread or meals, the oven is heated overnight with slabs of sheep dung set around the exterior. Upon our arrival, the women demonstrated baking bread in a clay oven (See Figure 10) and we discussed the characteristics of the best sheep dung for high performing fuel. According to the women sheep dung is best when gathered where the sheep are enclosed, as in the compound of Um Hamid Dalal (See Figure 11). There sheep dung is urinated on and trampled so the dung no longer remains in the original form of small round pellets. When sheep dung is compacted this way it can be gathered in large pieces then broken into smaller more manageable shapes (5 cm x 10 cm), The women store large supplies of this processed sheep dung (See Figure 12).

Behind Khrawla's roadside tents there is a field, which she owns and provides her with primary resources. She uses this field to grow okra, once the okra is harvested and sold, she gathers clay from the field, mixes it with water and straw to rebuild or repair her ovens. In winter, she fertilizes the field with sheep dung ash from the ovens.
Every day Khrawla sells bread to her neighbors and passersby from her cooking tent on the Desert Highway just south of the road sign to Ghawn, As Safi, 1 km. Khrawla said working alone at bread making and agriculture she earned enough money to send 8 daughters to university. At the end of our last visit, we collected sheep dung for our experiments, spinach-like greens to make soup, and several rounds of bread. We thanked the two women for their advice and demonstrations, then paid them for our purchases of food, and supplies of trampled sheep dung.

Results

Observations at ten pottery bonfirings confirm camel dung fuel hard fires clay vessels with the highest experimental temperature of 688.9°C (See Table 1a)

Firing	Highest temperature (Celsius)	Total time (Hours: minutes)	Dung type
1	606°	03:25	camel
2	571°	03:20	camel
3	611°	01:55	camel
4	**688.9°**	02:10	camel
5	621.7°	02:35	camel
6	552°	02:20	camel/ sheep
7	599.2°	01:30	camel/ sheep
8	556°	02:55	camel/ sheep
9	x	01:50	camel/ sheep
10	557.6°	02:05	camel/ sheep

TABLE 1A. OBSERVATIONS AT TEN POTTERY BONFIRINGS.

Median duration of warming fire was 20 minutes, median duration of pottery firing was 2.20 hours, and median highest temperature was 596°C (See Appendix 1). The data conform to recorded temperatures in bonfirings where the average rarely falls below 500°C.

The average weight of one dung filled bucket was 0.8 kg with median number of 6.5 buckets of dung used in each firing (See Appendix 1).

Small slabs of sheep dung were added to the camel fuel in five firings. The goal was to generate a rise in temperature and increase oxygen in the bonfiring of vessels. In order to minimize differences between firings, all vessels were made from the same clay body and were of similar diameter, height, and thickness of walls.

Firing vessel code	Fuel	Vessel size	Interior color	Exterior color	Core at fresh break	Mohs' code
Firing #3, A1	camel dung	D=10 cm, H= 5 cm, T=1.0 cm	10 YR 7/4 very pale brown	10 YR 6/4 light yellow brown	7.5YR 5/4 Light brown	5
Firing #3, A2	camel dung	D=9, H=3, T=0.7 cm	10 YR 7/4 very pale brown	10 YR 7/4 very pale brown	7.5YR 5/4 Light brown	4
Firing #3, A3	camel dung	D=13 cm, H=3 cm, T=0.9 cm	7.5 YR 6/4 light brown	7.5 YR 6/4 light brown	7.5YR 5/4 Light brown	5
Firing #4, B3-1	camel dung	D=12 cm, H=3 cm, T=0.6 cm	10YR 6/5 brownish yellow	10YR 6/4 light yellowish brown	10YR 6/4 light yellowish brown	4
Firing #4, B3-2	camel dung	D=12 cm, H=3 cm, T=0.7 cm	5YR 7/4 pink	5YR 4/2 dark reddish gray	5YR 6/4 light reddish brown	6
Firing #4, B5	camel dung	D=9 cm, H=4cm, T=0.5 cm	5YR 4/2 dark reddish gray	5YR 4/2 dark reddish gray	5yr 6/4 light reddish brown	6
Firing #7, B1	camel / sheep dung	D-12 cm, H=2.5 cm, T=0.6 cm	5YR 6/4 light reddish brown	5YR 6/4 light reddish brown	5YR 6/4 light reddish brown	6
Firing #7, B4	camel / sheep dung	D=12 cm, H=3 cm, T=0.4 cm	10YR 6/5 brownish yellow	10YR 6/4 light yellowish brown	10YR 6/5 brownish yellow	5
Firing #7, B6	camel / sheep dung	D=9.5 cm, H=4.5cm, T=0.5 cm	10YR 6/4 light yellowish brown	10YR 6/3 pale brown	10YR 6/5 brownish yelow	5
Firing #9, C1	camel / sheep dung	D=13 cm, H=9 cm, T= 0.5 cm	5YR 6/6 reddish yellow	5YR 6/6 reddish yellow	5YR 6/6 reddish yellow	7
Firing #9, C2	camel / sheep dung	D=12 cm, H=4 cm, T=0.4 cm	5YR 7/6 reddish yellow	5YR 6/3 light reddish brown	5YR 6/3 light reddish brown 3	6

Firing #9, C3	camel / sheep dung	D=12 cm, H=3 cm, T=0.6 cm	5YR 7/6 reddish yellow	5YR 7/4 pink	5YR 7/4 pink	6

TABLE 1B. OBSERVATIONS AT THE POTTERY BONFIRINGS.

There were few significant differences in firing temperatures, vessel color, or hardness between camel alone and a mix of camel/sheep dung fuel (See Table 1b). Exceptions were in Munsell colors: 5YR 7/4 (pink) in firings #4 and #9, possibly a result of stronger oxidizing atmosphere. Also in firing #9, Mohs' hardness scale had 7 on one vessel. These figures suggest very high temperatures were achieved in firing #9 when the thermometer was not working and we have no data! The median hardness in Mohs' Scale was 4.9 which is within range of 3 to 5 hardness for typical bonfirings (Rice, 1987, p.356).

A significant influence on vessel color was placement in the setting, whether mouth up or down, as they came in contact with dung fuel. When dung settled inside a vessel there was a black patch within the vessel caused by a reduced atmosphere. Vessels placed mouth down showed black patches on the outside.

Fresh breaks on twelve vessels presented clear colors throughout the section, an indication of a relatively well oxidized atmosphere (Rice, 1987, Figure 11.3). There were no black cores in any cross section (See Table 1b). After each firing enough ash remained in the hearth to expand the diameter, which nearly doubled by the end of the experiments from 51 cm to 79 cm. This buildup would not have occurred if the ash was removed for fertilizer.

Temporal and pyrometric data, drawn from notes taken during each firing, provided details for the following model *chaîne opératoire* of bonfiring with camel/sheep dung fuel.

Conversations among the Bedouin reflected the importance of dung in their lives and revealed the dominance of this social group in selection and sale as they engaged in the secondary product market.

Discussion, Conclusions and Future Directions

Discussion

What are the contributions of this study to archaeology? Since pottery sherds form an important category of artifacts retrieved from archaeological sites, it is a vital issue to archaeological research to reconstruct a subsystem of ceramic technology as presented in this *chaîne opératoire* based on a series of experimental firings.

The Fire Master's activities provided data for a typical household production mode of dung bonfiring. She alone judged when more fuel was needed and when to end addition of fuel. She had easy access to fuel supplies as she maintained a dome-shaped mound of dung pellets covering the pottery. The short periods of small flames on the dung during the firing did not threaten nearby equipment or structures. The Fire Master could leave the bonfiring unattended overnight once the final measure of fuel was added. The support team primarily assisted in gathering and preparing supplies, as would be typical in the organization of household production.

Furthermore, when recovered at an archaeological site, a large ashy domestic heath surrounded with burned earth and no wasters (i.e. pottery damaged in firing) may indicate house-hold pottery manufacture with dung fuel. However, the results of color and hardness tests on pottery from this series of firings present no unusual evidence that would point to dung fueled bonfirings.

All local materials performed well. Mohs' hardness scale data was proof that the factory clay fired hard with camel dung fuel and demonstrated bonfiring strategy as a good choice for the experiments. Camel dung performed well as the primary fuel and also when a small amount of sheep dung was included.

Temperature readings, in most firings registered between 500° - 700°C and were within the range of documented temperatures in ethnographic studies of bonfirings. Nearly 700° C reached in one of our firings suggest camel dung as potential fuel for pottery firing in updraft kilns on an industrial level. The main requirement would be large renewable quantities of camel dung because the greatest consumption of fuel occurs in heating the kiln structure.

The infra-red temperature gun was erratic and only recorded surface temperatures. Orton pyrometric cones placed in most firings were not effective because they were formulated to bend at temperatures higher than those in the bonfirings.

New ethnoarchaeological data document the role of social groups, such as the Bedouin population of Jordan, in resource selection and provisioning of secondary products.

Conclusions

It is clear in the findings described here that camel dung alone is positively identified as an efficient fuel in pottery bonfirings. Despite anecdotal information, the oxidizing atmosphere and higher temperatures we anticipated did not occur with addition of sheep dung to camel dung fuel.

Future Directions

Plans for further experimental camel dung bonfirings include larger hand-made vessels such as cooking pots and small water jars. This would be in keeping with the approach in this set of experiments as within a household production mode. For greater accuracy, temperatures will be monitored on a pyrometer with at least two thermocouples placed among the vessels in each firing. To control reduced patches vessels will be placed mouth down, to prevent dung settling within, then covered with large sherds.

An interesting follow up would be to investigate camel dung as primary fuel in an experimental updraft kiln, as suggested by archaeological and archaeobotanical findings. Our team is seeking potters experienced in construction of experimental kilns to continue exploration of the potential of camel dung fuel.

Attachment(s)

Appendix 1. Data from experimental firings. (99.9 KB)

Keywords ceramics
fuel
ethnoarchaeology

Country Jordan

Bibliography

Ali, N., 2005. The Relationship Between Subsistence and Pottery Production Areas: An Ethnoarchaeological Study in Jordan. Leiden. *Journal of Pottery Studies*, 21, pp.119-128.

Ali, N., 2010. Regionalism and Social Landscape as Inferred From an Ethnoarchaeological Study of Pottery Production in Jordan. *Journal of Anthropological Research* 66 (No. 3 Fall 2010) 351-373.

Ali, N., 2015. The Human Aspect of Technology. *Near Eastern Archaeology*, 78(2), pp.80-87.'Amr, K., 1991. Preliminary Report on the 1991 Season at Zurrabah. Annual of the Department of Antiquities of Jordan, 35, pp.313-321.

Arnold, D.E., 1985. *Ceramic Theory and Cultural Process*. Cambridge: Cambridge University Press.

Balfet, H., 1965. Ethnoarchaeological Observations in North Africa and Archaeological Interpretation. In: F. R. Matson, ed. *Ceramics and Man*. Chicago: Aldine Publishing Company. pp.161-177.

Callahan, E., Abbott, D. and Viars, K., 1998. Problem Solving in Primitive Ceramics: A Three Part Experiment. *Bulletin of Primitive Technology*, 15, pp.26-33.

Coles, J., 1979. *Experimental Archaeology*. New York: Academic Press.

Daviau, P.M.M. and Chadwick, R., 2007. Shepherds and Weavers in a 'Global Economy'. In: T.E. Levy, P.M.M. Daviau and R.W. Jounker, eds. *Crossing Jordan: North American Contributions to* *the Archaeology of Jordan*. London: Equinox. pp.309-314.

Daviau, P.M.M., Chadwick, R., Weigl, M., Johnston, E.K., Gohm, C., Edwards, S., Ladurner, M., Mulder-Hymans, N. and Ferguson, J., 2012. Excavation at Khirbat al-Mudayna and Survey in the Wadi ath-Thamad: Preliminary Report on the 2008, 2010, and 2011 Seasons. *Annual of the Department of Antiquities of Jordan*, 56, pp.269-308.

Fall, P.L., Falconer, S.E. and Lines, L., 2002. Agricultural Intensification and the Secondary Products Revolution Along the Jordan Rift. *Human Ecology,* 30(4), pp.445-482.

Gosselain, O.P., 1992. Bonfire of the Enquiries. Pottery Firing Temperatures in Archaeology: What For? *Journal of Archaeological Science*, 19, pp.243-259.

Graf, D.F. and Sidebotham, S.E., 2003. Nabataean Trade. In: G. Markoe, ed. *Petra Rediscovered: Lost City of The Nabataeans*. New York: Harry Abrams. pp.65-73.

Hyde, N., 1973. *Maria Making Pottery*. New Mexico: Sunshire Press.

Litto, G., 1976. *South American Folk Pottery*. New York: Watson Guptil.

London, G., 1991. Aspects of Early Bronze and Late Iron Age Ceramic Technology at Tell el-Umeiri. In: L.G. Herr, L.T. Geraly, O.S Labiancaand and R.W. Younkered, eds. *Madaba Plains Project: The 1987 Season at Tell el-Umeiri and Vicinity.* Berrian Springs, MI: Andrews University Press. pp.383-419.

Matson, F.R., 1971. A Study of Temperatures Used in Firing Ancient Mesopotamian Pottery. In: R. Brill, ed. *Science and Archaeology*. Cambridge, MA: MIT Press. pp.65-80.

Miller, N.F., 1984. The Use of Dung as Fuel: An Ethnographic Example and An Archaeological Application. *Paléorient*, 10(2), pp.71-79.

Parks, W., 1995. The Pottery of Mata Ortiz. *Bulletin of Primitive Technology* 10, pp.58-62.

Peacock, D.P.S., 1982. *Pottery in the Roman World: An Ethnoarchaeological Approach.* London: Longman.

Peterson, S., 1984. *Lucy M. Lewis: American Indian Potter*. New York: Harper and Row.

Ramsay, J.H. and Parker, S.T., 2016. A Diachronic Look at the Agricultural Economy at the Red Sea Port of Aila: An Archaeobotanical Case for Hinterland Production in Arid Environments. *Bulletin of the American Schools of Oriental Research,* 376, pp.101-120.

Rice, P.M., 1987. *Pottery Analysis*. Chicago: University of Chicago Press.

Rowan, E., 2015. Olive oil pressing waste as a fuel source in Antiquity. *American Journal of Archaeology*, 119(4), pp.465-482.

Rye, O.S., 1981. *Pottery Technology: Principles and Reconstruction. Washington*, DC: Taraxacum.

Rye, O.S. and Evans, C. 1976. *Traditional Pottery Techniques of Pakistan: Field and Laboratory Studies*. Washington, DC: Smithsonian Institution Press.

Schindler, W.I., 2006. *Middle Woodland Exploitation of Migratory Fish in the Delaware Valley*. PhD. Temple University.

Shepard, A.O., 1965. Ceramics for the Archaeologist. Washington, D.C.: Carnegie Institution.

Sherratt, A., 1983. The Secondary Exploitation of Animals in the Old World. *World Archaeology*, 15(1), pp.90-104.

Sidoroff, M. L., 1991. Acoma Pueblo Pottery. *Bulletin of Primitive Technology*, 2, pp.55-57.

Sidoroff, M.-L. 2013. Unpainted Petra Style Bowls from Wadi ath-Thamad, Jordan: A Technological Focus. In N. I. Khairy and T. M. Weber eds. *Studies on the Nabataean Culture I. Amman*, Jordan, University of Jordan. pp. 75-81.

Sidoroff, M.-L., 2015 An Ethnoarchaeological Study of the Zizia Pottery Factory in Jizza, Jordan. *Ethnoarchaeology* 7(No. 2 (October)) 86-113.

Sidoroff, M. L. and Higgins, K., 2017. Experimental Bon Firing with Peat/Spanish moss cakes. *Florida Anthropological Society: Annual meeting.* Jacksonville, FL, 5-7 May 2017.

Sidoroff, M. L. and Ownby, M., 2016. Preliminary Petrographic Study of Nabataean Painted and Unpainted Fine Ware Bowls from Mudayna Thamad, Jordan. In: N. I. Khairy, ed. *Studies on the Nabataean Culture II*. Amman: University of Jordan. pp.198-214.

Sillar, B., 2000. Dung by Preference: The Choice of Fuel as an Example of How Andean Pottery Production is Embedded Within Wider Technical, Social, and Economic Practices. *Archaeometry*, 42(1), pp.43-60.

Smith, A., Proctor, L., Hart, T.C. and Stein, G.J., 2018. The burning issue of dung in archaeobotanical samples: A case study integrating macro-botanical remains, dung spherulites, and phytoliths to assess sample origin and fuel use at Tell Zeidan, Syria. *Vegetation History and Archaeobotany,* 28(3), pp.229-246. Available at: < https://link.springer.com/article/10.1007%2Fs00334-018-0692-9 > [Accessed 31/12/2018].

Steele, J., 2012. Anatomy of a Pottery Bonfiring in the Port St Johns Region, Eastern Cape, South Africa. *Southern African Humanities*, 24, pp.121-142.

Share This Page

Corresponding Author

Maria-Louise Sidoroff
Independent researcher
PO box 967
Hobe Sound 33475 FL
USA
E-mail Contact

Gallery Image

FIG 1. EXPERIMENTAL FIRING SITE, AL FASALIA, JORDAN.

FIG 2. SCALE WITH DUNG IN BUCKET.

FIG 3. MIFLEH IN HIS COMPOUND.

FIG 4. MIFLEH AND BABY CAMEL.

FIG 5. KHRAWLA (LEFT) AND UM HAMID DALAL (RIGHT).

FIG 6. CITY FRIENDS FROM MADABA.

FIG 7. UM HAMID DALAL’S SON WORKS IN KHRAWLA’S DAY TENT STRIPING SPINACH-FLAVORED LEAVES FROM THEIR STALKS TO SELL FOR SOUP. NOTE BLANKETS STORED ON THE LEFT.

FIG 8. KHRAWLA'S COOK TENT WITH THREE CLAY OVENS. THE LID IS IN PLACE ON OVEN IN LOWER RIGHT OF PICTURE.

FIG 9. LID REMOVED FROM OVEN.

FIG 10. TWO FLAT BREADS WERE BAKED ABOUT FIVE MINUTES ON EACH SIDE WHEN PLACED ON SMOOTH STONES INSIDE THE OVEN.

FIG 11. THE SHEEP COMPOUND IN THE HOME OF UM HAMID DALAL.

FIG 12. KHRAWLA'S SUPPLY OF SHEEP DUNG STORED OUTSIDE HER COOK TENT.

FIG 13. KHRAWLA'S PLANTING FIELD BEHIND HER TENT.

FIG 14. EXPERIMENTAL FIRING SITE, AL FASALIA, JORDAN: 5:45 AM: ARRIVE AT FIRING SITE.

FIG 15. 5:50 AM: CLEAR ASHES FROM PREVIOUS DAY’S FIRING.

FIG 16. 5:55 AM: REMOVE VESSELS FROM PREVIOUS DAY’S FIRING.

FIG 17. 6:00 AM: REMOVE SHERDS FROM HEARTH AND DUST OFF ASH.

FIG 18. 6:00 AM: COLLECT ASH SAMPLE FOR ANALYSIS.

FIG 19. 6:15 AM: FIRE MASTER CREATES A CIRCLE OF DUNG AROUND THE POTTERY SHERDS WITH TWO BUCKETS OF CAMEL DUNG.

FIG 20. 6:30 AM: CIRCLE OF CAMEL DUNG AROUND EXTERIOR OF HEARTH WITH ASH IN PLACE FROM EARLIER FIRINGS.

FIG 21. 6:30 AM: DRIED GRASSES PLACED ON TOP OF DUNG.

FIG 22. THREE ORTON PYROMETRIC CONES TO BE SET AMONG THE VESSELS.

FIG 23. 6:45 AM: WARMING FIRE BEGINS AS CIRCLE OF GRASS AND CAMEL DUNG BURNS TO WARM THE SHERDS AND ASH BASE.

FIG 24. 7:00 AM: WITH VESSELS IN PLACE, SMOKE THICKENS AS CIRCLE OF DUNG BURNS.

FIG 25. 7:15 AM: VESSELS COMPLETELY COVERED WITH CAMEL DUNG FROM 3RD AND 4TH BUCKETS, WHICH BEGIN TO CATCH ON FIRE.

FIG 26. 7:20 AM: TEMPERATURE READING 552°C.

FIG 27. 7:30 AM: FIRE MASTER POURS 5TH BUCKET OF CAMEL DUNG OVER BURNING DUNG.

FIG 28. 8:00 AM: TWO SLABS OF SHEEP DUNG PLACED ON TOP OF BURNING CAMEL DUNG.

FIG 29. 8:05 AM: CAMEL DUNG WITH SHEEP DUNG IN FLAMES. NO MORE FUEL IS ADDED.

FIG 30. 8:30 AM: ONCE FLAMES DIE DOWN TEMPERATURE READING 668.9 °C.

FIG 31. ORTON CONES DID NOT BEND IN THE FIRING TO CONFIRM TEMPERATURE BUT ONLY BLISTERED IN THE FIRING.

FIG 32. FIELD LABORATORY, MADABA, JORDAN: TWENTY-FIVE CLAY VESSELS FIRED WITH PREDOMINANTLY CAMEL DUNG FUEL. AVERAGE SIZE OF HAND-MADE CLAY VESSELS: DIAMETER 9-11 CM, DEPTH 3 CM, THICKNESS OF WALLS 0.3 CM. ONE LARGER COIL-MADE VESSEL MEASURED: 14 CM DIAMETER, 11 CM DEPTH, AND THICKNESS OF WALLS 0.3 CM.

FIG 33. FIRING #3 INTERIOR VIEW, CAMEL DUNG FUEL.

FIG 34. FIRING #3 EXTERIOR VIEW, CAMEL DUNG FUEL.