RICE IN RICE BOWLS:
STARCH AND RESIDUES ON MARKET STREET CHINATOWN ARTIFACTS

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The first historic Chinatown in San Jose, California, was occupied from 1866 to 1887. The Market Street Chinatown was excavated in the 1980s; artifacts have since been analyzed through Stanford University and community partners. While artifacts from the Market Street Chinatown have been studied extensively, the viability of botanical analyses within the curated collection has only recently been tested. This study evaluates the potential for survival and recovery of starch and microfossil residues extracted from 15 ceramic artifacts. Microfossils were also recovered from 12 sediment samples associated with these artifacts. Research on the macro- and microfossils associated with these sediments indicated that the sediments were postdepositional and therefore did not relate to the human use of the artifacts. The significant differences between sediment recovered from within the artifacts and residues recovered from the surface of the artifacts indicate a lack of contamination of preserved residues. This paper describes the recovery of rice-like starch residues from glazed porcelaneous stoneware and whiteware artifacts within the collection. This is the first published study to extract starch materials from nineteenth-century glazed ceramics from within an historic overseas Chinese community assemblage.

The archaeological analyses of food within overseas Chinese communities have largely focused on faunal remains, macrobotanical analyses, and historical records (Baxter and Allen 2002; Piper 1988). Presented here is one of a limited number of studies of historic-period artifacts using starch and microfossil analyses. Starch grains preserved in the archaeological record represent the microscopic remains of plant food storage units (Coil et al. 2003:994) and of plant foods. Archaeological starch analyses typically recover, identify, and analyze starch residues preserved as part of the archaeological record (Pearsall 2000; Torrence and Barton 2006). Although leaves and stems of plants may contain transitory starch grains, these are typically non-diagnostic, and the most identifiable types of starch grains occur in plant storage organs, including seeds, nuts, and tubers (Piperno 2006:50).

Archaeological starch has been used to examine tool use at prehistoric sites (Barton and White 1993; Barton et al. 1998; Piperno 1998; Piperno and Holst 1998; Samuel 1996; Ugent et al. 1984, 1987), but is less commonly used to study artifacts in museum collections (although see Barton 2007; Fullagar 2006) collected through surveys, or from midden or rubbish disposal deposits rather than secure and undisturbed excavation sites (although see Hart 2011). Starch analysis may not occur due to concerns about potential contamination of residues, as well as to a lack of perception of the potential value of starch research. Food preparation has also been studied through starch analyses aimed at identifying the use of vessels or artifacts and experimentally assessing the morphological changes in starch through controlled cooking studies (Crowther 2005; Henry et al. 2009; Lamb and Loy 2005; Lu et al. 2005).

In terms of usefulness to historic archaeology, starch and microfossil analysis may be used to identify multiple uses or reuses of vessels or artifacts (Liu et al. 2011), to understand cooking and food preparation techniques (Ge et al. 2010; Henry et al. 2009, 2011), and to inform our understandings of historically underrepresented people and their uses of plants and foods, which are often absent from the historic record. This form of inquiry can also shed light on contradictions between the written and
archaeological records, or highlight discrepancies between the archaeological record and ethnographic
analogy (Piperno 2006:64). Preserved microfossils within soils and sediments are also useful for paleo-
environmental reconstructions (Lentfer et al. 2002) as well as in artifact contamination controls (Barton et
al. 1998).

When it was discovered in 2011 that sediments from vessels excavated in the 1980s had been
preserved, pilot projects were created to understand the depositional environment of these sediments.
Research questions guiding this project were: firstly, whether identifiable residues could be extracted
from ceramic vessels within the collection; secondly, whether the macro- and microfossils present in the
sediment samples collected from within the vessels relate to use of the vessels or to taphonomic processes
unrelated to human use; and thirdly, whether residues extracted from the vessels relate to cultural activity
and use of the vessels or to contamination from environmental conditions. A fourth research aim
examined potential contamination of residues or sediments associated with the vessels.

THE MARKET STREET CHINATOWN ARCHAEOLOGY PROJECT

The Market Street Chinatown was the first historic Chinatown in San Jose (Voss 2008; Figure 1).
This enclave was replaced by the Heinlenville Chinatown and the Wollen Mills company town after the
arson of the Market Street Chinatown in 1887 (Baxter and Allen 2002; Voss 2008:41; Yu 2001). Artifacts
from the Market Street Chinatown were excavated by Archaeological Resource Services (ARS) in 1985-
1988, and include storage jars, bowls, and sediment samples collected from within vessels. Identifying
practices within daily life can add to the social focus of research within the Market Street Chinatown
Archaeology Project, which has already examined markers of ownership and meanings of images on
individual ceramic vessels (Chan 2013; Michaels 2005). These types of research projects are crucial for
articulating aspects of daily life for Chinese immigrants, one of California’s hidden populations in the
nineteenth century (Voss 2008). In a separate preliminary study of the same assemblage, chemical and
microscopic analyses were conducted by Paleo Research Institute, Inc. in Golden, Colorado (Puseman et
al. 2012). These analyses have increased our understanding of food and culinary practices used by the
Chinese immigrants from San Jose’s first historic Chinatown. For a more general background on the
Market Street Chinatown and research on overseas Chinese archaeology, the reader is referred to Voss
Archaeology Project has been processing and interpreting materials from the initial excavation since 2002
(Voss 2004).

Vessel and Sample Description

Ceramic vessels sampled within the Market Street Chinatown collection include one British
whiteware vessel; five porcelaneous Asian stoneware bowls with “Bamboo,” “Celadon,” and “Four
Seasons” style decorations; as well as stoneware storage vessels with spouts, storage vessels without
spouts, and storage container lid pieces (Figure 2). Fifteen vessels were sampled, creating a total of 22
samples; these samples and 12 associated sediment samples were analyzed for microfossils (Table 1).
Artifacts with catalog numbers starting with 85-31 were excavated by ARS from July to November 1985,
while artifacts with catalog numbers 86-36 were excavated from 1986 to 1987 (for further information
regarding spatial distribution, see Kane 2011 and Voss and Kane 2012). These vessels included whole
bowls and jars with apparent residues on the surface, as well as lids and fragments of vessels.

With the assistance of the collections manager, Megan Kane, various types of vessels were
selected from a variety of contexts to complement samples that were chemically and microscopically
analyzed by Paleo Research Institute, Inc. (Puseman et al. 2012). The context most relevant to this
publication was Feature 85-31/18, a wood-lined privy pit that was later used as a trash pit. It was
approximately 4 x 6 ft. and was one of the few features that were stratigraphically excavated (Kane 2011).
Four of the vessels examined for residues were preserved within this feature.
Figure 1. Location of the San Jose Market Street Chinatown (Developed from Yu 2001:xii). Cartography by 360 Geographics. Used with the project director's permission.

Figure 2. Photographs of vessels from which starch was recovered a) British whiteware vessel, b) “Bamboo” bowl, c) Pit within “Bamboo” bowl showing collection location of residue sample 9. Table 1. Vessels and sediment samples analyzed.
SEDIMENT CATALOG NO.  | SAMPLE | VESSEL TYPE | VESSEL CATALOG NO. | SAMPLE  
--- | --- | --- | --- | ---  
85-31/2B-2 | MS1 | Stoneware Storage Jar | 85-31/2B-1 | V1  
85-31/18-7 | MS2 | Stoneware Shouldered Jar | 85-31/18-6 | V2  
85-31/18-11 | MS3 | Stoneware Spouted Jar | 85-31/18-10 | V3  
85-31/18-231 | MS4 | British Whiteware | 85-31/18-228 | V4  
85-31/20-9 | MS5 | Four Seasons Bowl | 85-31/20-8 | V5  
85-31/20-74 | MS6 | Bamboo Bowl | 85-31/20-62 | V6  
85-31/20-76 | MS7 | Celadon Bowl | 85-31/20-75 | V7  
85-31/28-4 | MS8 | Stoneware Storage Jar | 85-31/28-3 | V8  
85-31/18-396 | MS9 | Bamboo Bowl | 85-31/18-395 | V9, V13  
86-36/5-16 | MS10 | Stoneware Shouldered Jar | 86-36/5-14 | V10  
86-36/5-20 | MS11 | Stoneware Shouldered Jar | 86-36/5-19 | V11  
86-36/5-1582 | MS12 | Bamboo Bowl | 86-36/5-1583 | V12  
X | X | Thin Storage Container | 86-36/5-1535 | V14  
X | X | Storage Jar Lid | 85-31/20-58 | V15  
X | X | Storage Jar Lid | 85-31/20-162 | V16  

Note: X indicates that no sediment samples were associated with the vessel. Vessel samples V9 and V13 were both from the same vessel. These pieces were in separate places within the collection and received separate sample numbers and slides before it was discovered that they were both fragments of the same vessel.

**METHODOLOGY**

The two types of ecofacts examined here include residues taken from vessels and microfossils taken from sediment samples. Residues are defined here as microscopic remains associated with the use of an artifact or vessel and recovered from the surface of the vessel. Sediments were found inside vessels during the 1985-1987 excavation but were not necessarily related to the use of the vessels. In this study, microfossils were recovered from the sediments and were analyzed and identified. During this analysis, one of the aims was to determine whether the associated sediment samples were in fact related to the use of the vessel. Since these sediments were possibly not residues, they were termed “sediments” rather than “residues.” The different procedures used in the extraction of residues from the vessels are described below. The laboratory processing of the residues and of sediments from within the vessels to extract microfossils is also described below. To complement the extraction and identification of microfossils from ancient samples, modern reference plant and food materials were also examined.

**Archaeological Residues and Microfossils**

Residue extraction included the removal of microfossil residues from vessels through sonication (e.g., Piperno et al. 2009) and through wet pipettor and dry scraping extraction methods (e.g., Liu et al. 2011). Sediment samples were collected from inside vessels recovered during the 1985-1987 excavations. The contents of these sediment samples were examined macroscopically and further subjected to a laboratory procedure to recover microfossils. Fragmentary sherds and pieces of larger vessels (86-36/5-1535, 85-31/20-58, 85-31/20-162, 85-31/18-395, and 85-31/28-3) were sonicated in an ultrasonic bath for 3 minutes prior to heavy liquid separation and then mounted in water on microscope slides for analysis and identification. All other residue samples were collected through wet pipettor sampling and dry sampling where appropriate. Dry sampling involved the scraping off and collection of visible sediment from each artifact surface with a dry pipettor tip (Piperno et al. 2009:5022 used a needle for this). Wet pipettor sampling used distilled water and a pipettor to extract visible or potential residues (see Liu et al. 2011).
Processing of the extracted sediments involved the initial macroscopic examination to determine whether the sediments related to postdepositional infilling of the vessels. Processing of sediments to extract microfossils used 800 mg of sediment in a gravity settling sedimentation procedure (following Rosen 2005) and then preparation with a heavy liquid. Processing of residues to extract microfossils used the heavy liquid sodium polytungstate to concentrate starch prior to mounting on glass slides in water (after Liu et al. 2011, 2013). Microfossils were examined using a 40X objective with a Zeiss Axioskop microscope fitted with brightfield, differential interference contrast (DIC), and polarizing filters. They were photographed using a Zeiss AxioCam HRc microscope camera and Zeiss Axioskop 4.8 software.

Plant Reference Samples

Historic references to diet in overseas Chinese communities are typically vague and refer to foods such as rice, vegetables, fruits, and biscuits (Diehl et al. 1998; Piper 1988), although market gardens are also known (Lawrence and Davies 2011:234-236). Despite this, ceramic vessels are typically described in the literature as “rice bowls” or “soy sauce pots” (Wegars 1988:44,46) and described as general food storage vessels for pickled vegetables, among other purposes (e.g., Lawrence and Davies 2011:234-236; Muir 2003). In order to examine these general conceptions of vessel use, reference samples for pickled ginger, cooked rice, and soy sauce were created by mounting small fragments of each type of foodstuff on a glass microscope slide and sealing the slide with nail polish. In addition to these reference samples, over 900 plant remains were available for comparison through the Stanford University archaeobotanical collection (Liu et al. 2013). These were utilized as appropriate for comparisons to identify the archaeological starch grains recovered from the Market Street Chinatown artifacts.

Modern pickled ginger (*Zingiber* sp.) starch granules exhibit a diagnostic morphology, including both bell- and fan-shaped granules (images available in Becks 2012; see Lentfer 2009:Table 2 for descriptions of starch morphotypes). No ginger starch was recovered; therefore, ginger will not be discussed further. Modern cooked Kokuho Rose brand rice (*Oryza* sp.) was steamed in a rice cooker for approximately 35 minutes. The modern cooked rice sample contained gelatinized rice exhibiting unclear and damaged extinction crosses, as well as less damaged and measurable starch grains (Figure 3). Non-gelatinized starch was between 2.4 and 7.9 µm in length, with an average size of 4.8 µm Henry et al. (2009:917) described rice starch grains as “compound, subangular, faceted and small,” with a closed centric hilum and a range from 3 to 10 µm long, and this description is generally consistent with other measurements of rice starch (e.g., Liu et al. 2010:Figure 3). For modern samples, more than 100 of each type of reference starch grain were measured to get a baseline size range. Reference slides of Kikkoman brand soy sauce did not exhibit starch grains; this was attempted despite the fact that soybeans typically do not exhibit starch after harvest (Stevenson et al. 2006).

RESULTS

Ceramic Vessels

Residues were recovered from almost three-quarters (73.3 percent; n = 11) of the 15 vessels examined (Table 2). A total of five vessels contained diagnostic residues, while six yielded residues that were not diagnostic and will not be discussed further. Starch grains were recovered from two of the vessels (13.3 percent), and in both cases starches were recovered from pre-depositionally chipped ceramics. Residues from six (40 percent) of the vessels examined contained burnt phytoliths or charcoal, while bordered pits were recovered from one vessel only (6.6 percent). In this context, burnt phytoliths and bordered pits may indicate residues from cooking, ash and wood fires, or the use of wooden cooking and food preparation tools on the artifact.
British Whiteware 85-31/18-228 (Vessel 4)

A British whiteware vessel (Figure 2) was one of six vessels with minimal levels of charcoal and burnt phytoliths present. The cluster of starch grains recovered from this vessel represent small (4–12-\(\mu\)m), compound, faceted grains with centric extinction crosses (Figure 4; Table 3). These were consistent with rice starch in size and shape, as well as in the arched arrangement visible in part of the starch cluster.

“Bamboo” Porcelain Stoneware Bowl and Fragment 85-31/18-395 (Vessels 9 and 13)

Two samples were extracted from a bamboo bowl, a style colloquially described as a “rice” bowl (Wegars 1988:46). One sample was extracted from an imperfection in the glaze in the inner base of the
### Table 2. Sample residue results: presence and absence.

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<th>CHARCOAL*</th>
<th>BORDERED PITS</th>
<th>FIBER</th>
<th>PLANT HAIR</th>
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Key: X=Present; A=Abundant (≥100); M=Medium (<100 >30); F=Few (<30).

* There was a tri-scalar measurement for charcoal presence including abundant, medium, and few charcoal fragments present; however, no samples had a “medium” amount of charcoal present, so this scale is not visible in the table.
Figure 4. Archaeological starch recovered: rice (Oryza sp.) starch from vessel sample 4 in bright field, DIC and polarizing filters (a-c); rice (Oryza sp.) starch from vessel sample 9 in bright field, DIC and polarizing filters (d-f); rice (Oryza sp.) starch from vessel sample 13 in bright field, DIC and polarizing filters (g-l); wheat or barley (Triticeae tribe) starch from vessel sample 13 in bright field, DIC and polarizing filters (j-l); and corn (Zea mays) starch from vessel sample 13 in bright field, DIC and polarizing filters (m-o).
Table 3. Rice reference sample (Oryza sp.) and ancient starch grain numbers and sizes.

<table>
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<th>Measurements in Microns (µm)</th>
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<td>Sample V13 “Bamboo” bowl 85-31/18-396 Large Faceted Grains</td>
<td>18.7</td>
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bowl, and the other was sonicated from a vessel fragment (see Table 2; Figure 2). Both samples contained minimal levels of charcoal and burnt phytoliths. These samples also contained starch and fibers. Starch recovered from vessel samples 9 and 13 included several clusters of small, faceted starch grains between 4 and 7 µm in size (Figure 4). The circular arrangement of some of the granules is particularly characteristic of rice starch, and these granules are identified as rice (Oryza sp.). The lack of a clear extinction cross on many of the granules is consistent with experimental damage observed in modern rice starch boiled for over half an hour (Figure 3). The second type of starch grain recovered from this vessel was large (21.6 µm) and rounded, with lamellae, size, and shape diagnostic of the Triticeae (wheat and barley) tribe of grasses. The size and lamellae in this starch grain identify it as one of the AHT (Aegilops, Hordeum, or Triticum spp.) group within the Triticeae tribe of wheat and related grasses (Piperno et al. 2004). This starch is most likely wheat or barley. The third type of starch grain extracted from this vessel was large (18.7 µm) and faceted, with well-defined pressure facets, a chunky appearance and a tri-fissured central hilum. This is typical of maize starch (Holst et al. 2007; Piperno et al. 2009) and is identified as Zea mays.

Sediments Associated with Vessels

All 12 sediment samples analyzed yielded microfossils, but none of these samples contained starch. All samples exhibited relatively high levels of charcoal, and many burnt phytoliths were also observed. All sediment samples also contained phytoliths, mostly long cells or multicellular silica skeletons, from grasses. Many sediment samples also exhibited pollen grains (75 percent; n = 7). Only two sediment samples contained bordered pits that may be indicative of wood or tubers (16.7 percent). The majority of the sediment samples contained fibers of various descriptions (83.3 percent; n = 10), but plant hairs (33.3 percent; n = 4) and feather barbs (16.7 percent; n = 2) were uncommon.

DISCUSSION

Contamination is a significant issue in residue studies, and the identification of contamination is one reason for the analysis of microfossils extracted from sediment samples associated with vessels. The lack of starch grains from sediment samples collected from within the vessels may relate to the high temperatures sustained during the fire that destroyed the site. This is possibly because starch grains typically begin to gelatinize at temperatures above 50°C (Ubwa et al. 2012) unless they are protected or sheltered by the surface of an artifact (Barton and Matthews 2006). The lack of starch in the sediments associated with the vessels examined indicates that postdepositional events did not contaminate starch residues adhering to the surfaces of the vessels. The significant differences between residues extracted from the surfaces of these vessels, minimal charcoal remains, and some starch grains, are in contrast to
the microfossils recovered from sediment samples in which every sample contained charcoal and phytoliths, and no sample contained starch. The fact that many samples also contained pollen indicates completely different microfossil assemblage compositions between the residue samples and the sediment samples.

The microfossils in the sediment samples that were recovered from inside the vessels do not appear to relate to the human use of the vessels. Instead, these microfossils relate to environmental conditions, judging by the large numbers of grass phytoliths and pollen grains in these samples. The large amounts of charcoal in sediment samples are likely related to the arson of Market Street Chinatown and thus can be traced to depositional processes acting on the vessels. The prevalence of charcoal and other microfossils including phytoliths support the suggestion that the sediments found within these vessels represent infilling after their initial deposition. The burnt materials may represent either historic practices of trash burning or the final arson of the Market Street Chinatown in 1887 (Voss and Allen 2008). It appears that sediment samples have not contaminated the residues retained within the ceramic vessels.

A lack of contamination of starch grains in vessels indicates that residues extracted from the vessels likely relate to use of the vessel, including storing food or food consumption. The number of starch residues recovered from vessels examined was relatively small (n = 39), and these residues were recovered exclusively from chipped surfaces of whiteware and porcelaneous stoneware vessels. This is consistent with suggestions that starch preserves well in sheltered locations on artifacts (Barton and Matthews 2006), including on the rough or unglazed surface of a vessel or in a pitting or imperfection in a ceramic dish. Many of the small clusters of starch recovered can be identified as rice, based on the size and shape of the grains (see Henry et al. 2009) as well as the distinctive rounded clustering arrangement indicative of the packing arrangement of the grains within the plant storage cell. However, not all of the vessels tested for starch or identifiable plant food residues preserved identifiable remains. The tested ginger jars and soy sauce pots did not yield starch residues or other microscopically identifiable plant remains. This may be partly due to the damage of the starch grains or plant material during the pickling or fermenting processes.

The evidence of corn and either wheat or barley suggests that, while maintaining more familiar eating habits of rice and imported Chinese goods (Piper 1988), people within the Market Street Chinatown also incorporated at least one American cultigen into their diet. A similar process is described by Diehl et al. (1998:21), in which Chinese gardeners in Tucson, Arizona, merged corn and potatoes into their diet at the turn of the twentieth century. This integration of locally available foods is consistent with the inclusion of European-made vessels in eating practices within overseas nineteenth-century Chinese communities (Voss 2005:432-433). Future research may find other microfossils, including starch grains from different foods, possibly indicating multiple food preparation methods that may have occurred using different vessels. Analyzing archaeologically recoverable residues in domestic and commercial vessels has the potential to address issues of community interest, including identifying foods and food preparation practices involved in daily life and in mercantile practices (Voss 2008:47-48).

**CONCLUSION**

The starch and microfossils recovered from vessel residues and sediments within the curated collection of the Market Street Chinatown indicate that identifiable residues may be extracted from curated historic-period assemblages. Rice starch grains were recovered from rice bowls; however, wheat or barley and corn starch grains recovered indicate the incorporation of Euro-American foods into Chinese communities as well as the maintenance of a familiar diet. The significant differences in microfossils recovered from vessel residues and from sediments deposited after original deposition within vessels indicate that these two separate microfossil assemblages relate to different taphonomic processes. The high levels of charcoal and pollen and the lack of starch grains within the microfossil assemblage recovered from sediments indicate that this assemblage is likely unrelated to cultural use of the vessels. The charcoal, burned phytoliths, and pollen indicate environmental contamination, with the charcoal and
burned phytoliths probably resulting from the fire that destroyed the site. These sediments are unrelated to anthropogenic use of the vessels and likely indicate sediment infilling of the vessels after discard or deposition.

The difference in microfossil assemblages between sediments and residues suggests a lack of contamination of residues. Minimal amounts of charcoal and burned phytoliths were recovered from residues, in contrast to the high levels of charcoal in sediments. The small numbers of charcoal and phytolith fragments from residues likely relate to cooking and food preparation activities. In addition, no starch grains were recovered from sediments, indicating no contamination of starch on vessel surfaces from sediment, despite the fire and taphonomic processes that destroyed the Market Street Chinatown.

The results of this study indicate that glazed historic-period artifacts may yield identifiable, non-contaminated starch grains, especially when samples are extracted from areas of glaze imperfections. The results of the vessel residue extraction are consistent with expectations regarding the use of the vessels; rice bowls contained rice starch grains, as well as starch grains from foods such as wheat or barley and corn, which may also have been staple foods. This indicates that starch and residue analyses are potentially rewarding sources of information regarding identification of historic-period foods as well as cooking and food processing methods. Future research may uncover a broader range of foodstuffs eaten and stored in pottery or ceramic vessels by the residents of Market Street Chinatown.

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