Experimental Archaeology: Modeling the Costs of Groundstone tool-use for Maize Consumption in Range Creek Canyon, Utah.

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Abstract

Changes in environmental context and subsistence strategies are reflected in the changing technologies found in the archaeological assemblages of prehistoric farmers. Much research has been conducted in modeling the costs and benefits of the foraging strategies associated with the technology transitions of flaked lithic tools in the archaic record (Bettinger et al 2006). Considerably less research has been conducted on the costs associated with groundstone technology and the intensification of agriculture (Barlow 2002). This research focuses on Fremont groundstone use in the processing of maize for consumption. The existing data set on Fremont maize production on the north Colorado Plateau comes primarily from the Range Creek Field Station in east-central Utah. This research aids in the understanding of the question; how "expensive" was farming for the Fremont in Range Creek Canyon 1,000 years ago. Boomgarden et al. (2019) currently have quantitative data on the costs and benefits of many farming activities including; field clearing, planting, weeding, irrigating, harvesting, and yield using only technology available to prehistoric farmers. Unfortunately, they are missing a key, and very costly, piece processing the maize for consumption. This project begins to add the costs, kilograms per hour (kcals/hour), of processing maize to the existing data set. After gathering our data, I compared my return rates for grinding maize to ethnographically documented return rates and other maize grinding experiments for more complete estimates. This data is critically important to better understanding what trade-offs Fremont farmers faced and why they made the decisions they made. Ultimately, this research is a pilot study that has led to a great deal more questions to be explored and provided insights into what methods are needed to answer them moving forward.

Photograph showing experimental maize plots in Range Creek Canyon

Question

This experiment adds to the data set exploring how costly it was it to be a Fremont farmer in Range Creek Canyon, Utah, and why they made the decisions they made? This research aids in understanding this question by gathering quantitative data (kcals/hour) on the cost of processing maize for consumption. In addition to the quantitative data, participants in actualistic experiments provide many observations about the actual process of grinding maize that ethnographic accounts and the archaeological remains cannot provide.

References:

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Simons, E., Boomgarden, S., Metcalfe, D., Haisley, C. and Ermish, B. 2018 An Actualistic Experiment Investigating the *Costs and Benefits of Irrigation*. Poster presented at the 2018 Great Basin Archaeological Conference, Salt Lake City, Utah.

The Experiment

Materials/Tools:

Figure 1. Photographs showing Fremont manos (upper) and metates (lower) borrowed from teach collections at NHMU, UUAC, SHPO and the Range Creek Field Station. Metate 1and 2 are flat, where as 3,4, and 5 are troughed. Metate 4 is also broken on one side. We felt troughed metates helpful in minimizing corn loss, though this was not supported in the data

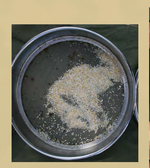
Figure 2. Photograph of small whisk brushes used, similar to types used ethnographically.

Figure 3. Photographs of heirloom varieties of maize used in the grinding experiments. Currently, the variety of maize grown by the Fremont is called Fremont Dent. Typically, cobs are found with no kernels on them in the archeological record. Research is still being done to better understand how Fremont corn is related to other ancient varieties. We used heirloom varieties grown by the Hopi and Akimel O'odham, some of which was grown in the Range Creek experimental gardens.

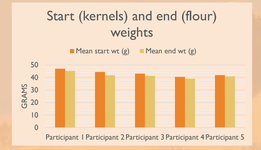
Methods

Preliminary: All participants met as a group prior to the start of the grinding trials to compare grinding techniques and establish a protocol for data collection methods before separating to grind individually. Data from the preliminary grinding trials was not included in the final results.

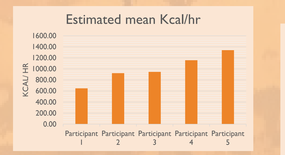
Grinding experiment: Each participant was given a Fremont mano and metate from a teaching collection (Figure 1). Each tool varied in size and shape but all tools reflect the variability in tools used by the Fremont in Range Creek Canyon. Each participant was given a small whisk broom (known to be used ethnographically-Figure 2), and bags of dried corn kernels (heirloom and modern varieties-Figure 3). Each tool is labeled and was noted in the spreadsheet. Each participant developed their own grinding techniques depending on the different set of tools used, thus produced varying results. To better document these differences, participants conducted at least six grinding trials on each metate and then traded tools with another participant so that their grinding rate could be established using multiple techniques (except for one, Participant 4, who conducted only four trials on one set of grinding tools and Participant 1 who conducted all trials on one set of tools). For each trial, participants measured and weighed ¼ cup of dried corn kernels. After the corn was placed onto the metate, participants started a stopwatch and began grinding with their mano. When the ground corn looked to be at a flour like consistency, participants stopped their stopwatch. Participants then sifted their flour through a screen aiming for approximately 95% to pass through before calling it complete. The screens used by each participant varied slightly in size so the flour was later sifted through a 1 mm sized sift to record the final proportion of fine flour to meal (slightly larger). The meal not able to fall through the 1 mm sift was then weighed. The final measurement was total weight of all ground flour and the total grinding time. The final weight was compared to the start weight to calculate a total loss. All measurements were recorded in an excel sheet along with additional observations on the experience. Data on the cost of processing dried maize into flour was averaged for each participant (Table1). The kcals per hour was estimated based on 3.86 calories per gram (www.nutritionvalue.org). I then compared our results with similar experiments and ethnographic data from other researchers (Barlow 1997, Buonasera 2015). These findings will be used in the Range Creek farming experiments when discussing total costs of corn farming.



Results



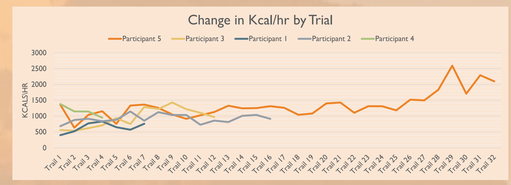
This chart shows mean starting kernel weight (1/4 cup kernels, weighed) and mean end weight (1/4 cup flour, weighed) for each participant. I predicted grinding speed, tools used, and grinding style would greatly effect amount of maize lost from start to finish. However, there was little variation between participants.



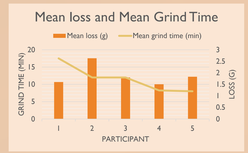
This chart shows each participants estimated Kcal per hour grinding rate. The range of average Kcals/hour for all participants is 648-1339. The variability in grinding rates is likely due to participants skill and techniques, number of trials, and variability in tool size and shape. The participant with the greatest number of trials also had the highest grinding rate. This suggests that skill and efficiency are gained with practice.

Table 1. Results of the grinding experiments summarized by participant.

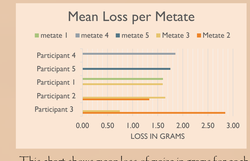
NAME	No. trials	Mean start wt (g)	Mean end wt (g)	Mean loss (g)	Mean grind time (min)	Mean amount >1mm (g)	Mean amount <1mm (g)	Mean g/min	Estimated mean g/hour	Estimated mean Kcal/hr
Participant 1	10	47	45.2	1.6	17.5	4.96	40.24	2.80	168	648
Participant 2	16	44.45	41.82	2.63	12	13.34	29.88	3.98	239	922
Participant 3	12	43.08	41.28	1.8	12	2.88	38.40	4.09	245	947
Participant 4	4	40.53	39.02	1.505	8.25	1.27	37.75	5.00	300	1157
Participant 5	32	41.91	40.91	1.83	8	1.09	38.99	5.78	347	1339



This chart shows the change in Kcal per hour over time per participant. We predicated participants would increase their kcal per hour each grinding session as they became more familiar with the skill. However, there is little trend. Participant 5, shows a minor trend over the span of 31 trials. This suggests that participants need to continue grinding experiments over long periods of time to show a learning curve. This makes sense for participants who did not grow up developing this skill like Fremont farmers would have.



This chart shows the mean loss compared to mean grind time per participant. I suspected that slower grind times might correlate with less maize loss from start to finish. However, little trend is recorded. Some participants noted lower losses might be associated with certain tools or styles rather than grinding speed.



This chart shows mean loss of maize in grams for each metate and participants. Each participant recoded their observations while using different sets of tools. Most felt that metates with a deeper trough led to decreased maize loss compared to flat metates. The numbers showed that this was not always the case. Metates 3,4, and 5 were deeper compared to 1 and 2. Participant 3 had the highest average losses on a flat metate, 2, and lowest average losses on troughed metate, 3.

Discussion

This research was a preliminary study looking at the costs of grinding maize for consumption using actualistic grinding experiments. This research will be added to farming experiments conducted in Range Creek Canyon regarding irrigation based maize farming return rates against hours and Kcal required for building, maintaining, and harvesting irrigated maize fields. Simons et al (2018), compiled a summary of the costs associated with this and a review of the benefits, however, cost of processing maize for consumption, this study, was not yet available. This research will be added to the current summary work to better understand the overall costs and benefits of maize farming in Range Creek Canyon, Utah by the Fremont people.

I compared our grinding times with a similar grinding experiments conducted in Barlow (1997). While using slightly different methods, Barlow reported return rates of 1800 to 2500 Kcal per hour. The average range of kcals per hour for our participants was 648-1339. While our upper ranges overlap with Barlow's, our lowest range was far lower than her recorded minimum. I suspect that this has to do with difference in participant methods, variability caused by using different tools, and the number of times the experiment was repeated (Barlow's participants ground for longer periods of time, conducted less trials per participant, and utilized multiple grinding methods). Further investigation is necessary to make the two experiments more comparable and explain the variability, but it is very promising that our ranges overlapped. When comparing our numbers (mine and Barlow) with ethnographic data suggesting grinders spent 1-5 hours a day grinding, I find that one hour of grinding would provide one to two people with half of their daily caloric intake, thus, when grinding for a family, it would take multiple hours (ex: family of 4 would take 2-4 hours). Then when supplemented with other foods (beans, squash, etc.) , daily Kcal and nutritional requirements would be reached.

There are many variables involved in this study that might affect return rates such as participant grinding style and the variation in the corn and tools used, etc. making it relatively challenging to interpret the data without additional trials. Additionally, we ground for short bouts rather than multiple hours at a time, as seen ethnographically. Grinding for 5-20 minutes, rather than 1-5 hours, has the potential to change return rates. Moreover, the flour texture and meal-size we aimed for is quite arbitrary. Different recipes call for different sized corn meal or flour texture, and thus could greatly effect a grinders decision about when to stop grinding. As a result, we have compiled an additional list of questions to consider in future experiments (right).

Future Questions

- How many individual trials are required to reach a steady grinding rate per participant?
- What is the difference in the return rates based on tool type?
- Do the participants' grinding styles effect return rates?
- Does different maize types influence return rates?
- How much does the participants skill or practice explain variance in return rates?
- Does outcome expectation (flour texture or cornmeal-size) affect return rates?
- Does a short grinding trial vs a longer trial influence return rates?
- How does nixtamalization (wet maize soaked in alkaline solution) compare to the return rates produced by grinding maize kernels dry?
- Is there physical damage that shows up as skeletal evidence for the processing of resources on groundstone tools for long periods of time?
- What were the tool preferences of the participants and why?

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