Hair and potters: an experimental look at temper

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Abstract

This paper explores the ways in which horse hair alters the properties of clay and resulting vessels when used as a temper. This is based upon archaeological evidence found in Kazakhstan, though the experiments conducted were of a general nature. Experimentation involved comparing tempered to untempered vessels by recording dimensional changes, porosity and permeability, and resistance to tensile and shearing strain. A discussion of the benefits of including such a temper follows, highlighting the probability that it was added in order to aid vessel formation rather than for specific vessel performance characteristics.

Keywords

Temper; hair; Kazakhstan; pottery; Makhandzhar; experiments.

Introduction

Within the Neolithic period in Kazakhstan, there were a series of vessels which were tempered with an unknown organic fibrous substance. The temper has been tentatively identified by the excavator, Dr V. Logvin, as horse hair, based upon the shape and orientation of voids in the vessel fabric (Outram pers. comm.) (see Plate 1). In order to facilitate future direct analysis of the archaeological material, the following research focused on producing experimental analogues for this hypothetical tempering, while attempting to understand whether horse hair would be a suitable tempering agent, and why it may have been used.

Kislenko and Tatarintseva (1999) briefly highlight the archaeological examples on which this study is based. The vessels inspiring this study were found near Kustani, Kazakhstan, and are of a 'distinctive' Makhandzhar type: 'Decoration was applied to the walls of the vessels before they had dried out, using a comb stamp. A composition of

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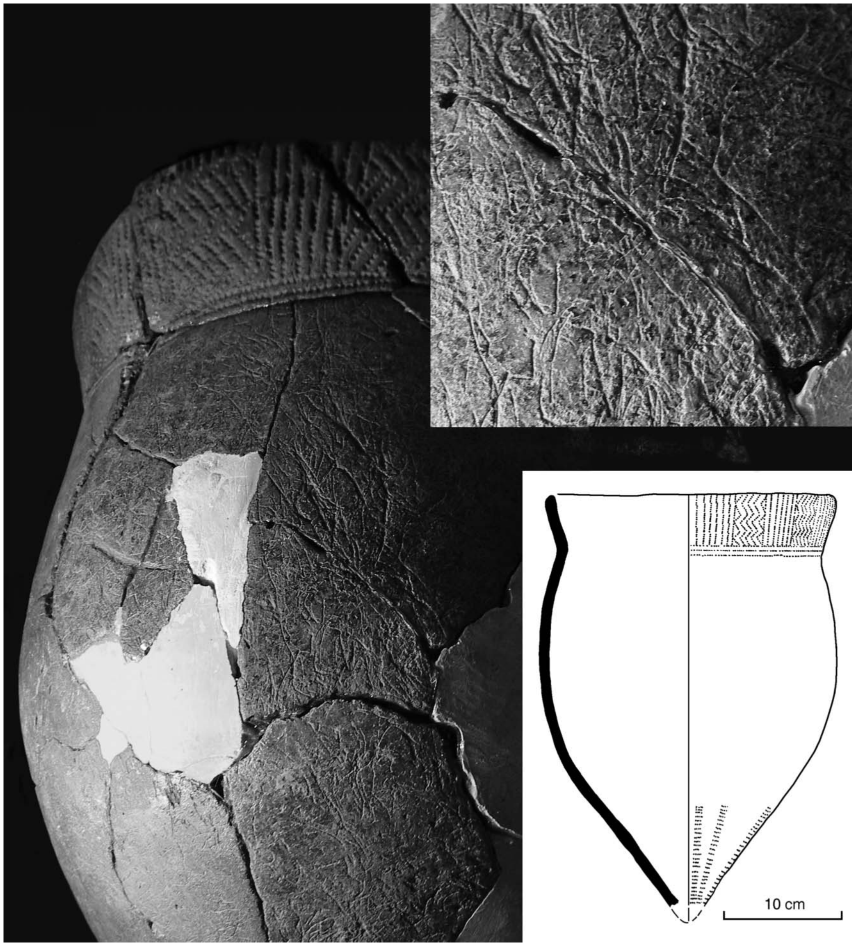

Plate 1 Makhandzhar type vessel, with detail of possible horse-hair tempering and overall vessel form inset. (Photo: E. Isayev; drawing redrawn from Kislenko and Tatarintseva 1999: Fig. 4.12.)

horizontal or vertical zigzags, parallel striations and other surface elements sometimes decorated the whole exterior surface' (1999: 196). The possible horse hair on the exterior of the vessels may fall into this final category of 'other surface elements'; however, the fibrous marks were not merely surface impression, but could clearly be seen running through the section of the pottery on broken sherds (Outram pers. comm.). It is this fact that suggests a temper rather than a decoration or accidental surface impression.

The bulk of known Makhandzhar sites are located within the Turgai depression, near the Ural Steppe in Kazakhstan. Because of similar geography and cultural attributes, Kislenko and Tatarintseva (1999) state that it is difficult to separate the Makhandzhar culture spatially from the Atbasar culture and the Kelteminar culture. The sites identified by Logvin have show several trends. They tend to be located on flood plains, possibly where those flood plains were connected to wide expanses of river. This would have provided access to beds of reeds and probably a rich resource for fish and water birds.

Altogether, such a location would have much potential for hunting and fishing. Of the sites identified, Logvin's excavations only located one structure, at Dubzai 1. It appears to be semi-subterranean, about a half a metre in depth (Kislenko and Tatarintseva 1999: 183–96). While termed Neolithic, due to the presence of pottery, all the evidence points towards this culture being one of mobile hunter-gatherers.

Previous research

There are a few written sources which discuss the supposed presence and purpose of organic tempering that are applicable to the aims of this study. Rye (1981) serves as an introduction to two concepts central to the tests conducted regarding organic tempering. By adding organic materials, he states (1981: 34), shrinkage is reduced and the workability of excessively plastic clay is improved.

Pratt (1999) gives descriptions of tempers used, and hypotheses regarding their function, within an early Colombian context in America. The vessels described were handmade pinch pots, tempered exclusively with flat, grass-like, bladed organic fibres. Though this is acknowledged as plant tempering, the type of plant used is as of yet unidentified (Pratt 1999: 75). Pratt also suggests, in agreement with Skibo et al. (1989: 140), that fibrous temper enables mobile groups to have a more expedient ceramic production sequence.

A more recent examination of the behaviour of temper in ceramics was undertaken by Tite et al. (2001). Through testing a range of archaeological specimens, they ultimately found that the vessels with the greatest toughness and thermal shock resistance had high temper concentrations, especially platy or fibrous tempers, and were fired at low temperatures (Tite et al. 2001: 301).

These findings could be somewhat misleading as the samples had undergone various uncontrolled taphonomic processes prior to testing. These processes have altered the properties of the samples in unmeasurable and inconsistent ways. In order to avoid this problem, sample vessels or sherds that were purpose-made in a controlled way should have been tested as well. By creating analogues to test alongside the archaeological specimens, stronger claims could have been made regarding the properties of the various tempers tested and the taphonomic processes affecting the sherds might be better understood. Finally, in creating a framework where the tempers are known from the outset, they would have avoided the dangers inherent in basing tests on materials which first required interpretation.

The above sources relate to this study in a general sense. Below, experimental studies which have been conducted to address specific questions in relation to tempering are discussed.

Bronitsky and Hamer (1986) investigated tempering materials relative to their effects on impact and thermal shock resistance. During experimentation, briquettes were produced and tempered with materials of varying size and content. These were tested for impact strength using a pendulum test, sampling five briquettes of each particular temper combination. The specimens also underwent thermal shock testing, which took the form of repeated cycles of dousing them in boiling water and ice water. Each test had two stages of degradation noted during the recording process: initial visible cracking and complete shatter of the briquette. Their findings indicate that, of the tempers tested, sand was the strongest and toughest, followed by unburnt shell and finally burnt shell.

Feathers (1989) responded to Bronitsky and Hamer with a sharp critique of their methods and a series of experiments testing burnt shell against sand at a low firing temperature. Feathers advocates the use of a static bend test for accurate and controlled experimentation, and found that burnt-shell temper provides increased strength and toughness against sand temper. The best tests to perform, of course, depend upon the aims of the experimentation and the hypotheses being tested. This difference between aims of temper studies is a main point of Bronitsky's (1989) response to Feathers.

Bronitsky (1989: 591) also draws attention to the relevance of briquettes in general. He questions the adequacy of studying failed pots and fragments when the questions asked centre around the ceramics in use. This is especially relevant to the above issues with the work of Tite et al. (2001), as their study focused entirely on failed pots.

Skibo et al. (1989) looked at organic tempered pottery to test various properties relating to its use and portability. The results of the study suggest that organic tempering represents a trade-off selected by groups in non-permanent settlements, as they 'sacrificed good abrasion resistance and good cooking effectiveness for a vessel that could be transported more easily'. At the same time, they observe that 'organic temper provides several advantages during vessel manufacture. Organic matter in the paste can act as a binder providing more strength to the wet clay and to unfired vessels' (Skibo et al. 1989: 140).

The range of experimental data covering the subject of tempering materials, and their relationship to the clay matrix surrounding them via different testing mechanisms, has influenced the selection of testing and analytical criteria employed in this study. Testing parameters have therefore been tailored to address the general question of whether horse hair could have been considered as an adequate tempering agent. Several of the above sources suggest a correlation between mobile societies and organic tempering, so testing and analysis were correspondingly influenced.

Experimentation

The series of measurements and tests employed in this experimental study aimed to quantify the performance of the vessels relative to their temper type. These 'performance tests' do not necessarily resemble the actual use of the vessels, but rather facilitate the comparison of those with and those without temper. Aside from some dimensional measurements, two other tests will approximate actual use, generating data from which general conclusions about horse hair as a temper can be drawn.

One set of observations that were recorded were of the changes vessels underwent during the firing process. These changes resulting from firing would have affected potters' decision-making processes, for there are direct correlations between altering production techniques/materials and changes in vessel success and usefulness. By recording changes in various dimensions of the vessels, as well as weight, success rate and distortion (if present), the behaviour of the vessels as they are fired can be observed.

Porosity measures have a range of applicability in understanding the use of vessels (Rice 1987: 350–4). In those used for cooking and storing liquids, low porosity is desirable as less of the contents is lost during use. Alternatively, some loss of liquid may allow the bulk of a vessel's contents to remain cooler by evaporation. By testing the porosity in two ways, quick absorption and saturation, a clearer picture of these performance characteristics can be drawn. Saturation demonstrates the effect of horse hair on pore quantity by measuring the full capacity of liquid absorption. The quick absorption test focuses upon the immediate effects of brief immersion, and therefore addresses pore size as well as frequency.

Rice (1987: 359) defines six types of strain that vessels undergo: compression, tension, shear, torsion, transverse and impact strain. Combinations of these, rather than one in isolation, lead to eventual failure. Testing in the project combined shear and tensile strain, as Rice (1987: 358) notes that almost all vessel failures are the result of the two. This comparison may serve as a springboard for later investigations using different measurable forces.

There are three routes that could have been taken in strength testing: actualistic vessel forms, simplified vessel forms or briquettes. Actualistic vessel forms are problematic in a controlled study for several reasons. The curvature of the vessels, variable wall thickness, differential orientation of temper and the presence of random internal structural weaknesses with the vessel walls all obscure and complicate the reasons for vessel failure. Simplified vessel forms may not be as homogeneous as briquettes but are more actualistic and have the benefit of greater homogeneity (and greater control over variables) than actualistic forms. Briquettes may be easily standardized, but they are not actualistic enough. By testing simplified vessel forms a balance is struck between actualism and homogeneity.

Materials

A single clay type was used for all vessels produced, a standard red terracotta clay, which is described as a blend of Etruria Marls. The recommended firing range is between 1080 and 1160C. The horse hair used for temper was collected from the clipped manes of horses at a stable near Beer, Devon. The hair was washed thoroughly in warm water to remove any chemicals. The hair varied in length from less than 1cm to 8cm.

A small terracotta flowerpot served as a mould. The mould was 10cm in height, 7.5cm to the lower edge of the rim which was used to standardize the height of sample pots. Along this edge, the interior diameter was 8.5cm, and at the base the interior diameter was 5.5cm. Following the discussion above regarding the use of a simplified form for sample vessels, the straight sides and simple rim of the mould ensured as much control over vessel attribute variables as possible.

Methodology

Clay for untempered pottery was cut away from the block and then worked to remove air bubbles before it was formed in the mould. In order to add the horse hair, about 1.5g of hair per vessel was worked into the clay to randomize its orientation as much as possible (see Plate 2). The tempered clay was then shaped into a ball for use in the mould. Tempered vessels were constructed in the same way as untempered vessels, though overall the manufacture process was more difficult with tempered clay. After forming, vessels were left to dry for one week.

Weight, base thickness, wall thickness, rim diameter, base diameter and height were recorded prior to and following firing. The vessels were fired directly without the use of a drying oven, in a small gas furnace. By firing in a furnace equipped with a thermocouple and temperature regulation, this study is precluded from testing issues relating to the use of temper as directly related to archaeological firing methods. The furnace used does allow for more consistency between firings, as two separate firings were conducted. Therefore, this study is constrained to claims about vessels fired to 940C, and vessels are comparable between firings as conditions were tracked throughout the process.

Vessels were removed using cotton gloves, in order to avoid affecting the porosity, and allowed to cool to room temperature prior to testing. Saturation mass was measured by immersing vessels for five minutes in a graduated cylinder of room temperature water. Their weight was recorded and then compared to post-firing weight to establish the amount of water absorbed during saturation. After drying to within 0.2 per cent of their post-firing weight, they were retested for quick absorption porosity. To this end, the vessels were immersed for 15 seconds and weighed. This measure was then compared to the post-firing weight to find the quick absorption capacity.

Strength testing was accomplished by applying a static load to create a tensile strain. The vessels were positioned using a clamp at the underside of a table. A second clamp held a bucket in place from the lower side along the rim of the vessel. Sand was slowly poured into the bucket until a complete breakage occurred. The weight of the load was recorded after a complete failure of the vessel.

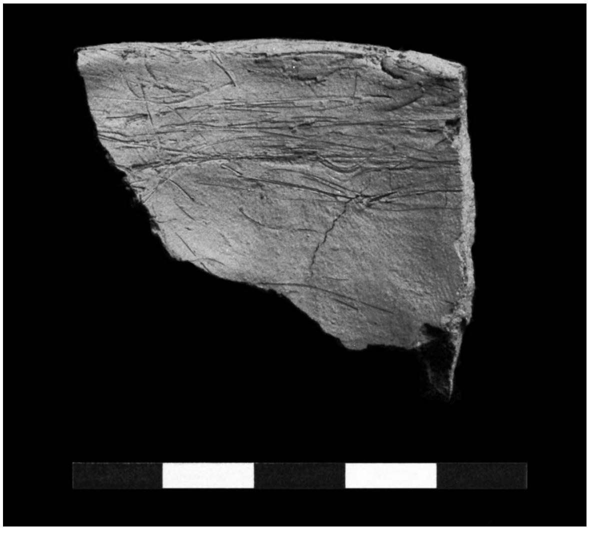

Plate 2 Experimental vessel, showing detail of horse hair temper. (Photo: S. Goddard.)

Observations

The production of the vessels demonstrated a few of the effects of temper upon clay. The hair gave a marked increase in wet strength to the vessels produced, their walls deformed far less during handling between removal from the mould and placement on the drying board. As each vessel had a number etched into its rim while still wet, the tempered vessels felt stronger overall from the moment they came out of the mould. Working the clay within the mould was more difficult, however.

There was inevitably an uneven distribution of temper throughout the clay, which was due to the fact that commercial clay was used and workable directly from the bag. The temper increased the wet strength of the clay to the point of being detrimental to creating vessels in a mould. The only way to have better distribution of temper within the clay would be to integrate the hair into a very wet or very dry clay body.

The drying process was less kind to the tempered vessels than to the untempered vessels. The mouths of many were warped, oblong or egg-shaped along the rim rather than rounded like the untempered vessels (see Plate 3). Additionally, cracks were visible along the rims of many, though these were superficial and would not affect the strength testing. This may also be related to the way in which hair was smoothed down after the excess rim clay was removed. One in particular was not fired as cracks ran along one side of the vessel and would have severely diminished its overall strength if it were to survive the firing process.

Once fired, the tempered vessels were light to handle, but also seemed more fragile. Areas where hair was not distributed evenly enough had become voids with ribbons of fired clay remaining. These thin strips of clay were very delicate and crumbled away on contact, exposing a section of the cavity left from the hair.

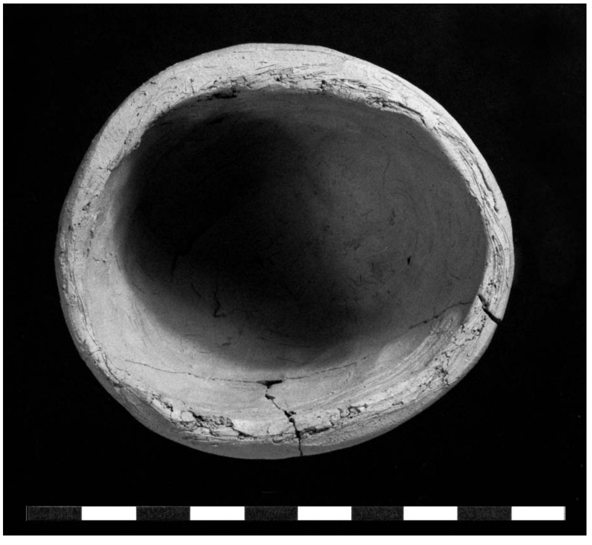

Plate 3 Experimental vessel showing detail of rim shape distortion. (Photo: S. Goddard.)

Results

The results of the experiments were largely as expected. The workability, dimensions, porosity and strength of the clay and vessels all changed with the addition of temper. The tempered vessels had diminished performance characteristics. They were more prone to warping and cracking during drying, were more porous and less strong. These tendencies do not seem to indicate that temper was added for post-production improvements.

The difference in weight between tempered and untempered vessels was a positive alteration (see Table 1), especially when supposing that lighter weight vessels were used by mobile societies. That mobility would be facilitated best by lightweight possessions. Unfortunately the weight change was negligible.

The dimensional measurements made it clear that the careful addition of temper to the vessels was necessary. This would have alleviated some of the problems of difficulty in manufacture. An even distribution of hair throughout the clay body would have prevented warping and cracking. As vessels dry, the water surrounding the clay particles evaporates, first from the vessel surface and gradually from the interior as well. This period of drying can expose many problems for improperly made vessels. The uneven distribution of temper in the sample vessels was indeed detrimental, as it led to differential interior drying. The natural contraction of the clay particles during drying occurred at different rates, and therefore vessels warped and in some cases cracked.

The heightened porosity of the tempered vessels may be desirable in some uses, but overall such an increase in porosity could be considered as a negative trait (Table 2). Though some surface treatment would inhibit this, porous vessels do not hold liquids without allowing them to leach out through the walls. As surface treatments were not the subject of this study, the basic porosity of the vessels and the implications of that porosity cannot be underrepresented. These vessels would have performed poorly for cooking as they would lose their contents more quickly than similar untempered vessels, and would probably have poor thermal shock resistance as voids in vessels tend

Table 1 Mean change in weight of vessels overall and relative to initial mass. Tempered vessels lost proportionally more weight during the firing process than did untempered vessels. Vessels from the second firing tended to lose more weight than those from the first firing, which probably relates to the differences in firing curves. Significantly, the difference in proportional weight change between tempered and untempered vessels is almost identical from one firing to the next

Group	*Mean hair added (g)*	*Mean weight (g)*		*% loss*
		Dry	*Fired*	
U1	0.0	188.4	171.6	8.92
U2	0.0	185.0	166.8	9.29
T1	1.4	177.9	160.9	9.56
T2	1.5	200.6	180.7	9.91

to break down fairly quickly, showing symptoms of thermal fatigue, eventually leading to outright failure.

Just as with cooking, heightened porosity would inhibit the applicability of storage as a vessel function. In the case of liquid storage, the effects are apparent: the contents would leach from the vessels and defeat the purpose of storage. Perhaps equally, dry storage would not be feasible. The porosity of the vessels would allow for atmospheric moisture to reach the contents and potentially cause mildew or rot.

The strength of any vessel is an important characteristic. The tensile and shearing strength of the sample pots was shown to depend on tempering as well as thickness (Tables 3 and 4). It is therefore conceivable that tempered vessels could be produced to have similar strength to untempered vessels, but this would probably sacrifice the weight difference between vessel types. In any case, the strength, as between tempered and untempered vessels, was not terribly different, and for this reason it may not have been a noticeable change to those using the vessels.

The workability of the clay, once tempered, is noteworthy as well. As stated above, the workability was diminished once temper was added, and this definitely contributed to the difficulty in ensuring even distribution of temper throughout the clay. Had the clay been less workable from the outset, wetter and less plastic, working the temper in evenly would have been easier. With even distribution of temper throughout the clay, the drying process would not have produced so many irregularities.

Table 2 The mean saturation and quick absorption capacity of the vessel groups. The two measurements are then related to one another by showing the proportion absorbed during the quick dip compared to the full saturation capacity of the vessel. Contrary to expectations, the results did not show cohesive trends

Group	*Mean water saturation (g)*	*Mean quick absorption (g)*	*Quick dip: saturation (%)*
U1	18.3	9.3	51.22
U2	19.4	10.0	51.83
T1	20.5	12.2	59.72
T2	24.0	12.2	50.86

Table 3 Mean tensile and shear strength. Though the untempered vessels did seem to perform better than tempered vessels (they were on average able to withstand a greater weight), the data from the second firing are fairly close. This does not take into account the effects of wall thickness. A possible solution to this difficulty in expressing strength could be to reference the data to physical characteristics of individual vessels

Group	*Mean breakage weight (kg)*
U1	30.2
U2	29.8
T1	26.1
T2	29.7

Table 4 By combining vessel weight data with the breakage weight data, a 'breakage factor' can be generated. The formula for this is as follows:

$$\frac{\text{Breakage weight (kg)}}{\text{Vessel weight (kg)}} = \text{Breakage factor}$$

The breakage factor shows numerically how many grams of tensile weight are required per gram of vessel weight to cause a complete failure. The behavioural differences between tempered and untempered vessels are clearer as a result. The breakage factor of each vessel was found and then the mean for each group was established

Group	*Mean breakage weight (kg)*	*Mean vessel weight (kg)*	*Breakage factor*
U1	30.2	184.04	0.16
U2	29.8	178.34	0.17
T1	26.1	163.38	0.16
T2	29.7	163.33	0.18

Discussion

The results highlight that various weaknesses of tempered vessels could be compensated for by altering vessel form, or perhaps by applying surface treatments (though this is beyond the scope of this study). So why bother changing clay recipes if compensations must be made for a similar result?

One of the most plausible explanations for such a decision lies within the link between mobile groups and organic tempering. Rather than for post-production characteristics, it is conceivable that temper such as horse hair was added to expedite the production process. The process of preparing clay can be a long and labour intensive one, especially when considering that in many areas clay can be found wet and slightly workable immediately upon collection. Preparing clay from collection to production requires several steps to ensure its quality and consistency of texture. Clays are first collected, and dried if not already dried. They are then broken down, sifted, and then tempered as desired. The result is then mixed with water and allowed to rest so that the water molecules become as evenly distributed as possible. This resting period can last as little as a few weeks, and can extend over the course of several years, depending on the customs.

In the case of vessels that generated the questions for this study, the increased wet strength may be the key to understanding the possible use of horse hair, or any organic fibrous temper for that matter. By altering the clay's properties in this way, it would have enabled more expedient pottery production.

Regardless of this specific example, the potential for creating larger vessels quickly is present when horse-hair temper is used, and probably extends to other types of organic fibrous tempers. Overall, many desirable performance characteristics of vessels seem to be diminished when horse hair is added, so it seems likely that altered workability would be the aim of this inclusion.

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