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The Ethnoarchaeology of Pottery Tempers in the Bolivian Amazon: Two Indigenous Traditions of Paste Recipes with Preparations of Freshwater Sponge, Pottery Sherds, Bone, and Turtle Shell

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ABSTRACT

This article integrates ethnoarchaeological investigations of the pottery *chaîne opératoire* from two research projects conducted with Indigenous peoples of the Llanos de Moxos region in the Bolivian Amazon. Two distinct technological traditions of pottery temper are documented: freshwater sponge temper (*cauixi*) used by Cayubaba potters and ground turtle shell, bone, and pottery sherds employed by Tsimane' potters. Substantial information is provided on the composition of the distinctive tempers and pastes, the origin of materials, and their preparation, careful mixing into different recipes, and appearance in the finished product. Pottery temper and clay paste recipes distinguish the identity of potters within and between technological traditions in the region. Furthermore, this study contributes to the developing understanding of the importance of ceramics in Amazonian Indigenous ontologies. New questions and challenges are raised for the analysis of archaeological ceramics in Amazonia, one of the most culturally and linguistically diverse regions of the world.

RESUMEN

Este artículo integra investigaciones etnoarqueológicas sobre la cadena operatoria cerámica de dos proyectos de investigación desarrollados con pueblos indígenas de los Llanos de Moxos, en la Amazonia boliviana. Se documentan dos tradiciones tecnológicas alfareras con distintos temperantes: esponja de agua dulce (cauixi) utilizada por alfareros Cayubaba y caparazón de tortuga molido, hueso y tiestos cerámicos empleados por alfareros Tsimane'. Estos ejemplos proporcionan información sustancial sobre composición de temperantes y pastas, el origen, preparación y cuidadosa mezcla de materiales en diferentes recetas, y apariencia en el producto final. Las recetas de temperantes y pastas distinguen la identidad de alfareros dentro y entre tradiciones tecnológicas de la región. Además, este

KEYWORDS

Amazonian archaeology; Amazonian pottery; *Chaîne opératoire*; ceramic ecology; *Cauixi*; Tsimane'; Cayubaba; Llanos de Moxos

PALABRAS CLAVE

Arqueología amazónica; cerámica amazónica; *cauixi*; *chaîne opératoire*; ecología cerámica; Tsimane'; Cayubaba; Llanos de Moxos

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estudio contribuye a la comprensión de la importancia de la cerámica en las ontologías indígenas amazónicas. Plantea nuevas cuestiones y retos para el análisis de cerámica arqueológica en la Amazonia, una de las regiones con mayor diversidad cultural y lingüística del mundo.

Introduction

The Llanos de Moxos are a tropical savanna ecological region located in Bolivia in the Department of Beni in the southwestern Amazon River basin (Figure 1). Consisting of more than 120,000 sq km, it is one of the largest flooded savanna complexes in the Amazon and in the world. This region has many significant characteristics. For example, it is considered one of the first centers of early plant cultivation (Lombardo et al. 2020), it is a center of linguistic diversity worldwide (Crevels and Van der Voort 2008), and it currently includes the territory of 50 percent of Bolivia's 36 Indigenous groups (Díez Astete 2011). The Llanos de Moxos contains 14 protected areas, 18 Indigenous territories, and three Ramsar Sites, wetlands of great significance due to their biological and cultural features (Grupo de Trabajo para los Llanos de Moxos [GTLM] 2022b). Due to this diversity, it has been the focus of archaeological research for decades, and for that very reason, we consider it an essential region for ethnoarchaeological research.

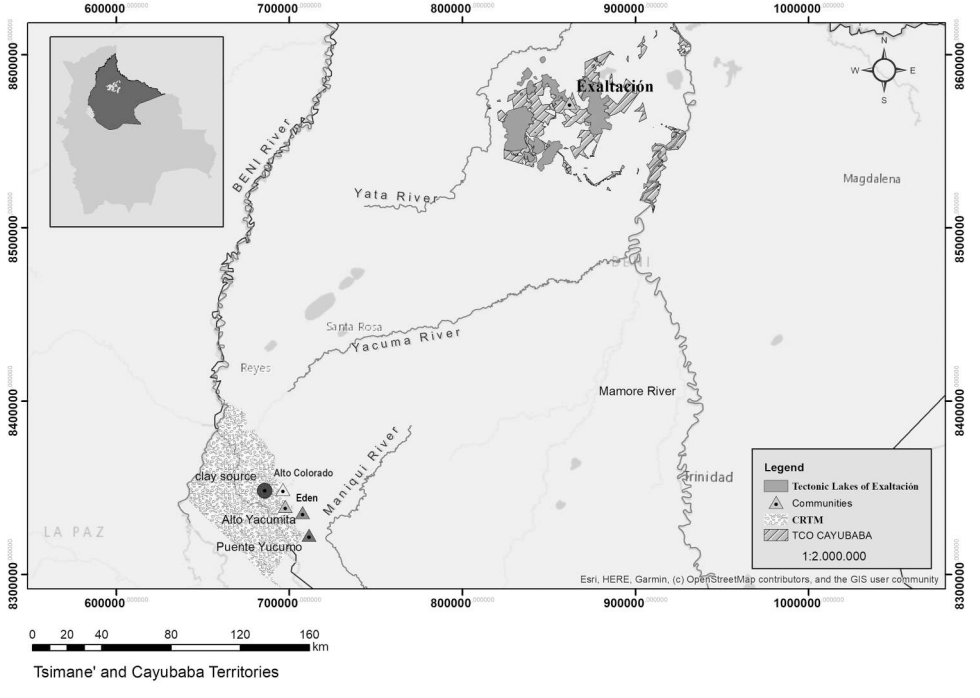

Figure 1. Map of Tsimane' (CRTM) and Cayubaba (TCO) territories. Data sources: Histórico GeoBolivia (2024) and Instituto Nacional de Reforma Agraria (2023), Consejo Regional Tsimane' Mosetén (CRTM) and Tierras Comunitarias de Origen Cayubaba (TCO Cayubaba). Map prepared by: Kodiak Aracena.

Considering its prevalence in archaeological sites, pottery is a privileged object of research in ethnoarchaeology. As shown in a recent review (Silva 2021), ceramics are studied ethnoarchaeologically from many different perspectives to address a wide range of subjects, including taxonomy, morphology, and function, ceramic use-life relationships with ecology, spatial distribution, processes of formation of the archaeological record, standardization, artifact variability, innovation and change, and teaching-learning processes. The same review shows that ceramics also are important in the construction and maintenance of identities, communicating multiple symbolic meanings, and their capacity to embody cosmological understandings and otherness beyond human beings. According to Roux (2016), with the *chaîne opératoire* approach, ethnoarchaeology has become a powerful strategy to support archaeology in identifying specific material traits resulting from actions on materials. For Roux, studying teaching-learning processes at different scales (e.g. individual and collective) helps to make social boundaries more visible in terms of techniques and to reinforce the understanding that *chaînes opératoires* are traditions inherited through generations.

Drawing on the work of Mauss ([1934] 2003), in which each technique is understood as a traditional and efficient act, Leroi-Gourhan developed the concept of *chaîne opératoire*: "Techniques involve both gestures and tools, sequentially organized by means of a "syntax" that imparts both fixity and flexibility to the series of operations involved" (Leroi-Gourhan 1993, 114). This theoretical concept helps archaeologists to address the technological choices responsible for the selection of raw materials and their subsequent transformation into manufactured products. Moreover, this approach provides a versatile methodological tool for describing and documenting the people who conduct technical activities. It requires laborious work, capturing a single event based on the ethnographer's observations (Coupaye 2015) and identifying its material traces. It is important for understanding the dynamic actions of the past based on the static products recovered in the archaeological record, presenting great potential for investigating empirical facts in synchronic and diachronic studies (Roux 2016; Schlanger 2007; Stark 1998). In ethnoarchaeological contexts, it offers a methodological framework for recording the five related components of techniques that Lemonnier (1992) noted: matter, energy, objects, gestures, and specific knowledge. In addition, it can help to clarify the relationships and ethnoconceptions involved in the productive processes and the social characteristics of techniques (Coupaye 2015).

In studies of ceramic production, the concept of *chaîne opératoire* leads archaeologists to obtain, organize, and understand information on how materials have been acquired and prepared through the various stages of the production process, including manufacturing, finishing, surface treatment, firing, use, and disposal or reuse. It also has led to these stages being studied in greater detail.

In the context of the Llanos de Moxos, little attention has been paid to the ceramic *chaîne opératoire*. This gap becomes important given the prolonged decline of pottery craftsmanship and the modern abandonment of technological practices. Thus, this ethnoarchaeological research offers valuable insights into the enduring nature of traditions and their adaptive evolution over time. Especially in the Amazon, where many of the tempers used in ceramic practices were derived from organic materials, studies of these materials and the processing involved will help archaeologists to identify these components in archaeological ceramics, which are notoriously challenging to

discern. An example of such organic temper is *cauixi* (Tupi-Guarani), a temper found in ceramics in the Amazon dating back more than 4000 years (Villagran et al. 2022).

Here, we present the ceramic production of the Cayubaba and the Tsimane' peoples of the Llanos de Moxos (Figure 1). Emphasis is placed on the selection, preparation, and addition of different tempers for the preparation of the clay paste. We consider these materials to have great interpretive potential for thinking about and rethinking the archaeological materials of the region in question. To better understand these important materials in ceramic production, our study also draws on the concept of performance characteristics (Schiffer and Skibo 1997), which allows us to think about technological options aimed at improving the production process and the use of ceramics, considering the specific interactions between people and objects.

Ethnographic work with the Cayubaba people took place within the framework of the Great Tectonic Lakes Expedition (GTLM 2022a). The ethnographic work with the Tsimane' people occurred in 2022, during the first field season of the project, Heritage and Territoriality: Past, Present and Future Perceptions among the Tacana, T'simane, Mosetén and Waiwai. Despite the diversity of peoples in the region, pottery-making activity is conducted only in a few communities, carried out by a small number of individuals, a detail that is addressed below. The corresponding ethical authorizations were obtained from the Wildlife Conservation Society Institutional Review Board, training on research ethics was given to the authors of this article, and formal consent was obtained from the persons mentioned in the article

A Brief Archaeological and Historical Context

The Exaltación area in the Llanos de Moxos holds rich archaeological evidence of pre-colonial occupation, characterized by numerous large raised agricultural fields and monumental sites. Recent studies have shown that approximately 6.4 percent of the region is covered by raised fields, estimated at around 51,500 ha (Lombardo 2010; Rodrigues 2016). Research by Walker (2018) has revealed a chronological framework divided into five phases: an early phase (6000-4000 BCE) associated with sporadic hunter-gatherer occupations, the San Francisco phase (1200 BCE–200 CE) marked by the earliest construction of raised fields, the San Juan phase (400–700 CE) characterized by ceramic styles with *cauixi* temper found in both residential and agricultural contexts, and the Estancia I (700–1000 CE) and Estancia II (1000–1200 CE) phases showing differences in spatial use intensity within and outside circular ditches. The El Cerro phase (1200–1500 CE) is strongly associated with large raised fields; most of the pottery presents ground sherds as temper and few fragments with *cauixi*, especially painted pottery (Walker 2018, 70). Particularly noteworthy is the archaeological site of El Cerro, a rectangular forest island with evidence of human activity, such as dark earth and scattered ceramics (Walker 1999, 2011). The latest phase of El Cerro's occupation coincides with a marked reduction in fire use around 1260–1280 CE (Whitney et al. 2014), indicating a relationship between El Cerro's occupation and the construction of raised fields.

Furthermore, El Cerrito, a rocky outcrop on El Cerro Island that has been recently investigated (GTLM 2022a), stands as the sole known site with stone architecture across the entire Llanos de Moxos region. Its significance in the worldview of the Cayubaba people since missionary times underscores the need for extensive

archaeological inquiry. This suggests a complex narrative of cultural exchanges and alterations in the landscape (GTLM 2022a). The density and diversity of monumental archaeological sites documented in the Exaltación Tectonic Lakes unveil a profound history of landscape transformations linked with diverse cultural settlements, hinting at the region's potential role as a nexus for intercultural interactions (Walker 1999, 2018).

The Tsimane' territory is located in the extreme west of the Llanos de Moxos, in the sub-basin of the Beni River. Archaeologically, there is only a record of habitation sites in the region, although not precisely in Tsimane' territory, and the ceramic chronology still needs to be established. However, research currently is being conducted within the Heritage and Territoriality Project framework. Although there is not much archaeological information for this region, there are important references mainly related to the research of European explorers such as Nordenskiöld (1924) and valuable ethnographic work carried out by Hissink (1989) and, more recently, by Riester (1993).

The Exaltación community, where the ethnographic study of Cayubaba pottery was conducted, and the Tsimane' communities visited for this research are relatively recent settlements, as the region has experienced significant changes since European colonization. Initially, Jesuit missions were established, leading to the concentration and sedentarization of local populations. Following the expulsion of the Jesuits, colonial administration abuses resulted in the dispersion of Indigenous peoples, with many returning to their ancestral territories (Moreno 1888, 134–135).

Toward the end of the eighteenth century, a military government took power in the region, generating conflicts and uprisings among the populations until the nineteenth century, which further impoverished the Indigenous peoples (Moreno 1888). At the same time, although the core of the extractivist economies of the mid-nineteenth century was not located specifically in the savannas of the Llanos de Moxos, the Indigenous labor force did come from there (Vallvé 2010, 293–294), which caused sharp demographic declines and the arrival of a sizeable non-indigenous population in the region (GTLM 2022b, 43).

By the late twentieth century, protected areas and Indigenous territories were officially recognized by the national government under the designation Tierras Comunitarias de Origen (TCO) (GTLM 2022b, 45).

Materials and Methods

Pottery making is dependent on a suitable combination of environmental and cultural factors (Arnold 1985, 2000). Natural resources vary from place to place, including the clay sources, tempering materials, fuel, water, and pigments used in pottery manufacture. A fundamental requirement of ceramic production is the adequate availability of raw materials. In this study, we focus on tempering materials, primarily sponge spicules and turtle shell, as well as bone and crushed ceramic sherds (grog).

To better understand the great diversity of ceramic materials and styles archaeologically recorded in the Amazon and particularly in the Llanos de Moxos, we used an ethnographic approach to document the pottery *chaîne opératoire* of two Indigenous peoples of the region, the Tsimané and Cayubaba. This study explores the potters' choices involved in the first steps of the *chaîne opératoire*, the selection and preparation of clays and tempers, contributing to the identification of raw materials and different steps of the ceramic process in archaeological artifacts. We consider this

an essential aspect of determining specific technological choices of pre-colonial peoples and evaluating the duration of these traditions and their transformations over time.

In the *chaîne opératoire* of Cayubaba potters, the tempering material used is *cauixi*, a Tupi-Guarani term adopted by archaeologists to refer to a freshwater sponge (*Demospongiae* class, *Drulia* spp., or *Parmula batesii*) and ceramic temper made from the sponge. The sponge is found attached to tree trunks or branches in the form of "balls of thorns" ("bolas de espinho" in Portuguese or "bolas de espinas" in Spanish). Freshwater sponge is common in Amazonian blackwater rivers, which are characterized by very high acidity as a consequence of their organic compounds, as well as in lakes and small streams (see Barreto, Pinto Lima, and Jaimes Betancourt 2016, 557). But what happens when the rivers are not black and the *cauixi* is not a local natural resource? This is the case, for example, in the Beni, Maniqui, and Mamoré rivers, where *cauixi* is absent from the natural environment, and other types of pottery tempering agents are recorded in this study. This is true in the case of the pottery *chaîne opératoire* conducted by the Tsimane' people, among whom we recorded the use of turtle shell mixed with ground pottery (grog) or ground bone as tempering materials, where freshwater tree sponge is absent from the natural environment.

Case Study 1: Cayubaba Use of *Cauixi* as a Tempering Material

The Cayubaba are Indigenous people of the Yacuma Province in the Department of Beni, Bolivia. Their language forms an unclassified or isolated linguistic family whose name has been self-assigned (Díez Astete 2011, 246). A large part of the Cayubaba population is concentrated around the town of Exaltación, where they share territory with Chácobo and Movima families. The main economic activity of the Cayubaba is agricultural production, but they are also known for producing other products such as Cayubaba tobacco, *chivé* (Sp.) (an unfermented typical Amazonian drink made from cassava flour), wooden canoes, wheels, and furniture, plant fiber, cotton fabrics, and ceramics (Díez Astete 2011, 244).

Freshwater sponge is used as a temper in Cayubaba ceramics. Better known as *cauixi,* as already mentioned, the sponge, when observed under a binocular lens, shows large siliceous spicules called megascleres by specialists (Volkmer-Ribeiro and Viana 2006). These spicules look like small, elongated rods with sharp points resembling smooth and polished hyaline rock crystals (Hilbert 1955). The freshwater sponge temper in ceramics can also be identified by touch, as it makes the surface of the ceramic rough and irritating to the skin, a characteristic that gives it the name *cauixi*, a term of Tupi-Guarani origin meaning *mãe da coceira* in Portuguese, which translates to "mother that itches" or "mother of itching" in English (Volkmer-Ribeiro and Viana 2006, 311).

The use of *cauixi* in ceramics contributes to uniform firing due to pressure absorption, increasing resistance to thermal shock and impact (Machado 2005-2006; Natalio et al. 2015). Comparison between archaeological ceramics with and without *cauixi* indicated that ceramics including it had higher porosity (Rodrigues 2011). This is a typical Amazonian temper found in profusion in most of the ceramic complexes of the region in acrosschronological periods, even in one of the oldest Amazonian ceramic traditions, as demonstrated by recent petrographic analyses for the Monte Castello

pottery of the Bacabal phase dating to 2050 BCE in Rondônia, Brazil (Villagran et al. 2022). In this respect, the presence of *cauixi* as a useful constituent to define traditions or temporal transitions in pottery technologies was already highlighted by Lathrap in the early 1970s, when he identified "sub-traditions" from the Polychrome Horizon in Central Amazonia (1970, 155–156) and associated *cauixi* with traditions related to Carib expansion (1970, 165).

There is information showing that some peoples used *cauixi* as a tempering material until the first half of the twentieth century (Métraux 1948; Willey 1949). Currently, however, there are a few potters producing ceramics with this temper, including potters in Waujá communities in the Xingu River region (Barcelos Neto 2005-2006) and Cayubaba potters of the Llanos de Moxos, such as Mrs. Eulogia Quiroz Landivar.

Ethnography of the Pottery Chaîne Opératoire in Exaltación with Eulogia Quiroz Landivar

The town of Exaltación, home to approximately 1000 inhabitants, was visited during the six-week expedition to the Great Lakes of Exaltación (GTLM 2022a). Mrs. Eulogia Quiroz Landivar was interviewed on two occasions, while she was making pottery in her open-air workshop. Interviews were conducted without the participation of other people, except for brief interventions by Mrs. Eulogia's husband. The only phase not documented was the firing, because it was scheduled for a later time, which limited direct observation, allowing only questions related to this last process. Interviews were conducted in Spanish, filmed, and audio-recorded.

Currently, apart from Mrs. Eulogia, only one of her aunts knows how to make pottery. However, only Mrs. Eulogia is now dedicated to pottery production, because her aunt has poor health. Mrs. Eulogia mentioned that there used to be many people who knew how to make pottery, but that generation has passed away, and no one else in her community is interested in this activity. Nevertheless, we observed that her granddaughter was playing with the clay during the whole process, making miniature pots.

During conversations with Mrs. Eulogia, she only mentioned women as the people who produce ceramics, and in the teaching-learning process. At some point, when her husband participated in the conversation, he did not mention that he performs some tasks of pottery-making and rather refers to her when describing the different steps of the process. According to Mrs. Eulogia's narration, however, men may help throughout the pottery-making process, when collecting materials or during firing, for example, but it is apparently a technical tradition maintained primarily by women, as she repeatedly mentioned her grandmother, mother, and aunts as the potters in the family.

Preparation of the paste: According to Mrs. Eulogia, the clay she uses comes from the streams near the Mamoré or Iruyañez rivers. The Mamoré River is located approximately 1.5 km from Exaltación, although Mrs. Eulogia could not tell the exact distance from town to the clay source. She looks for black clay, clean and without roots. Depending on the place, the good black clay might be at a shallow depth or very deep, which requires deep digging. After it is collected, the clay is left to dry for two or three days and then pounded and ground using a stone batan (*batán* [Sp.]) (Figure 2a) obtained from one of the hills near the Beni River. Although the hills are about 200 km from

Figure 2. (a) *Batán* stone. (b) Metal sifter or *urupe*. (c and d, respectively) *Cauixi* collected and burned. (e) Mrs. Eulogia preparing a thick band of paste to form the neck of the vessel. (f). The neck. Photo credits: Carla Jaimes Betancourt.

Exaltación, Mrs. Eulogia considers them "nearby hills." Once ground, the clay is sieved through an *urupe* (Sp.), an elongated metal sieve (Figure 2b).

Cauixi, or "fish dung" (*bosta de pescado* in Sp.) as it is known locally, is used as a tempering material. These freshwater sponges are attached to the branches of trees in rivers, streams, or ponds, and can be collected only during the dry season (July to September) when the water level drops. According to Mrs. Eulogia, there are several different types of *cauixi*, but she chooses the elongated ones (Figure 2c), because other types have more thorns and are therefore, according to her, useless. Mrs. Eulogia stated that the porosity that *cauixi* causes in the preparation of the clay paste helps the fired vessels to keep liquids cold, but *cauixi* also can be used to make pots for boiling and cooking food.

The *cauixi* requires treatment before adding it to the clay. After removing the sponge from the branches where it is attached, a bed of firewood is prepared and the sponge is placed on top. When the sponge comes into contact with the fire, it decomposes into fine sand, and then the thorns are released. This step is essential since, in its natural state, this material is "very itchy" and cannot be handled easily. Once burned, and after the sponge has cooled, the ashes of the firewood and fragments of the charred stick are gently blown

away from the sponge. This prevents the *cauixi* from mixing with other materials to keep it clean so that it can function well as temper (Figure 2d). Once cleaned, the *cauixi* is crumbled by hand or in a wooden mortar (*batán* or *tacu*) to obtain a whitish or grayish powder. Mrs. Eulogia mentions that the *cauixi* also may be yellowish or orange, depending on the combustion.

After grinding the clay as discussed above, it must be sifted well and mixed with the clean *cauixi* powder, which must be weighed and mixed in correct proportions with the clay. The choice of the type and quantity of tempering material to be used will depend on the type of vessel to be made or its intended use. According to Mrs. Eulogia's grandmother's recipe, for small vessels the *cauixi* constitutes one-third of the materials necessary for the preparation of the clay paste; for a jar, two *arrobas* (Sp.) of clay (approximately 50 pounds total) are needed for one *arroba* of *cauixi*. When making large pots to prepare corn chicha (a fermented beverage), or *chivé*, a greater amount of *cauixi* is required: a ratio of one-to-one with the sifted clay is required, because, by including more *cauixi*, the fired piece will have greater hardness, which is necessary for using the pot on the cooking fire.

Mrs. Eulogia assures us that, once the paste mixed, it will be necessary to knead the paste by hand at least three times in 15 days before using it. This will give the vessel a shiny surface and prevent the paste from coming off when she is shaping the pottery piece.

Forming the vessel. For the manufacture of the vessel, long, thick coils of clay paste are rolled out and joined together, using the most common modeling technique: hand modeling. A coil is a long mass of paste rolled between the hands or on a flat surface. The width and length of the coils will depend on the size of the vessel (diameter, height, and wall thickness) being made. The thickness of the walls also depends on the intended use and will vary according to the section of the vessel being made.

As the coils are joined by applying pressure with the hands, the walls of the vessel are formed and smoothed using a *marlo* (Sp.) or corn cob (Figure 3a), repeating the action until the vessel is built into the desired shape and height. The cob is held with one hand, while the walls of the vessel are handled with the other. If force is being applied with the cob on the exterior of the vessel wall, the hand is placed on the interior of the vessel holding the walls or vice versa. The cob naturally leaves impressions, which are then obliterated by smoothing the surface with a small scraper made from a piece of a gourd or calabash such as *Crescentia cujete* (Figure 3b). This technique stiffens the surface while compacting the paste and reducing permeability, as the inclusions are aligned parallel to the wall (Druc and Velde 2021, 173).

Surface treatment. With the vessel formed and left to dry, Mrs. Eulogia smooths the surface again with the *tutuma*. The vessels then must dry in the sun for three days. It is therefore important to model the pottery on sunny, rain-free days. Once dry, the vessel is burnished using a basalt stone. The stone used by Mrs. Eulogia belonged to her mother. She does not know where her mother brought it from because the basalt is not available near her mother's town, but she mentions that it can possibly be found in the Rurrenabaque area (a straight-line distance of 280 km away).

Firing. As mentioned above, we did not observe the firing process because it was scheduled for a later time. Mrs. Eulogia explained that the firing process takes five hours and the preferred firewoods are *pacae* (*Inga feuilleei*, also known as ice cream bean in English), *caricari* (*Acacia bonariensis*, commonly known as cat's claw in

Figure 3. (a) Primary surface treatment using a corn cob. (b) Secondary surface treatment using a *tutuma* or *matato* scraper. Photo credits: Carla Jaimes Betancourt.

English), or *zama* (Sp.), also known as *negrillo* (Sp.) (*Nectandra megapotamica* with no common name in English). She says that all of these are strong woods that allow the embers to develop. Firing begins with the production and control of the embers; therefore, if the selected wood is not suitable or the embers are not well managed, the pots will break during the firing process.

The brick oven for firing pots is a permanent, closed, round structure built at one side of the potter´s backyard. At one end of the brick oven, firewood is burned and the embers are accumulated. At the other end, pots are placed on wooden boards or ceramic support. The embers are kept burning for at least three hours. To determine when the embers are ready, cow dung is placed inside the oven at the start of the firing process. As soon as the cow dung begins to blacken and smoke, the temperature is right to bring the pots closer to the embers.

Gradually, large chunks of charcoal from the fire are introduced into the oven. The pots are then brought closer to the embers. Once the pots have acquired a reddish color, they get covered with firewood, which should be placed quickly, preferably by two people, so that the fire burns evenly. It takes about half an hour to burn, for the pots to be fully fired. Mrs. Eulogia's husband usually helps her during these steps, and she recalls that when she was young, she helped her mother and grandmother in the firing process. Mrs. Eulogia also clarifies that her grandmother used to fire the pottery in the forest so that no one could see the pots. According to Mrs. Eulogia, there is a Cuyababa belief that pregnant or jealous people can damage the pots during firing. Today, she is not concerned about firing the pots in full view.

Although, the manufacturing and use of ceramic vessels are not as frequent as in the past, Mrs. Eulogia continues to produce ceramics throughout the year, even fulfilling special orders. Her ceramics are both sold by made-to-order requests and marketed at fairs that take place in various locations, including Santa Cruz, San Joaquín, San Ramón, Santa Ana, Trinidad, among others. This means that her ceramics reach a remarkable distribution, reaching distances of more than 200 km from the town of Exaltación.

Over time, the shapes of the vessels have changed. In the past, large vessels were made to contain liquids and keep them cold; this has changed now that people have freezers or refrigerators as well as metal and plastic barrels to store water. The preferred shapes today are globular or tall-necked pitchers, platters or dishes with pinched decoration on the inner and outer rims, and small gourd-shaped vessels (Figure 4).

As the vessel forms vary over time, it is plausible that the techniques and handling of *cauixi* have undergone effective adjustments to facilitate its manipulation. For example, no precise information is available about when *cauixi* began to be fired as part of the manufacturing process. The only ethnohistoric records that provide details on the use of *cauixi* in the production of ceramics in the Llanos de Moxos come from a description by Eder in the eighteenth century:

> " … a certain dry material, of a dark color, which covers the branch of the tree … it is like a porous sponge and full of spikes, very fine but quite long. The Indians cut it with the branch, burn it, and reduce it to ash" (Eder 1772 [1985], 68; translated from the original Spanish by the authors).

Perhaps, some potters in the past chose not to fire the *cauixi*, or burned it incompletely, which could explain the presence of intact spicules in microscopic sections that do not appear to have been exposed to heat and have longer spicules. In this context, it is plausible that alternative methods were employed to release the spicules, hypothetically, such as allowing the sponge to decompose in a water-filled container. In this way, the spicules could be deposited at the base in the form of fine sand.

To discern variations in the various archaeological and ethnographic traditions, it is necessary to conduct specific research on the various spicule species. This would allow

Figure 4. Modern shapes of Cayubaba pottery. Left to right: Globular tall-necked pitcher; round pot with short neck and pinched decoration on the rim exterior; and small gourd-shaped pot.

us to obtain a more precise understanding of their dimensions and properties, given their variable morphology. In addition, this analysis would help to determine the modification that these spicules may have undergone.

Case Study 2: Tsimane' Pottery Temper from Turtle Shell, Ground Bone, and Ground Pottery

The Tsimane' people, with a population of approximately 7000 people, are known for their high levels of autonomy and monolingualism. Despite access to industrial products, local production of household objects and items for sale is still a common practice, especially baskets. In recent decades, pottery production has experienced a notable reduction, influenced by the prevalent use of plastic and aluminum containers. As a result, knowledge about the practice of pottery production, *puñuj tsimdye*' (Ts.), is currently reduced to the memories or experiences of very few people, sometimes one or two people in each community. Knowledge of pottery-making is retained by both men and women who, even without being pottery producers, have memories of what they observed, heard, or learned from their mothers or grandmothers. Documentation of this *chaîne opératoire* was only possible through the collection of information and materials in four Tsimane' communities: Alto Colorado, Eden, Puente Yucumo, and Alto Yacumita. Tsimane' communities range in size from seven or eight families to more than 90 families. There are fewer than 10 families in Alto Yacumita, 15 families in Eden, around 90 families in Puente Yucumo, and more than 90 families in Alto Colorado.

This ethnographic study was conducted with the participation of two Indigenous researchers, Juan Gabriel Supa and Cupertino Hizta, as part of the project, Heritage and Territoriality: Past, Present and Future Perceptions among the Tacana, Tsimane', Mosetén and Waiwai. The main objective of the project is to document and analyze the complexities of the cultural heritage of Tacana, Tsimane', Mosetén, and Waiwai Indigenous peoples and its relationship to their perceptions of time, space, local knowledge, and the defense of their territories. In this context, during the 2022 field season, one of the activities carried out was the recording of the *chaînes opératoires* of those materialities that the Tsimane' people consider of cultural importance to them and for the next generations. The objects most represented in the study communities were those related to basketry because they are an integral part of Tsimane' daily life and activities. However, the communities also brought attention tothe objects that have been replaced by industrial objects in recent decades, whose production is sometimes in the hands of a single family or individual with the necessary knowledge in a community. This was the case with pottery.

In the four Tsimane' communities that we visited during the 2022 field season, we held initial community meetings to discuss our project. Further interviews were planned during these initial meetings. On all occasions, community members suggested the people whom they knew had knowledge about pottery making. On no occasion were they themselves the ones who mentioned that they had this knowledge, but once mentioned by other members of the community, they willingly agreed to participate in the activity. The appointment for a follow-on interview was usually made for the day after the community meeting.

In the four communities, only two people knew the exact location of clay sources: Mr. Mariano Lero Apo and Mr. Javier Apo Lero, both over 60 years old and community members of Alto Colorado. They also remembered collecting and processing temper materials, particularly to produce the turtle shell powder, and mixing the tempers with clay. Three women had more detailed memories about the production process because they had made pottery when they were young: Mrs. Dolores Nate Vie (85 years old) in the community of Eden, Florinda Quete Cuata (68 years old) in Alto Yacumita, and Rita Nosa Vies (77 years old) in Puente Yucumo.

Of the five people interviewed, none currently produce ceramics as part of their daily routines. In fact, two of them, Mrs. Dolores and Mrs. Florinda, last made pottery more than 40 years ago. Therefore, it was of great importance to carry out this ethnographic work using the method of life stories (Bertaux 1999; Cornejo 2006). In most cases, the participants had to think back to their childhood and adolescence memories, because their mothers or grandmothers were the people who were engaged in pottery making. Structured interview questions were important, especially in relation to the details of the *chaîne opératoire*. These were prepared in advance in the form of a questionnaire. Informal unstructured interview questions arose as a task was carried out or specific themes emerged in the interviews. In the case of the interviews with the Tsimane', the participation of an interpreter was essential, since it is not common for older people, especially women, to speak Spanish. The interviews in the different Tsimane' communities aroused such interest that in all cases the families gathered to listen to the potters' stories.

In the case of Mrs. Dolores, we agreed not only to conduct the interview but also for her to produce ceramics. The research team was responsible for providing the materials, including clay and tempering materials, specifically turtle shell powder and potsherds. We had managed to gather these materials days before in Alto Colorado, where we tried to make pottery with Mr. Mariano and Mr. Javier, who not only remembered the location of the clay source, but also some details of the recipes used by their grandmothers several decades ago. We were not able to produce ceramics with the recipe they remembered, but they gave us the leftover materials, which we then brought to Mrs. Dolores in Eden.

We received the pottery fragments from the villagers of Alto Colorado when they heard that we were interested in learning about their ceramic production techniques. They indicated that these fragments are usually found on the banks of an arroyo known as Arroyo Colorado. However, since ceramics have not been produced in the community for several decades, it is becoming increasingly difficult to find pottery sherds.

The women contacted in the other three communities who had knowledge of the pottery process did not have the necessary materials nor access to them, or they had some other impediment, and therefore were unable to carry out the tasks of collecting raw materials for making pottery. All the interviewees mentioned as a common reason for the abandonment of the pottery practice the distance to the necessary materials and the difficulty in obtaining them, particularly clay and potsherds for grinding to prepare the right temper. Nevertheless, all the interviews conducted with Tsimane' community members allowed us to gather valuable information about the materials used by the Tsimane' people in pottery production, as well as the main sources of

materials, the cosmovision, and the community, family, or individual similarities and differences in the practice.

Chaîne Opératoire – Turtle Shell, Grog, and Bone as Tempering Materials

The clay (*potso'* in Tsimane') used in this process is white. The source is located 10.5 km in a straight line from the community of Alto Colorado, which is equivalent to a 12-hour walk roundtrip. Although there are ethnoarchaeological studies that indicate the majority of clay sources are usually located close to the pottery communities (e.g. Arnold 1985, 1993; Wai Wai and Jácome 2021), there is information from Amazonian contexts in which the distance to clay exceeds 10 km (Silva 2008), ranges from a few minutes' walk to 50 km (Bowser 2005, 26), or averages up to 30–40 km (DeBoer and Lathrap 1979; Rostain et al. 2014). Therefore, as we were able to record in this research, the distance to clay sources is a highly variable aspect of pottery production in Amazonia, consistent with previous findings (see also Arnold 1985; Druc 2013; Villanueva Criales 2014, 20). The rest of the materials involved in the pottery-making tasks depend mainly on the availability or access that each community has to them.

Clay collection can be carried out during any season of the year, and it is generally the men who are in charge of this task. The economic activities of Tsimane' families are conducted at the nuclear and extended family levels. Therefore, it was reported during interviews that the men involved in the supply of raw materials for pottery making were relatives of the potters. It was also mentioned that they took advantage of hunting, fishing, or resource gathering trips to collect the materials needed for the pottery-making task. The trade or sale of raw materials was not mentioned in any of the interviews conducted. One aspect that is extremely important is to comply with behavioral norms so as not to offend the clay, such as behaving respectfully on the way to the clay source and having no sexual relations beforehand. These prohibitions reflect the Tsimane' people's ontological relationship with ceramics.

In the 1970s, Jürgen Riester (1993, 246) documented traditional oral narratives that addressed the origin and relevance of clay and pottery in the Tsimane' worldview. The first narrative highlights the importance of the use and care of ceramic pots and clay: he was told that there was a man, known as Kanchi (a Tsimane' surname) who found a clay pot abandoned by its owner. Taking a stick, he struck the jar. It was not until after two or three blows that the jar finally broke, and it had ears and a mouth, similar to humans. Two days later, the owner of the jar died. According to the belief, the clay has an owner: ancient beings who get angry when someone discards a jar. Tsimane' people insist on taking good care of it, avoiding the waste of clay. Another narrative relates the use of palm leaves to make organic pots in the past, until a man was killed and subsequently transformed into clay, thus teaching people the skill of making pots (Riester 1993, 333–334).

In the ethnographic case study that we conducted, this white clay is found beneath red clay on a hillside (Figure 5a). The white clay is used for pottery making because the red one contains impurities such as plant matter, soil particles, and other intrusive elements. After removing the red clay by hand and reaching the white clay, lumps of white clay are collected by hand, carefully cleaned to remove any small bits of vegetation or other inclusions, and briefly kneaded before being wrapped in banana leaves for transport

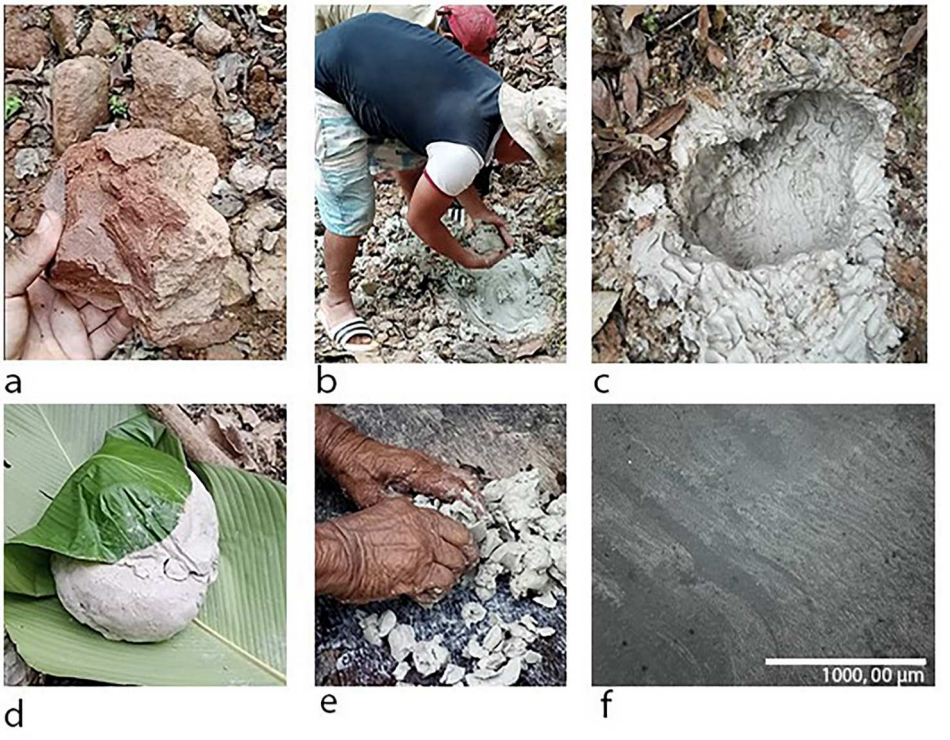

Figure 5. (a) Red clay that overlies the preferred white clay on the hillside; (b-c) white clay being collected by Cupertino Hizta; (d) clay being wrapped in a banana leaf for transport; (e) the clay being pulled apart by hand to make sure it is clean; (f) microscopic view of the clay before tempering material is added (Digital Microscope VHX Eyence VH-Z100UR, RZ x 100 – x 1000 Universal zoom Lens). Photo credits: Cupertino Hizta (a), Juan Gabriel Supa (b–d), Lesly García (e), and Mike Lyons (f).

(Figure 5b–d). Apparently, this was the main source of clay used by many potters in the past, and people from two other villages further away knew of the Alto Colorado as a source of clay, despite the long distances.

Of the five Tsimane' potters who were interviewed, only Mrs. Florinda Quete from Alto Yacumita mentioned soaking the clay as a particular step in clay preparation. She said that her mother used to soak the clay before mixing it with tempering materials. The rest of the interview participants emphasized the importance of kneading the clay at the time of its collection and when beginning to mix it with the tempering materials.

The tempers used by the Tsimane' potters consist of ground pottery (grog) or *cafuntacdye'* (Ts.) and ground bones or *jin* (Ts.) These are used together. The bone component can be made from either the shell of a river turtle (*Podocnemis expansa*) (Conservation Internacional Bolivia 2023) known as *quijbó* (Ts.) or cow bones. Mrs. Florinda from Alto Yacumita stated that her mother used only ceramic sherds, usually obtained from the margins and bottoms of nearby streams or from recently broken pots at home. Given this information on the use of animal bones as temper, we suggest that the bones used for pottery in the past also could have been from tapir or *anta* (Sp.), deer, or other animals. The utility of these bones may help explain why, in

zooarchaeological studies, the long bones of these animals are not commonly part of the archaeological record in the region (Mannert 2015; von den Driesch and Hutterer 2012).

The turtle shells used in the preparation of the paste are accumulated by people in their homes, and it is common for the Tsimane' to keep the bones of many of the animals they consume. Riester also collected information on the preservation of the bones of hunted animals, especially tapir or *anta*. According to Tsimane' beliefs, these bones should be preserved and, when enough have been collected, they are wrapped in leaves, tied with some fiber, and thrown into the river to prevent the *anta* from escaping when it enters the water during the next hunting season. The bones should be buried to ensure that there will be more animals to hunt (1993, 508). In the particular case of the turtle known as *peta* (Sp.), it is found in the forest during the dry season, mainly between the months of July and September. Although there are several ways to prepare *peta* for consumption, one is to remove the meat from the shell in such a way that the shell can be kept for future use.

The turtle shell temper was prepared by two men in Alto Colorado, Mr. Mariano and Mr. Javier. The process of preparing the turtle shell begins by scraping it with a knife to remove any dried meat that may have remained after consumption (Figure 6a).

Figure 6. Turtle shell temper preparation process. (a) Scraping the turtle shell to remove any bits of dried meat. (b) Heating the turtle shell to soften it before removing the scutes. (c) The charred shell after being placed near the smoking embers for about an hour to dry, which facilitates the crushing process. (d) Crushing the shell. (e) Turtle shell powder after crushing. (f) Microscopic view of turtle shell tempering powder (Digital Microscope VHX. Eyence VH-Z100UR, RZ x 100 – x 1000 Universal zoom lens). Photo credits: Juan Gabriel Supa (a-c), Lesly García (d), Carla Jaimes (e), and Mike Lyons (f).

Subsequently, the shell is placed near the fire, to soften the scutes for easy removal from the inner and outer surfaces of the shell (Figure 6b). Once the scutes have been removed, the shells are placed once more near the fire. This will allow the potter, or another person in the household who assists in the task, to grind the shell with ease (Figure 6c and d). The *tacu* (Sp.), a wooden mortar usually utilized for grinding food, is used for grinding the roasted shell. The *tacu* is first used uncovered, but when the turtle fragments have been ground to small fragments, the *tacu* is covered with a cloth to avoid losing the small pieces when pounded. Once the shell is ground well, it is sieved with a cloth to obtain the fine turtle shell powder (Figure 6e and f).

Mrs. Dolores uses the same amount of clay as tempering materials. Turtle shell powder mixed with ground ceramic is her preferred combination. If the turtle shell powder is insufficient or unavailable, ground bone is used (Figure 7a). According to Mrs. Dolores, the ground pottery is as important as the turtle shell powder, because the mixture is essential in the drying and firing process.

After washing her hands and because she does not have enough turtle shell powder at that time, she proceeds to combine large, fragmented bones, previously burned, with ceramic sherds, making sure the bones and sherds were clean and free of dirt. To begin the task of mixing the clay paste, a clean surface is needed, such as a board used by Mrs. Dolores that was made from the trunk of a *cachichira* (Sp.) tree (*Sloana obtusifolia*). The use of this tree for this purpose is mentioned in Erland Nordesnkiöld's ethnographic studies more than a century ago (1919, 78).

Placing the bones and sherds on the *cachichira* wooden board (*ta'ta' shesherenaj* in Tsimane'), she uses a small stone to pound the fragments into smaller pieces, which she then crushes with a larger, heavier stone, similar to a semi-flat *batán* stone. She moves the stone back and forth over the surface of the *cachichira* slab, without lifting it, using her own weight to grind the fragmented bones and ceramic sherds, until a fine powder is obtained (Figure 7b–d).

The ground bone and ceramics are sieved twice. The fragments remaining in the sieve are ground once more until sufficient powder is obtained for mixing. Once the tempering material is ground, it is mixed with the clay, the paste is kneaded continuously, and water is added in small quantities until it is absorbed. While this task is being completed, Mrs.

Figure 7. (a) Bones and pottery sherds burned before grinding. (b) Mrs. Dolores grinding bones and sherds with a stone. (c) The mixture is sieved twice. (d) Grinding the mixture with a stone *batán*. Photo credits: Cupertino Hizta (a) and Lesly García (b-d).

Dolores constantly cleans the work area to prevent the bone dust or clay from getting mixed with dust or sand. The paste is ready when it has a homogeneous gray color and no longer sticks to the fingers or the surface of the *cachichira* slab.

Forming the pot: Mrs. Rita, who is from Puente Yucumo, told us that they used to make large pots for chicha and cooking meat, and smaller pots were made for cooking other foods. Mr. Mariano told us that chicha was kept mainly in clay pots, but also in containers called *ojtuj* (Ts.) or *ojdoj* (Ts.) made of palm leaves. Mrs. Dolores recalled that her great-great-grandmother made large pots, pitchers, plates, bowls, and cups.

The first attempt to form a pot was made in Alto Colorado, with Mr. Mariano and Mr. Javier. Although they had never practiced this task before, they had memories of the techniques of their mothers and grandmothers. Perhaps due to this lack of experience, the pots cracked before drying. The materials left over from this first attempt were taken to Eden, where a new attempt was made by Mrs. Dolores. We documented the manufacture of a pitcher, called *puñuj* (Ts.) (Figure 8).

Beginning with very wet hands, Mrs. Dolores makes balls of clay the size of her hand and hits each one between both palms, passing it from one hand to the other to flatten it to start forming the base. She flattens the top of the clay ball by pressing on it with the bottom of a calabash or gourd bowl known as a *tutuma* (Sp.) or *erepaj* (Ts.). She then turns the bowl over and places the clay onto the base of the bowl (Figure 8a).

Figure 8. (a) A calabash bowl (*tutuma*) is inverted and used as a working surface to form the base of a new pottery jar. (b) A ball of prepared clay paste has been hollowed out to form the bottom of the new pottery jar. (c) Placing a flattened coil to form the middle section of the jar. (d) The lower portion of the jar. (e) Finishing the upper part of the body before building the neck. (f) The neck. Photo credits: Lesly García.

Mrs. Dolores begins to form the vessel by hollowing out what will become the bottom of a jar, making an opening with her thumbs in the center of the clay mass, pulling outward, while guiding the exterior with her other fingers, shaping the walls of the bottom of the jar (Figure 8b). Then, the rest of the paste that has accumulated in the bottom of the jar is flattened, spread evenly, and pressed into the interior surface of the walls, while applying continuous finger pressure on the outside to avoid deforming the vessel.

To begin smoothing the surfaces, Mrs. Dolores carefully washes her hands with water. The shell of a freshwater mussel (Unionidae family), approximately 6–8 cm in length, is used as a tool throughout the rest of the process. With this shell, she starts the process of smoothing the exterior surface, working from the bottom of the pot upwards. After repeated movements, she scrapes off the clay paste that has accumulated on the shell and on her hands. The remaining paste is set aside for making coils for the rest of the vessel.

After removing the paste residue from the shell and her hands, Mrs. Dolores rinses everything again with clean water from a bowl. It is important to replace the water in the bowl with clean water when it becomes soiled by the particles of clay. Likewise, it is important to continue rinsing her hands and materials being used. Once the tool is clean, Mrs. Dolores starts working on the interior of the jar, steadying the outer walls with one hand and smoothing the interior surfaces with the shell tool. Once the base is smoothed on both surfaces and there is little build-up of clay paste in what will be the center of the base, she lets the piece dry for about 15 minutes, then wets her hands again, smooths both surfaces again, and lets it dry for another 15 minutes. Each time she finishes smoothing the surfaces, she leaves the piece in the sun to dry and works on making more coils to build the next section of the pot.

Mrs. Dolores scrapes the clay from the worktable with the same shell to avoid wasting the clay and to keep the surface clean, then begins the coiling process (Figure 8c and d). This technique consists of preparing coils by rolling clay paste on the work surface and flattening them slightly. The flattened surface is joined to base, building the lower body by placing coils sequentially on top of the base, adding layers of coils on top of each other, while smoothing the seams until they are no longer visible and a smooth surface is achieved. The vessel is given a spherical shape until it reaches the part where the neck will be built. From this point on, Mrs. Dolores makes thicker coils that will be added to become the high neck for this vessel (Figure 8e and f).

As it dries, some parts of the vessel begin to crack, and Mrs. Dolores adds more paste to cover the cracks, hoping the vessel will be able to resist cracking and breaking as it dries. She mentions that the cracks might have occurred because the turtle shell powder we obtained and had brought was not fully calcined since the color should be whitish but instead was reddish. She clarified that if the turtle shell is not well calcined, the powder obtained from the grinding is not as fine and uniform as it should be. Once the neck of the jar is in place, Mrs. Dolores trims the irregularities of the rim using the same shell tool. The same steps and use of the same tools were described by the other interviewees.

Surface treatment. During interviews conducted in Alto Colorado, Javier Apo Lero explained that the pottery is smoothed with a shell to take advantage of the designs it

leaves when the potter wets the pottery piece and goes over it with the shell to leave an impression on the surface of the vessel. He believes that in the past, red clay could have been used as a slip to color the exterior of ceramic vessels, immediately after firing. Although he did not know the process of obtaining the color, he supposed that the red clay could have been used as slip because today Tsimane' people dye cotton using red clay, as well as avocado leaf, the *bi* apple or *jagua* (Sp.) (*Genipa americana*), urucú or achiote (*Bixa orellana*), and mahogany or *mara* (Sp.) (*Swietenia macrophylla*), and other plant materials. Mrs. Rita related something similar, further explaining that the color should only be applied after the ceramic piece has been fired and cooled. Mrs. Florinda explains that potters did not use paint because after firing, the ceramics already have a natural red color. Mrs. Dolores does not apply any surface treatment other than using a wet green banana peel after the vessel has dried, leaving the impressions from the peel as decoration, but she believes that other people probably used the banana peel to make designs.

Drying. Mrs. Dolores asked us to return after two days when the vessel would be dry and ready to be fired. All the specialists said that two days are enough for the pots to dry before firing, except Mrs. Florinda from Alto Yacumita, who waits a week before firing (Figure 9).

Firing. We were not able to fire the pot because it broke while drying. Mrs. Dolores said that this happened because the clay was not treated with respect or the turtle shell was not properly burned. However, she described the process of firing. Once the pots have dried, a hole is dug in the ground, and the pots are placed upside down in the pit. In the following step, firewood is placed on top, covering the pots. Once the firewood is burning, it is necessary to wait until the fire consumes it, and after it cools down, the pots can be removed from the ashes in the pit.

A second version of firing was provided by Mrs. Rita, who told us that it takes a lot of firewood. After the embers have burned to ash, the fire is piled up again and more wood is placed on top. When there are enough embers, the pot is placed on top of the embers

Figure 9. Modern shapes of Tsimane´ pottery jar and small bowl.

and left there to fire for a day. The next morning, once the pottery has cooled, the pot is removed, and the color can be applied.

Mrs. Florinda, from Alto Yacumita, told how she and her mother used to fire pottery using chunks of termite mound as fuel. They would dig a hole in the ground, place the unfired pottery vessels at the bottom, and place the chunks of termite mound on top of the pottery and light them on fire. They did not use firewood because the logs would break apart and shift during the burning firing process, which could cause the pots to move and break. For the pots to be sufficiently fired and red in color, they had to be left in the fire for a night and a day.

The worldview related to the potter's tasks is very present among the Tsimane' today. Tsimane' community members know the significance of using clay that embodies a living essence in creating a new object. Like our study, Jurgen Riester (1993) documented several Tsimane' narratives related to the origins of clay as a living agent. Similarly, he recorded Tsimane' narratives that attach symbolic meaning to the storage, use, and disposal of animal bones. Today, we observe that Tsimane' community members do not discard the bones immediately after the consumption of some animals, keeping turtle shells and cow bones for future use, as well as feathers and ceramic sherds.

Discussion and Conclusions

This research focuses on documenting, analyzing, and understanding the traditional techniques used by two Indigenous groups of the Bolivian Amazon in the production of ceramics, particularly the importance of *cauixi* temper among Cayubaba potters and the combination of turtle shell and ground bone with grog by Tsimane' potters. These cases contribute to Amazonian archaeological ceramic studies, which until now have been limited mostly to the identification of different types of organic and inorganic tempering agents. Other recent studies highlight the importance of these resources, the need to analyze and compare in depth their use in different regions, and the need to apply other methodological, theoretical, and disciplinary approaches. For example, Juliana Machado (2005-2006), based on the concept of performance characteristics (Schiffer and Skibo 1997), has presented the properties of *cauixi* as a tempering agent in Amazonian archaeological ceramics and the importance of studying its physicochemical behavior to better understand the selection of raw materials in the process of pottery making and use. According to ethnographic information, adding *cauixi* increases the strength of the vessels (Barcelos Neto 2005-2006). Experimental studies have shown that its use improves the stiffness of the paste during vessel construction, as well as the shatter resistance of the pottery during use (Natalio et al. 2015). Similarly, for the Orinoco River basin, by using the *chaîne opératoire* approach and modern macroscopic and microscopic analytical methods, Natalia Lozada (2019) systematically identifies diverse ceramic manufacturing sequences using *cauixi* and the potter groups that execute them.

Interestingly, although outside the Amazon River basin, zooarchaeological analysis of archaeological ceramics from the Lagoa Santa region in Minas Gerais, Brazil has identified diverse types of spicules, corresponding to five different species of freshwater sponges (Rodrigues, Volkmer-Ribeiro, and Machado 2017). The authors discuss the possibility that this may be related to intentional actions as part of the

chaîne opératoire, resulting from the choice of certain clays from sedimentary deposits with the presence of such spicules, which sometimes occur naturally in clays. In Lago Rico in the interfluvial area of the Araguaia and Peixe rivers, a recent study conducted by Estrela (2023) compiles information on 25 species of *cauixi* existing in the Araguaia basin. Estrela also suggests that the presence of *cauixi* spicules in ceramics is not necessarily attributable to the additional inclusion of processed spicules, but rather to the natural presence of spicules in clay deposits exploited to manufacture ceramics, as opposed to other organic tempering agents, such as *cariapé* (Port.; Sp.) (Estrela 2023), a tree bark ash that must be added intentionally after being processed. The latter is a tempering agent widely used in Amazonian ceramics, made from the bark of ash trees of the genus Licania, containing small silica crystals, identifiable by the siliceous part of the bark, which appears in the paste as partially carbonized wood fragments (Barreto, Pinto Lima, and Jaimes Betancourt 2016, 556–557). Potters in the Juruti region of Lower Amazon River basin recognize the presence of *cauixi* in the clay just by touching it (Panachuk 2016). In the Tapajós River region of Amazonia, there are reports that potters select raw clays that naturally contain *cauixi*, because they consider the clays to be suitable for firing (Moraes 2013).

The Cayubaba ethnograpic study presented here reveals the artisan's preference for a specific type of *cauixi* for its specific properties, deliberately excluding any other material in the process, and demonstrating deep empirical knowledge about these materials. Our analysisconfirmed that the clay used does not contain natural inclusions of *cauixi.* In interviews, the Cayubaba potters relate the use of *cauixi* to the production of large vessels designed for liquid storage. This association is consistent with the ability of porous ceramics to keep liquids cooler, as noted by Rice (1987). It is important to note that the proportion of *cauixi* temper in the mixture is equivalent to the amount of clay used.

Furthermore, our research underscores the importance of the firing process followed during preparation of *cauixi*, enhancing its disintegrationwhile not entirely dinsintegrating its spicules. This transformative process significantly influences the final characteristics of Llanos de Moxos ceramics, improving porosity, lightness, strength, and durability. These findings present novel avenues for future exploration in the field. Additionally, integrating the Llanos de Moxos ceramics into ongoing debates regarding perceptions and preferences surrounding this tempering method in Amazonian archaeological ceramics, as proposed by Alves (2019, 265–267), emerges as a compelling area for further investigation.

Looking ahead, potential research endeavors in the Llanos de Moxos region may involve identifying diverse *cauixi* sources and species, aiming to understand their unique characteristics and discern preferences in their utilization. The examination of pottery from various archaeological traditions within the Llanos de Moxos – such as the Casarabe Tradition (Jaimes Betancourt 2012), Jasiaquiri and Irobi (Jaimes Betancourt 2016), as well as different cultural styles across various latitudes of Llanos de Moxos (Jaimes Betancourt 2013, 2017; Walker 2018) – reveals apparent differences in *cauixi* application methods (burned vs. unburned), resulting in distinct traces. *Cauixi* spicules are more discernible when not subjected to combustion, whereas they become nearly imperceptible after this burning process. Whether this discrepancy in *cauixi* manipulation is rooted in cultural practices or functional requirements remains

uncertain. However, existing evidence indicates that the use of *cauixi* in ceramic styles across several traditions within the Llanos de Moxos is associated with vessels exposed to heat (such as large casseroles and *budares* [Sp.], a fired clay dish, usually plain and circular in shape, used for roasting food) and vessels designed for liquid storage.

Establishing ethnographic reference databases or collections in the future could facilitate the examination and identification of various archaeological tempering materials in the Llanos de Moxos. This effort should extend beyond *cauixi* to encompass other tempering substances like tree bark or bone, pigments (both organic and inorganic), and sources of clay.

The ethnographic documentation of the combination of turtle shell powder or ground bone with clay as a tempering agent in Tsimane' pottery production is an important first step not only to consider in its identification in archaeological ceramics but also to understand how vessels differ due to varying practices and relationships with the environment. Additionally, it is important to understand the diverse beliefs and practices involved that define the appropriate ways of interacting with the materials that are considered necessary for the proper performance of Tsimane' tasks. According to Tsimane' knowledge, clay is jealous and should not be offended since it is a living agent that requires care to be collected. This type of interaction with materials also has been observed in other ethnoarchaeological studies of the Amazon region (e.g. Rodrigues 2021; Silva 2019). This contributes to an understanding of technology that includes the intentionality of other agents as well as part of ethnoconceptions that describe technical relationships. This understanding needs to be considered alongside the *chaîne opératoire* to better ascertain the variations in human-material relationships.

The ethnographic information on the use of ground turtle shell and ground bone indicates the need to review the archaeological materials from the region or, at the very least, give more attention in future analyses to recognizing these types of temper in archaeological ceramics and characterizing them more precisely. Furthermore, a more detailed understanding of cosmological and ontological perspectives on the choices of these tempering materials and other pottery-making resources needs to be addressed in the future, as ethnoarchaeology can contribute to understanding "the relationships between people and their tangible, intangible and invisible worlds" (Lyons and David 2019, 102).

Ethnographic studies of potters in the Llanos de Moxos region show us the complexity of the task due to the variety of elements involved in ceramic production. As Arnold (1985; 1993) proposed decades ago, the relationships between ceramics, society, and the environment cannot be observed directly in the pottery itself but can be understood by studying these relationships ethnographically. As discussed for Andean communities and from an ecological approach, based on the "ceramic ecology" formulated by Matson (1965), it is fundamental to apply a more broadly ecological approach to ceramic production along with studying pottery use and discard as part of a broader socio-cultural system and ecosystem (Arnold 1993).

Another significant contribution of studying these *chaînes opératoires* is the documentation that the distances to the sources of raw materials, particularly clay, are not limited to a small radius, because potters from relatively distant communities know the same source of clay and confirmed having used it in the past, in some cases

over three or four decades. The same is true for other raw materals involved in the ceramic production process, such as the *batán* stone and the basalt polishing stone used in Exaltación, both of which come from distant mountainous areas.

The modeling techniques, shapes, temper materials, and tools used for smoothing the pots are distinct traditions among Cayubaba and Tsimane' potters. These practices come from generations of pottery making rooted within families and entire communities. These traditions are currently in clear danger of disappearing. As we observed in both studies, very few individuals, mainly women and, in most cases, women of advanced age, still practice this craft. All of them are recognized either by their current pottery practice or by the possibility of recalling the practices that, in some cases, they abandoned decades ago.

Further ethnoarchaeological studies will help us to better understand the diversity of pre-colonial ceramic traditions in the Llanos de Moxos and past and present cross-cultural interactions, considering individual and family agency when studying ethnographic practices or collections since, as Gaspar has stated: "they can reveal the agency of artisans in relating to other people and shaping their traditions, which are in constant movement and recreation" (2023, 44).

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