IMPERIAL NEEDS, IMPERIAL METHODS: CHIMÚ CERAMIC MANUFACTURING PROCESS THROUGH CT SCAN ANALYSIS OF STIRRUP-SPOUT BOTTLES

Valentine Wauters

The stirrup-spout bottle is one of the most representative forms in the Chimú (A.D. 900-1470) ceramic repertoire. I discuss the ceramic assemblage of this coastal culture and describes more precisely the various manufacturing processes of the stirrup-spout bottle. Although molds used to produce these complex vessels are known today, only little information has been published on the various stages involved in their manufacture. My purpose is to contribute to this research using medical imaging computed tomography (CT) scans of intact stirrup-spout vessels. Based on my findings, I propose that changes in the construction of these vessels correlated with a transition in ceramic production to a semi-industrial level during the time of the Chimú Empire.

La botella de asa estribo es una de las formas más representativa del repertorio cerámico Chimú (900-1470 d.C.). Este artículo aborda el contexto cerámico de esta cultura costera y describe con mayor precisión los diferentes procesos de fabricación de la botella de asa estribo. Mientras que los moldes utilizados para la producción de este tipo de recipiente complejo son conocidos hoy en día, se publica poca información acerca de los detalles de las distintas etapas de su fabricación. El objetivo de este artículo es contribuir a este campo de investigación a través del método del escáner médico de la Tomografía Axial Computarizada (o TAC). Basado en mi investigación, propongo que los cambios en la construcción de estas botellas parecen correlacionarse con una transición en la producción cerámica a un nivel semi-industrial en la época del imperio Chimú.

Located on the North Coast of Peru, the Chimú culture (A.D. 900–1470) is known for its technological accomplishments in architecture, metallurgy, textiles, and ceramics. This article focuses on ceramic production and, more precisely, on the technology of stirrup-spout bottles. Among the very diverse ceramic shapes produced by Chimú potters, the stirrup-spout is undoubtedly one of the most representative forms. Stirrup-spout bottles consist of two parts: the body, or chamber, which varies in shape, and the spout, which includes a handle in the shape of a stirrup (Figure 1). The Peruvian North Coast has the largest concentration of stirrup-spout bottles, but this iconic vessel of the South American precolumbian cultures has also been found in other regions of Peru, Ecuador, Colombia, Venezuela, Brazil, and Chile, as well as in some parts of Mesoamerica and the southern United States (Wauters 2008, 2014). In the case of the Chimú, stirrup-spout bottles derived from earlier Moche examples, with which they share form, technology, and some iconographic themes. The technology used to produce these vessels in Moche culture has been studied by Christopher Donnan (1965:122–124, 1992:60–65, 1997:35, 2004:28–31; Donnan and McClelland 1999) and other authors, such as Bankes (1980), Della Santa (1962:18–20), Digby (1948), Parsons (1962), Purin (1980a, 1980b, 1983a, 1983b, 1985), Tello (1938), and Wauters (2008, 2014).

Previous studies have addressed different topics relating to Chimú ceramics, such as production centers, the organization of work, and the role of power and hierarchy in the production of goods. Far fewer studies have examined the technology of Chimú stirrup-spout bottle manufacture. The most important works are those of Lima

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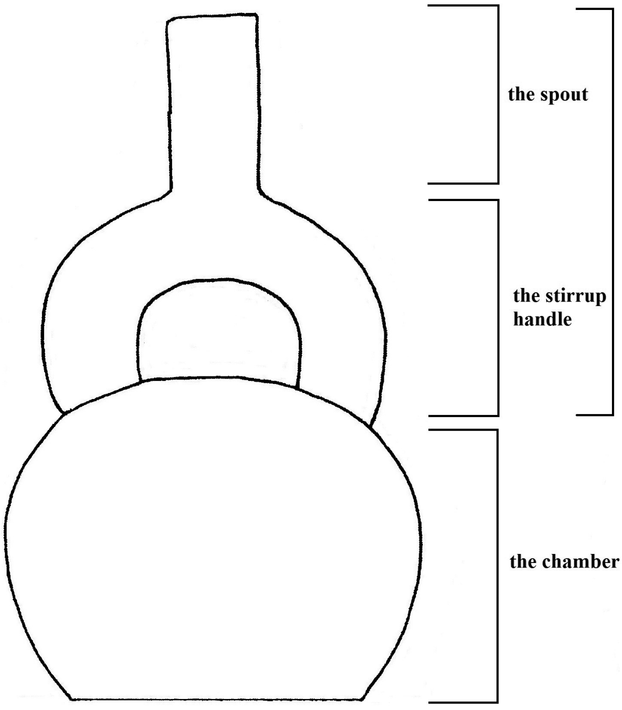

Figure 1. The parts of a stirrup-spout bottle.

(2010) and Mowat (1988). Other authors, such as Collier (1955:129–131), Digby (1948), Donnan (1992), and Tschauner and colleagues (1994:373), have also briefly touched on this subject. My purpose is to use archaeometry via medical imaging to contribute to a more detailed and thorough understanding of the *chaîne opératoire* of the stirrup-spout bottle. The identification and analysis of macro-traces on the inner vessel surfaces via CT scan is the basis of this study.

Stirrup-Spout Bottle Shaping

Chimú ceramists used two shaping techniques: modeling (using paddle and anvil) and molding. The two techniques could be used in the same workshop, and even be combined for the manufacture of a single item (Tschauner et al. 1994:374). For the production of stirrup-spout bottles, Chimú potters preferred the use of molds, specifically two types of molding techniques. The bottle could be composed of different parts molded separately and then assembled, or it could be made in a single, complete, or total mold that included the stirrup-spout handle and the chamber. Both types of molds were of the vertical bivalve type, which was inherited from the earlier Moche culture. Molds used by Moche potters had an opening at the base or at the top of the chamber, but during the later Chimú period the opening was always found on the base (Bankes 1989:Figure 37, Donnan 1992:Figure 8) for technical reasons (see below).

The use of molds offers many advantages: speed and easiness in learning the technique (Arnold 1999:64-65) and in shaping the vessel (Shepard 1956:63), standardization (especially for the reproduction of major iconographic themes) (Tschauner 2006:183), and serial production of identical objects (Mowat 1988). Chimú ceramic manufacturing is indeed referred to as "mass production" (Bawden and Conrad 1982:64, Collier 1955:118, 1959:428, Donnan 1992:94).

The use of molds also has disadvantages. The molds allow speed in execution but Arnold (1999:67–69) and Costin (2007:290) rightly point out that other time-consuming steps are required, such as drying the piece at different manufacturing stages. Therefore, the continuous production flow required multiple molds whose manufacture also generated work. Each potter had several

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molds allowing production of new vessels while other pieces were drying in their molds.

The use of molds also required large spaces for the manufacturing and drying of the pieces (preferably protected from bad weather) as well as for storage of the molds (Arnold 1999:70–71, Tschauner 2001:214–215, 2006:176, 2009:275). The molds prescribed the production of smaller-sized vessels (not exceeding 20 cm), because the drying time for larger pieces is very long (Arnold 1999:66–67). Supporting this argument, Tschauner (2001:185, 226, Tschauner and Wagner 2003:166) informs us that at the Pampa de Burros ceramic workshop (site number S166C), molded vessels were of small size.

The reason for the common use of molds is probably due to the fact that they could be used by a large number of artisans because the technique is quite simple and does not require great skills (Arnold 1999:64–65). If ceramics made from separately molded parts were manufactured by relatively unskilled artisans, those made from a total mold could be produced by even less experienced craftsmen, allowing the production of very large number of vessels.

Secular Tradition and Transformation

Chimú stirrup-spout bottle production reflects the knowledge of a long ceramic tradition, established over many generations in the same region. All cultures from the North Coast of Peru that produced stirrup-spout bottles with molds used the vertical bivalve mold, sharing a "common technological tradition" (Wauters 2008). Although Chimú potters adopted the use of bivalve molds for chamber manufacture from their predecessors, the Moche, they did not use the potential of this technology in the same way.

The context of stirrup-spout bottle production also changed. During the Moche period, the attached ceramic specialists who produced these fine vessels did so under the control of rulers or urban elites (Bernier 2009; Jackson 2008:50–51; Russel and Jackson 2001). The potters themselves were sometimes considered members of the Moche elite (Uceda and Armas 1998:107-108). On the contrary, Chimú potters were of lower social status, and ceramic workshops were located mainly in provincial sites showing no evidence of government control (see below).

The innovation is the use of a two-piece mold for the stirrup-spout handle manufacture and the use of a second two-piece mold for the manufacture of both the chamber and the stirrup-spout handle. Potters of the Sicán-Lambayeque (A.D. 750–1375) culture used a similar technique (Shimada and Wagner 2007:178, 189–195, Figures 9.7, 9.12–13). This culture coexisted with the Chimú for several centuries in the region before the latter conquered and assimilated it to their empire around A.D. 1350 (Mackey 2000; Conlee et al. 2004).

During the Inca period (A.D. 1450–1532), Chimú ceramics become more stylistically diverse. The Chimú-Inca ceramic style combined Chimú forms and techniques with Inca elements (Mackey 2004:87). This new style included more frequent polychrome decorations and a more pronounced lip on the spout. Although Inca ceramics from Cuzco were generally produced using coiling, Chimú-Inca style vessels were made using molds (Donnan 1992:112–115, Hayashida 1999:344–346, Levine 2011:170–171, Sidoroff 2005:101–107). Artisans continued to use regional technological traditions while adopting and integrating some shapes and patterns of the new imperial power. For example, aryballoid jars produced at provincial sites are markedly smaller (20–30 cm) than those produced in Cuzco (up to 100 cm; Sidoroff 2005:102, 106). Chimú craftsmen copied the typical Inca vessel form but did so using local mold technology (Donnan 1992:218–219), which ultimately restricted the size of the vessel.

Chimú Ceramists and Work Organization

During the Chimú period, the status of potters appears to have declined, in contrast to artisans working on metallurgy and textiles. Moreover, it seems that of the many craft specialists working at Chan-Chan, none were potters (J Topic 1982:165; Tschauner 2001:174). Craft production focused on high quality goods, metalwork, and textiles manufactured in workshops associated with the residences of the ruling elite (J Topic 1982, 1990). Other sites, such as the secondary site of Manchan, also produced metals and textiles, but in much lower quantity and quality than Chan

Chan (Mackey 1987:128; Mackey and Klymyshyn 1990:211). Artisans, grouped in different workshops, were probably stratified and supervised (J Topic 1990:156). In contrast, ceramic production was apparently concentrated at provincial sites such as Pampa de Burros (Shimada 1994:25; Sidoroff 2005:94; Tschauner 2001; Tschauner et al. 1994). Most of these provincial sites operated independently, without any control of production by Chimú elites (Tschauner 2001:174, 211-212; Tschauner et al. 1994:378-380).[2] Work organization outside the capital was also less hierarchical, and potters working at sites such as Pampa de Burros likely operated under a model of a "corporate group or a multi-family household unit of specialized potters, independently producing a large quantity of small molded vessels for exchange" (Tschauner 2009:288). Tschauner and colleagues (1994:379) argue that "horizontal exchange is the most likely alternative."

Although Chimú ceramic production was not state-controlled, and manufacture and distribution were probably organized at the local level, it was designed for mass-production. It is possible that local leaders wished to control at least some part of the production as the distribution was no longer aimed at the elite, but at a wider group. Being mass-produced, ceramics were not a status symbol in Chimú society (Donnan 1992:96; Tschauner 2009:277; Sidoroff 2005:88). Despite the relatively low social status of Chimú potters and the carelessness in production that can be observed in some vessels, there is a homogeneity in manufacturing techniques and iconography that suggests the transmission of an ideological message (Mackey 2000; Sidoroff 2005:89). Some of ceramics and stirrup-spout bottles are of high quality, especially the fine blackware vessels, and were probably intended for more prestigious persons or elites.

Technological Study using CT Scanning

The CT Scan Method

The study of manufacturing traces on the interior surfaces of mold-made stirrup-spout bottles can help us reconstruct the various processes and stages involved in the making of these vessels. Nonetheless, the closed form of the bottles has generally inhibited scholars from observing such traces. More recently, the use of medical imaging as an analytical method has provided viewing access to the interior of closed vessels. In comparison with X-ray radiography, which only allows for 2D images, the vessels considered for this study were analyzed using computed tomography (or CT) scanning for the 3D reconstruction.

The earliest studies of ceramic manufacturing techniques using X-ray radiography were performed in the 1940s (Digby 1948), and the method continues to be in use today (Beckett and Conlogue 2010; Heck and Feldmüller 1990; Heinemann 1976; Leonard et al. 1993; Lima 2010; Lima et al. 2011; Middleton 2005; Pavel et al. 2013, 2014; Purin 1980a, 1980b, 1983a, 1983b, 1985; Vandiver and Tumosa 1995). Nevertheless, for the analysis of macro-traces relating to the manufacturing technology of such a complex form as the stirrup-spout bottle, CT scanning and its 3D results are noticeably more accurate and appropriate.

The vessel is scanned by X-rays inside the CT scanner. The information is then digitized and used to reconstruct the object in 3D. From this, sections across the vessel can be made to examine the interior in all its details (Wauters 2008, 2014). This revolutionary method in the field of ceramic studies allows very accurate results and can be used for the analysis of vessels from all periods and regions of the world (Anderson and Fell 1995; Applbaum and Applbaum 2005; Bouzakis et al. 2011; Ghysels 2003; Harvig and Lynnerup 2012; Jansen et al. 2001; Middleton 2005; Robertson 1997; Wauters 2008, 2014).

This study aims to deepen the technological understanding of Chimú stirrup-spout bottles through the use of medical imaging to determine the different stages of the *chaîne opératoire* of their manufacture.

Vessel Analysis

I studied 16 Chimú stirrup-spout bottles from the collections of the Royal Museums of Art and History (RMAH) of Brussels and the Ethnography Museum of Geneva (EMG). Fourteen of them were analyzed using CT scan and two using X-ray radiography[3] (Table 1).

The analyses were performed at the Erasmus Hospital in Brussels with a Siemens Sensation

16-slice scanner and at the University Hospitals in Geneva with a Siemens Sensation 64-slice scanner. The resulting imageres provide cross sections of the vessels and access to their interior surfaces from all angles of view. About 20 to 30 images of these sections were saved in JPEG format. During the creation of the images the software allowed us to see the ceramic vessels in opaque (Figure 2b) or transparent views (Figure 2c). The interplay of these two possibilities can reveal many details. Transparent views provide a kind of X-ray radiography but in three dimensions, while opaque vision gives a reconstructed image of the object in all its details. Based on the study of these images it is possible to reconstruct the manufacturing processes used by Chimú potters. The following section provides the results of the analysis of six of these vessels.

Vessel 1. RMAH – Brussels, Inventory number AAM 53.64. The chamber of this stirrup-spout bottle has the form of a truncated cone (Figures 2a-b). At the height of its shoulders, there are two conch shells between the cone and the stirrup handles. The stirrup handle is rounded and annular, and the spout is straight. A small stair-shaped element is present at the base of the spout. Two break lines at the base of the stirrup handles confirm that the vessel has been restored.

CT scan sections of the vessel indicate that it was manufactured with a total bivalve mold that produced the stirrup-spout handle and the chamber in a single piece (Figure 2c). All parts of the vessel, even the decorative conch shells, are hollow and adjoin respectively with the stirrup-spout handle and the chamber. A mold seam is present on the interior surface. The seam is a mark in the clay, generally in the form of a ridge in relief, resulting from the junction of the two molded halves. It is marked in the stirrup-spout handle and at the beginning of one of the conch shells. Mold-seam traces are no longer visible in the chamber, parts of the conchs, and the spout. The Chimú potter could have smoothed the seams inside the spout by inserting a finger or narrow instrument through the opening. The interior seams of the stirrup handles and chamber were smoothed by inserting a small hand or instrument through the open bottom of the chamber. This part was closed last (Figure 2d) to allow the potter to smooth accessible parts (in this case the chamber and the beginning of conchs). Potters smoothed these parts from the inside and outside in order to strengthen the adherence of the two halves. A trace of a centripetal movement of the clay on the bottom of the chamber suggests that the artisan stretched the paste toward the center to close the vessel. Lastly, he or she smoothed the clay on the outer surface.

Vessel 2. RMAH – Brussels, Inventory number AAM 53.65. This bottle is the "twin" of the previous bottle (Figures 2a, 3a). Both are identical and have the same dimensions because mold technology allowed reproduction in series. The spout is straight although its edge is slightly damaged. The small stair-shaped element at the base of the spout is larger than on its twin vessel indicating that these two solid elements were not necessarily part of the mold but could have been added later.

This vessel was also made from a total bivalve mold. The seam remains visible on the interior vessel surface in the stirrup handle and both of the conch shells, in contrast to the previous exemplar (Figure 3c). The craftsman smoothed only the mold marks on the interior surfaces of the chamber and the spout. Closure was achieved through a centripetal movement of the paste. A horizontal line visible at the base of the vessel indicates where additional clay was added and stretched to close the chamber (Figure 3d).

Because Vessels 1 and 2 are identical and have the same manufacturing marks, they may have been produced using the same mold, and perhaps even in the same workshop.

Vessel 3. RMAH – Brussels, Inventory number AAM 5328. The chamber of this small bottle is shaped like a gourd (Figures 4a-b) indicated by a few decorative elements in low relief. It was probably made with a total bivalve mold (Figure 4c). The gourd neck was perhaps added later; a line is clearly visible in the clay at the junction with the chamber (Figure 4d). This additional step is surprising because the gourd neck could easily have been included in the mold. Moreover, a seam is present in its distal portion indicating that it was also mold-made.

The interior surface of the chamber between the two holes of the stirrup handle is quite rough and irregular (Figure 4d). This is probably the result of a coarse clay addition as reinforcement. On the rest of the interior chamber surface and the beginning of the gourd head, mold seam traces

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Table 1. Summary of the Technological Analysis of the Sixteen Stirrup-Spout Bottles.

Vessels	Molding Procedures	Junction Chamber to Stirrup-Spout Handle	Additional Elements*	References
Vessel 1	Total mold	Parts of the same piece	-	RMAH, AAM 53.64
Vessel 2	Total mold	Parts of the same piece	-	RMAH, AAM 53.65
Vessel 3	Total mold	Parts of the same piece	The gourd neck	RMAH, AAM 5328
Vessel 4	Separate molds	Inserted handle arms	Four legs and tail	RMAH, AAM 39.149
Vessel 5	Total mold	Parts of the same piece	Four legs and perhaps the tail	RMAH, AAM 5376
Vessel 6	Total mold	Parts of the same piece	-	EMG, ETHAM 009989
Vessel 7	Total mold	Parts of the same piece	Two little elements above the carina (?)**	RMAH, AAM 46.7.128
Vessel 8	Total mold	Parts of the same piece	Two little elements above the carina (?)	RMAH, AAM 47.97
Vessel 9	Separate molds	Inserted handle arms	-	RMAH, AAM 39.125
Vessel 10	Total mold	Parts of the same piece	-	EMG, ETHAM 010017
Vessel 11	Separate molds	Inserted handle arms	-	EMG, ETHAM 014202
Vessel 12	Separate molds	Inserted handle arms	-	RMAH, AAM 5355
Vessel 13	Total mold	Parts of the same piece	-	EMG, ETHAM 032519
Vessel 14	Total mold (?)	Parts of the same piece (?)	The pelican head	RMAH, AAM 4790
Vessel 15	Total mold (?)	Parts of the same piece (?)	-	RMAH, AAM 39.61
Vessel 16	Total mold	Parts of the same piece	Two ears (?)	RMAH, AAM 52.63

Notes: *Elements that were not molded with the chamber or the stirrup-spout handle.
** (?) = Image (from radiography or CT scan) not precise enough to observe the element.

were smoothed and erased. This would have been possible by passing a small hand or instrument through the vessel base, which was later closed. Because the potter did not have access to the inside of the stirrup handle, there the seam of the mold remains visible. The mold seam traces on the interior surface of the spout were smoothed.

The bottom of the vessel was closed by spreading clay outwards. The clay was then pressed inwards, resulting in a thick clay blob at the center (Figure 4c).

Vessel 4. RMAH – Brussels, Inventory number AAM 39.149. The chamber of this vessel has the form of a monkey (Figure 5). The ears are on the side, the arch of the eyebrow is pronounced, the nose is flattened, and the mouth is prominent. The body ends with a tail folded over the left thigh. A line is present around the hindquarter. This element is also present in other similar pots (see Vessel 5). The legs are large, stocky, and poorly executed. The animal body is topped by a rounded, annular stirrup-spout handle. The spout is straight and annular with a slightly converging edge.

The little monkey placed at the base of the spout is a common element in stirrup-spout bottles. Generally the tail of the monkey is folded on the side that the animal faces. It is noteworthy that small monkeys on the shoulders of stirrup-spout vessels occurred during the final Phase V of the preceding Moche culture (Donnan and McClelland 1999:Figure 5.49).

The bottle was built from different parts that were manufactured separately and then assembled. At least two different molds were used: one that included the body and head of the animal, the other the stirrup-spout handle. The legs of the animal were probably modeled separately. The monkey's tail was also manufactured separately and then attached to its hindquarters (Figure 5b). This was not included in the mold because it does not lie on the rest of the body. It is surprising that the tail is hollow. The aim was probably to reduce the weight of this element and thus keep it from breaking. Nevertheless, such a fully-enclosed hollow space risks expansion and explosion during firing.

The stirrup-spout handle and legs are attached to the body of the animal through six holes that were perhaps part of the mold. These holes allowed the craftsman to smooth the internal traces of the mold seam using his fingers or an instrument and strengthen the joint between the two assembled parts. The mold seam is therefore visible only inside the head of the animal and its upper back, because these parts were probably

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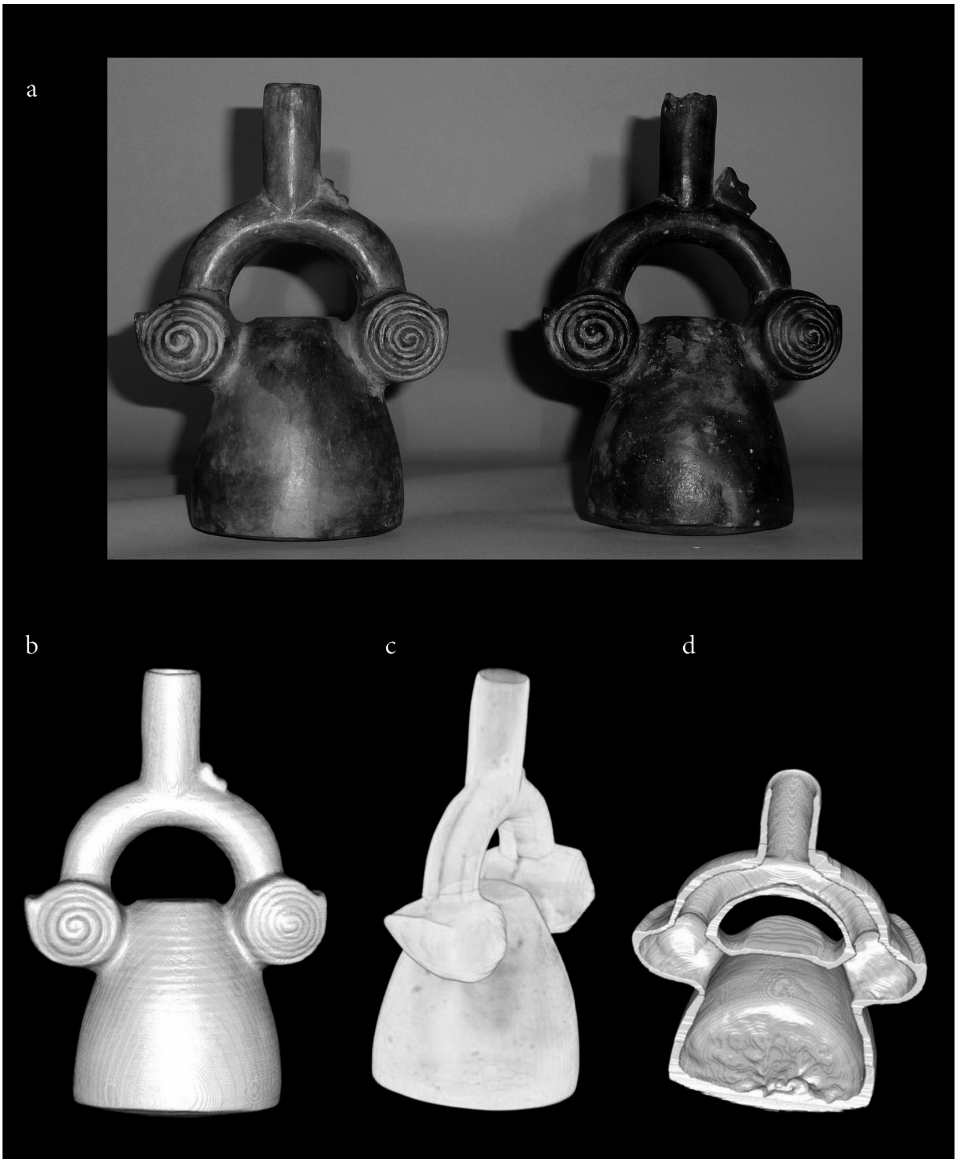

Figure 2. (a) AAM 53.64 and AAM 53.65 bottles, RMAH–Brussels; (b) 3D reconstruction (opaque view) of the AAM 53.64 bottle; (c) 3D reconstruction (transparent view); (d) vertical section.

more difficult to access (Figure 5c). The two stirrup-spout handle arms were inserted into the body of the animal. Clay was added to the outside of this junction to consolidate it. A clay thickening is observed in this location (Figure 5b). The legs of the animal may have been attached last because they were simply inserted into the animal's body and no retouching or internal reinforcement was observed (Figure 5d).

The stirrup-spout handle also was mold-made. The mold was been smoothed and erased up to the shoulder of the handle (Figure 5d). This operation was performed either while the handle was still in the mold, or after it was removed from the mold. The artisan smoothed this section by passing a finger or instrument through the entry of the two handle arms. He or she did not have access to the part of the handle between the curvature of the shoulder and the spout

Traces left by the mold inside the stirrup han-

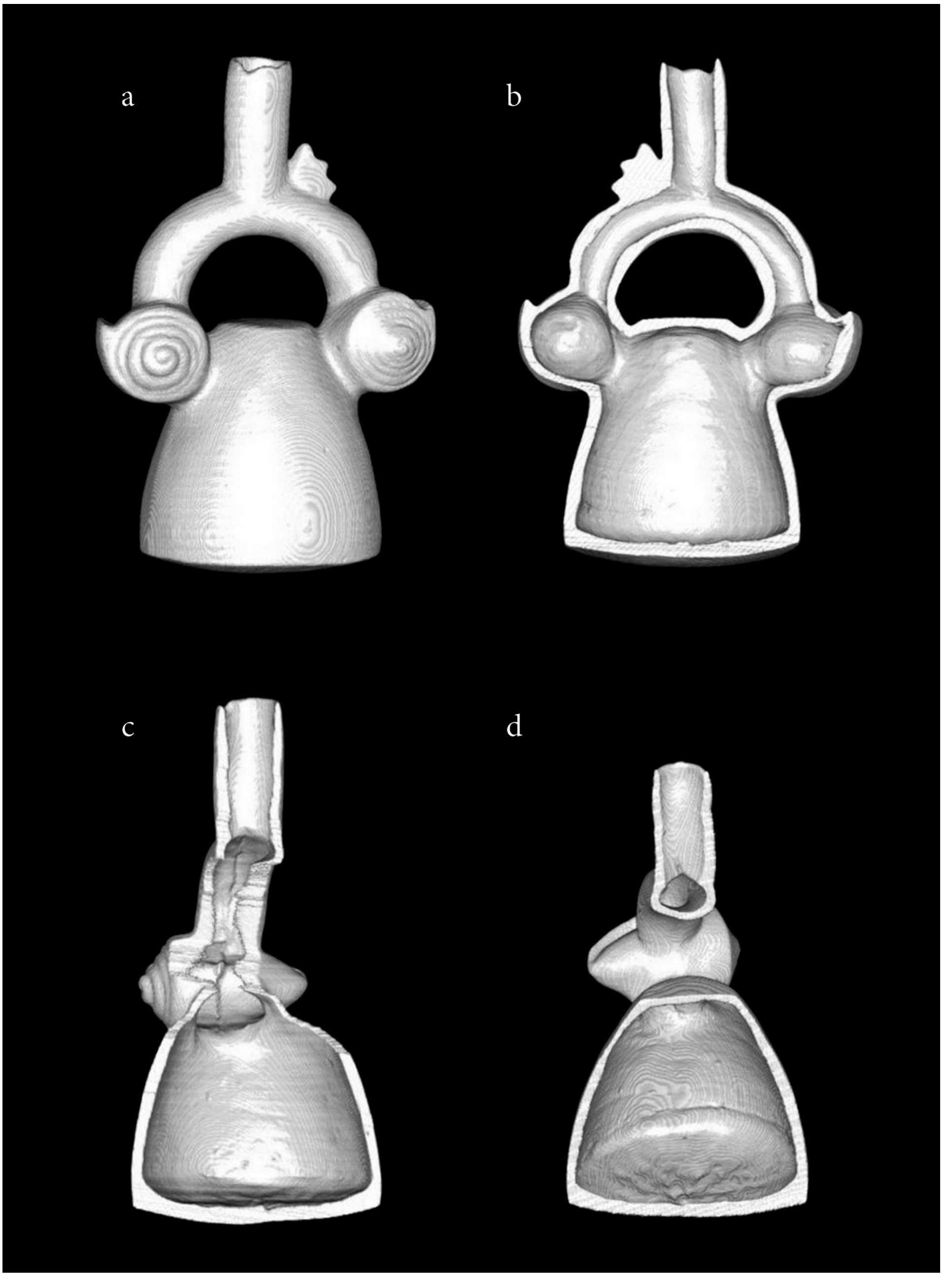

Figure 3. (a) 3D reconstruction (opaque view) of the AAM 53.65 bottle; (b) frontal vertical section; (c) profile vertical section; (d) profile vertical section.

dle are visible only on the CT scan images made in 2011. On 2D images from X-ray radiography (performed in 1984) it was not yet possible to identify these traces (Wauters 2008:293, Figure 18). This is why traces of a clay blob at the shoulder height of the stirrup handle were originally interpreted as incision patterns reminiscent of those used by Moche potters for internal reinforcement (Wauters 2008:293, 295–296, Figure 18). The CT scan of the handle arms that permits us to see the vessel interior shows that the clay blob resulted from the smoothing of the interior

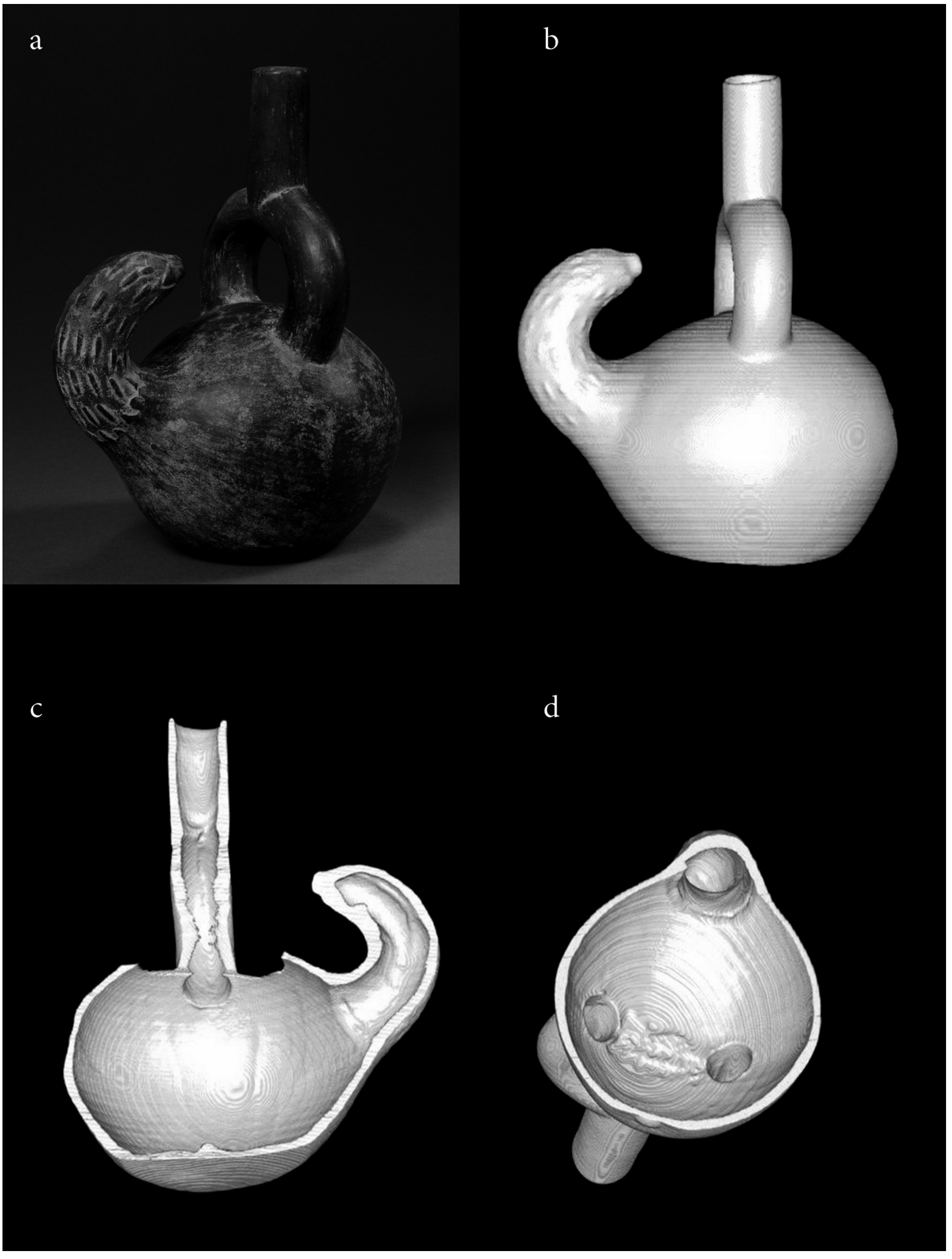

Figure 4. (a) AAM 5328 bottle, RMAH–Brussels; (b) 3D reconstruction (opaque view); (c) vertical section; (d) horizontal section.

handle arms. Thus, the Moche incision technique was no longer used during the Chimú period.

Vessel 5. RMAH – Brussels, Inventory number AAM 5376. The chamber of this bottle has the form of an animal. Based on the position of the ears on the top of the head (Figure 6a), it is probably a feline. The rest of the head has few diagnostic features. The eyebrow arches are slightly pronounced, the nose is flattened and the mouth is indicated as a simple line. The body of the animal is elongated and ends in a tail. The four legs are large, stocky, and poorly executed. They are damaged. The animal also has a line encircling its hindquarter, an element that is found on many

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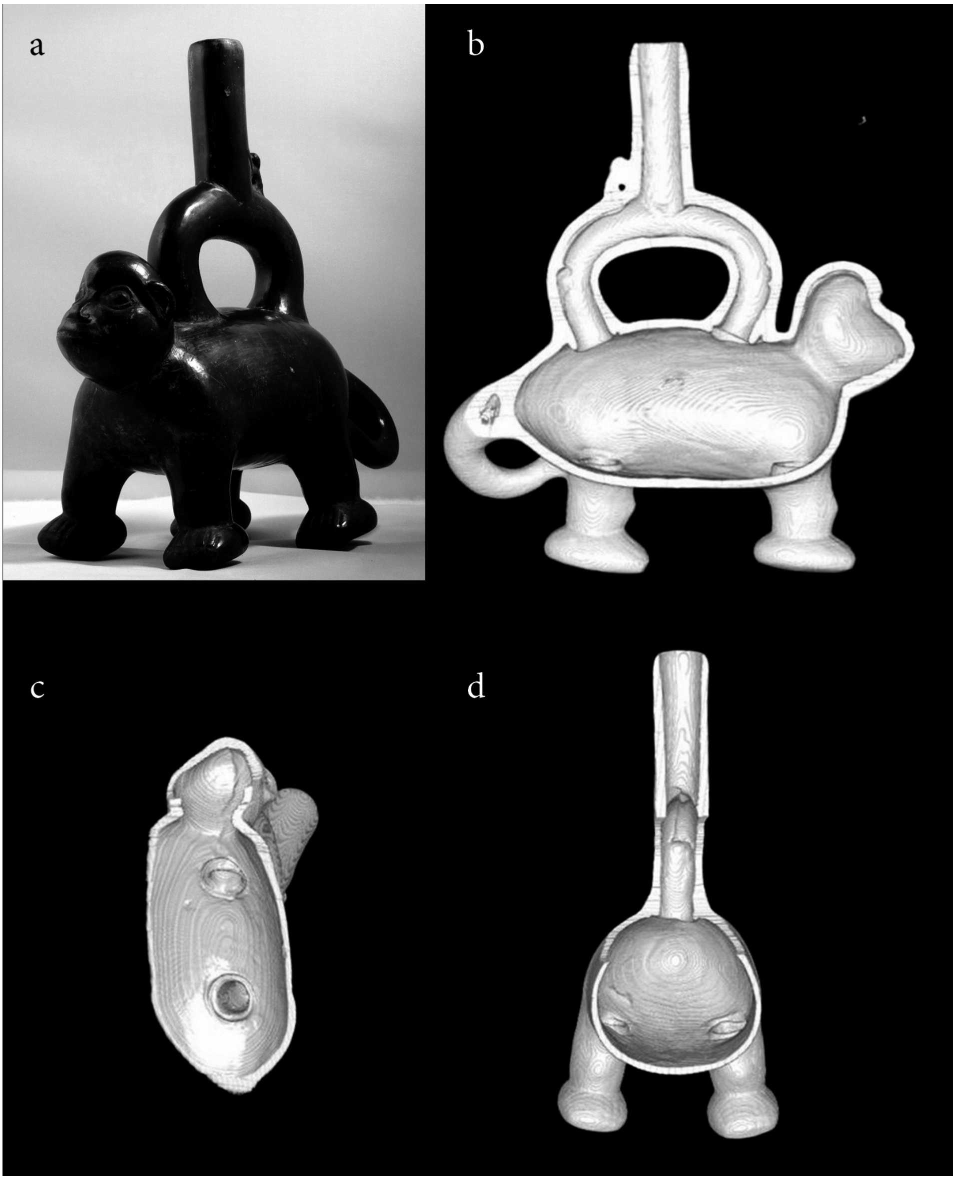

Figure 5. (a) AAM 39.149 bottle, RMAH–Brussels; (b) profile vertical section; (c) horizontal section; (d) frontal vertical section.

similar vessels. Similar to Vessel 4, this line does not appear on the interior surface of the chamber and therefore it does not correspond to a manufacturing mark. The stirrup handle is rounded and has a square cross-section. The spout is elongated and has an annular cross-section ending in a slightly converging edge. A little monkey at the base of the spout has a curling tail and its face is turned toward the side.

This vessel is quite similar from a formal point of view to Vessel 4 but was manufactured with a total two-part mold that included the stirrup-spout handle and the animal's head and body (Figure 6b). The legs were made separately. Mold seam traces remain visible on the interior surface of the stirrup handle, the head, and body of the animal (Figures 6c-d). The inner back of the animal is the only smoothed interior surface (Figure 6e). The potter accomplished this with an instrument passed through the holes left open for the legs.

Figure 6. (a) AAM 5376 bottle, RMAH–Brussels; (b) profile vertical section; (c) frontal vertical section; (d) horizontal section; (e) horizontal section.

It is clear that the animal tail on Vessel 4 was made separately and attached later to the body. In the case of Vessel 5, the tail was molded together with the body of the animal, because it is solid and attached to the body. This process is fairly consistent with the fast and sloppy work of the manufacture of this vessel. Clay was added to the base of one of the handle arms likely in an effort to reinforce its attachment. The four legs, of variable shapes, were modeled separately and inserted onto the body. The insertion of these elements was probably the last step in the construction of this vessel since they include no trace of modification or interior smoothing (Figure 6d).

It is compelling that Vessels 4 and 5, though similar in appearance, were made using different manufacturing processes. The CT scan images immediately reveal which process the potter chose. While the different elements of Vessel 4 were pushed into each other, the different elements of Vessel 5 were part of a single piece without connection joints between them.

Vessel 6. EMG – Geneva, Inventory number ETHAM 009989. The superior part of this angular or keel-shaped chamber is decorated in low relief (Figure 7a). The stirrup-spout handle is round and has an annular cross-section. A bird leans against the base of one of the handle arms. The spout is damaged and was restored. The traces of the mold seam are visible on the exterior surface of the vessel.

This bottle was manufactured with a total two-part mold because the interior mold seam extends continuously between the chamber and the handle arms (Figures 7c-d). Usually, the mold seam is smoothed at least in the chamber and often in a part of the stirrup-spout handle (see previous vessels). In this case the potter did not perform this step. The seam is present on the entire interior surface of the bottle, with the exception of the bottom wall of the chamber and the base. As with Vessels 1, 2, and 3, the bottom of the chamber was closed by stretching the clay toward to the center. The clay was pushed into the vessel, creating a central blob.

The bird on one handle arm was not separately made. It was part of the mold as indicated by the seam passing without interruption through the animal and other elements with which it communicates (Figure 7d). The transparent view (Figure 7b) shows that the animal beak is solid but the rest of its body is hollow. The paste is not completely homogeneous; small masses are included in different parts of the chamber wall. Overall, technological study of this bottle shows a rather crude, poorly executed, and expedient production.

Discussion

The "Chaîne Opératoire" of the Chimú Stirrup-Spout Bottle

With the help of the CT scan and X-ray radiography images of sixteen Chimú stirrup-spout bottles, it was possible to identify different manufacturing protocols. For the six stirrup-spout bottles described in this article, and for 10 others, the use of molds was the most popular technique. Indeed, the production of each of these vessels required at least one mold.

Chimú stirrup-spout bottle manufacture consisted of the following sequence of steps:

1. *Matrix and Mold Manufacture*. The first step was matrix manufacture. The matrix was modeled by hand with all details appearing on the matrix precisely and clearly enough to transfer to the mold. A line was incised on the perimeter of the surface of the mold and it was split into two parts. A mold could also be made by directly pressing clay onto objects such as fruits or vegetables (Dunn 1979).

Chimú molds always consisted of two parts. Mowat (1988:5–7) reconstructed the mold manufacturing of a vessel from the matrix to the finished product. She noted that the matrix did not always have a base since it was never molded but it offered stability to the chamber, nor was the matrix necessarily fired. All the molds observed by Mowat (1988) were fired in an oxidized atmosphere in contrast to the reduced atmosphere commonly used for firing the stirrup-spout bottles themselves.

2. *Vessel Manufacture*. The technological analysis of these vessels demonstrates the use of at least one mold for the manufacture of each bottle. The potter applied the wet and flexible clay to the two mold parts before assembling them. Two types of molding procedures were used (Figure 8).

The first consisted of manufacturing the various parts of the vessel in different molds (see Vessel 4), the chamber and the stirrup-spout handle were made in two separate sets of molds. In some cases, the holes intended for the stirrup-handle arms were already part of the mold (Donnan 1992:Figure 8). The two handle arms were then inserted into the holes in the chamber (Wauters 2008:Figure 21). Other elements that were not part of these molds for technical reasons could also be made in other molds or modeled and then added to the vessel (Table 1). The observation of these elements and their junction is another advantage of CT scanning, since they are more often visible on complete vessels than on isolated vessel fragments. In my opinion, the various components were assembled in a specific order. In fact, by leaving some elements to be added last, the potters kept spaces open that allowed them access to the interior of the vessel. They were able to smooth and strengthen the joints of the assembled elements, in the case of the spaces destined to receive the legs and stirrup handle arms of Vessel 4.

The second molding procedure consisted of manufacturing the entire bottle in a single mold. This total mold included the stirrup-spout handle

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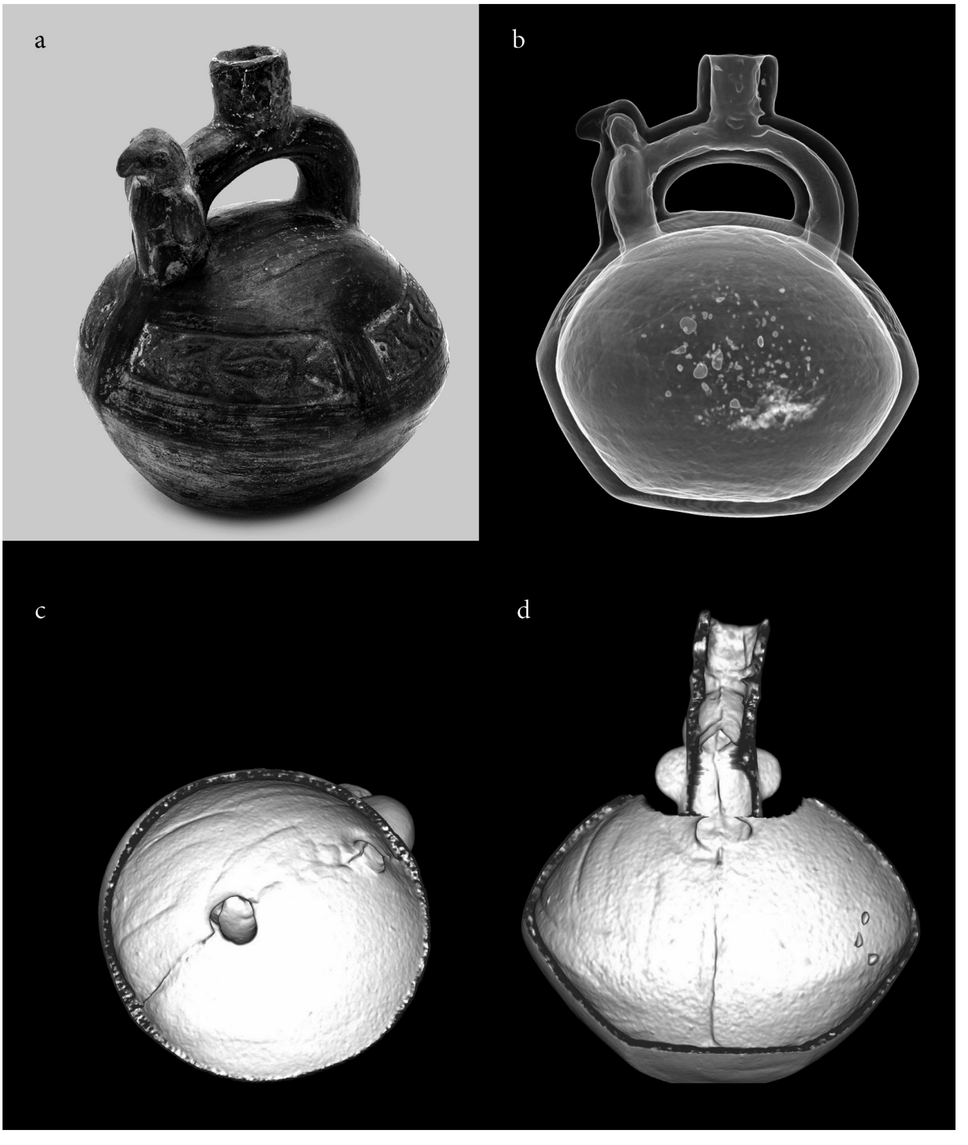

Figure 7. (a) ETHAM 009989 bottle, EMG–Geneva; (b) 3D reconstruction (transparent view); (c) horizontal section; (d) vertical section.

and the chamber, but the base of the vessel was excluded for technical reasons. As a result, internal reinforcement could be performed only through the open base.

In sum, the scanning of the ceramics facilitates the identification of different manufacturing processes. Having access to the inside of the bottle we can see if the handle arms were pushed into the chamber, which indicates that these two elements were separately mold-made and then assembled according to Procedure 1 (Figure 5). In the other case, the junction between the chamber and the handle arms were part of a single piece originating from a single total mold that was used to construct the entire vessel according to procedure 2 (Figures 2–4, 6–7).

With regard to the spout, CT scan sections suggest that it was most often molded as part of the handle. Visual examination of the vessel exterior often shows a V-shaped line, as if the spout was inserted into the handle. This method of insertion was used during the Moche period, and it

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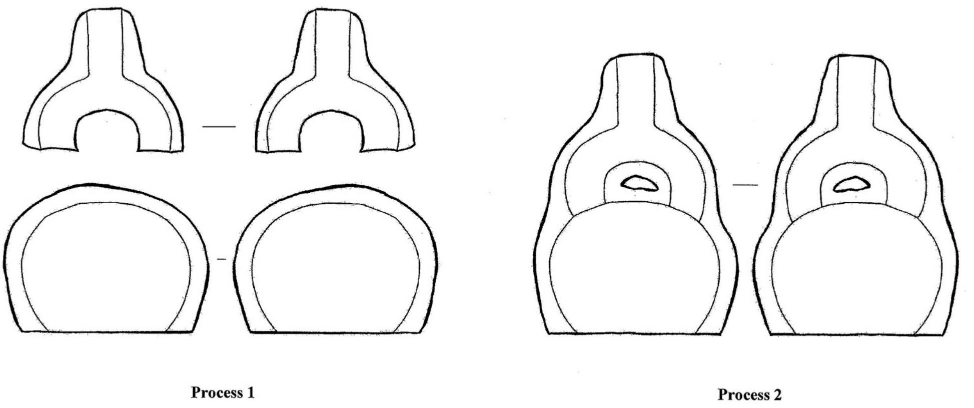

Figure 8. The two Chimú molding processes.

seems that Chimú potters chose to continue to indicate this element from an external point of view. Several CT scan sections show that the mold seam, remaining marked in the stirrup handle, extends a little into the base of the spout, indicating that these parts were mold-made as one piece (Figure 4c). The seam in the spout was smoothed by a finger or instrument passed through the opening of the spout. On several bottles, the mold seam was not sufficiently smoothed and remained visible (Figure 4a). In addition, the stirrup-spout handle molds that I have examined are composed of the stirrup handle and the spout (either for the mold of only the stirrup-spout handle or for a total mold comprising the chamber and the stirrup-spout handle).

Regardless of the type of procedure the potter chose for molding, he or she then passed a hand or instrument through the open chamber base to smooth the mold seam on the interior surface as far as possible. Foster (1948:357) explains that some modern potters of Michoacán, Mexico, who use the vertical two-valve mold, smooth the inner seam with a wet cloth. Because the potter did not have access to the entire interior of the bottle, the interior seam remains visible in some places (especially beyond the curvature of the handle arms). Entering the vessel interior through the base, the accessible parts were the chamber and the beginning of the two stirrup handle arms. The spout was accessible through the top of the bottle. As explained above, molding the chamber and handle separately had the advantage of creating additional access to the inner surfaces before assembling the different parts of the bottle.

The CT scan images allow us to appreciate the various degrees of attention provided by the potters at this stage. On some vessels the traces left on the interior surface by the mold technique are only visible in inaccessible places (see Vessel 4), while on others they can also be seen in some parts of the chamber (see Vessel 6). For both molding procedures, it is difficult to know whether the smoothing of the inner mold-seam was performed when the vessel was still in the mold or after it was already removed. It may have been preferable to do this while the vessel was still in the mold to avoid deformations and when the clay was still wet enough.

When the molding was completed, the piece dried in the mold. Once the clay began to dry, it would shrink slightly and could easily be removed from the mold. At this time, the mold-seam on the exterior surface was erased. The care taken in this step varies, however. In some cases, the seam is still perceptible by touch (by passing the hand over the surface of the vessel) or even by sight (Figures 4a, 7a; Lima 2010:plate 20).

To strengthen the vessel, potters sometimes applied a little bit of clay to the external base of the stirrup handle arms, where the CT scan sections show a thickening of the material (Figure 5b). It seems that the Chimú artisans practiced this extra step only on bottles whose stirrup handle and chamber were molded separately and then assembled. The junction was more fragile than for a vessel molded with a total two-valve mold, for which external reinforcements were very rare.

The last step in the ceramic manufacture was the closure of the chamber. Mowat (1988:9) speaks of a coiling closure as described by Donnan (1965:123) for the chamber closing of the Moche stirrup-spout bottles. The coiling closure seems quite plausible but does not appear on the CT scan images. Indeed, on all Chimú pots that were analyzed the paste seems to be stretched towards the center and not coiled. Potters probably added clay to the base of the chamber walls and stretched it toward the center. A line is sometimes observable in this junction place. In the center of the base, the clay was therefore pushed inward, causing a clay blob, which remains visible on the inner surface (Figure 3d).

3. Finishing and Firing. Decoration and paint elements were added last. The decoration was generally part of the mold although some elements made from modeling, molding, or stamping could be added to the vessel. Painting was only used for vessels fired in an oxidized atmosphere, which was less common during the Chimú period. Most of the ceramics were polished.

The last stage of the *chaîne opératoire* of stirrup-spout bottle production was firing. It was usually performed in a reduced-oxygen atmosphere (Echallier 1984:20–21) and provided the characteristic black color of the Chimú ceramic. The return of firing in a reduced atmosphere, an ancestral firing technique used by Cupisnique potters (1200–200 B.C.), was probably guided by its ease of execution and the relative time saved compared to firing in an oxidized atmosphere. According to Donnan (1992:123), this choice corresponds perfectly to the desire to speed up the mass production of Chimú ceramics. Indeed, firing in a reducing atmosphere requires less control, and a greater number of vessels can be fired simultaneously. Time is also saved in the decoration, often made by the sculptural form of the chamber or by a decoration in low relief that may already be part of the mold. Finally, no painting was required, in contrast to the meticulous work of the Moche fine-line painted vessels, for example.

Consequently, the manufacturing of Chimú stirrup-spout bottles could have been performed by two types of artisans: specialists and non-specialists (Costin 2007:279–282). Unskilled workers without special knowledge could perform the molding, drying, and the decoration, while master craftsmen dedicated themselves to the manufacturing of the molds and the firing of the vessels (Arnold 1999:66, Tschauner 2001:223, Tschauner 2006:184).

Conclusion

This technological analysis of 16 complete Chimú stirrup-spout bottles has shown that their manufacturing methods were standardized, consistent, and expedient. The use of molding and technological innovations that simplified production processes allowed Chimú potters to transition from an artisanal and specialized production inherited from the Moche to a semi-industrial production.

This analysis highlighted the use of two types of molds for the production of Chimú stirrup-spout bottles: separate, modular molds for creating the vessel in two or more pieces and the total two-part mold. One may question the use of these two molding techniques. Were they linked to geographical, chronological, or other differences? Or simply used simultaneously depending on potters' preference for one or the other technique? One of the answers can be found in the technical limitations of total two-part molds, which were used only to manufacture small vessels (ca. 20 cm height) (Arnold 1999:66–67). For larger vessels, the use of several molds was preferable, because it would reduce the drying time for each part and the risk of damage to the piece. Moreover, vessels with complex shapes could not be made using a total bivalve mold for technical reasons. Finally, the use of several molds allowed for the various elements to be assembled in a particular order that left open spaces for interior reinforcement operations (see open spaces destined for the legs of the monkey and handle arms of Vessel 4).

The use of molds suggests that Chimú potters intended to produce these vessels in large quantities and standardized series. Some forms and iconographic themes were probably more popular since they were produced in larger numbers. A popular pattern could be replicated in different postures using different molds. Variations are sometimes minimal and are identifiable by some small details (anatomical details or attributes, etc.). These variations could occur even for vessels manufactured using the same mold, by adding details (molded or modeled separately and then added) that made them slightly different.

There also were what we may call "fraternal twin" vessels. These ceramics are identical at first sight and appear to have been produced with the same mold, but their dimensions differ slightly. Therefore, many different molds represented the same theme. A possible explanation for this may be that different workshops produced the same popular form with different molds. Since ceramic production was concentrated in provincial sites, perhaps workshops copied vessels produced by others workshops at the same, or a different, site. Another hypothesis would be that the same workshop wanted to manufacture a form in large numbers. The use of different molds with the same form allowed more artisans to work on the same subject simultaneously, increasing productivity. Alternately, a mold could not be used indefinitely, and eventually it had to be replaced with a new mold of the form. These scenarios can explain the variation in dimensions between ceramics of identical appearance.

The number of stirrup-spout bottle molds that have survived to this day is quite limited compared to the amount of recovered vessels. The number of vessels identical in form and dimensions that were likely produced in series is also limited. It is difficult to identify and locate exact replicas of ceramics and usually only two, three, or at most four identical pots are known. There are a number of possible scenarios that may explain why the quantity of identical vessels is so limited today. The most obvious one is the destruction and the dispersal of ceramics. Most vessels were destroyed over time, especially those not kept in closed or protected contexts, such as tombs. Others were damaged or destroyed by looting, because looters keep only ceramics that are judged the most aesthetic and thus most easily marketable. For those pieces that have survived, the problem is dispersal. Ceramics are stored in museums or private collections around the world, often far from their original location, making it very difficult to reconstitute series. Nonetheless, it would be illogical to think that potters were making molds to produce only a small number of identical pieces. Given the complexity of the manufacturing process revealed by this research, it is plausible that stirrup-spout bottles of similar forms were produced in large quantities.

The technological tradition of the stirrup-spout bottle began during the Early Horizon, intensified during the Moche period, became more industrialized during the Chimú period, and continued on the northern coast of Peru until the Spanish Conquest. Although some technological changes can be observed (such as the use of the two-part mold for the stirrup-spout handle or the total two-part mold), Chimú stirrup-spout vessels display many manufacturing similarities with other cultures in the region. Under the advent of their empire, Chimú potters transformed the stirrup-spout bottle production, inherited from an ancestral manufacturing complex, into a semi-industrial process that was focused on producing large quantities of vessels outside the craft production centers of the Chimú capital.

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Notes

1. Levine (2011) also talks about a local rather than a centralized production at the time of the Inca domination for the ceramics of Chimú-Inca style.

2. CT scans were performed between 2011 and 2014 and X-ray radiographs were performed in 1984 (for the research conducted by Sergio Purini).

3. Vessels CT scans of the Royal Museums of Art and History of Brussels were performed by José Ordonez, medical imaging technologist of the radiology department at Erasmus Hospital of Brussels. Those of the Ethnography Museum of Geneva were conducted by Dr. Xavier Montet, radiology head of unit, Patrice Bregis, technician chief in medical radiology, and their team at the University Hospitals of Geneva. Vessels post-scan and 3D reconstruction work was performed by Jose Ordonez at Erasmus Hospital of Brussels.

4. The CT scan images presented in this article are stored by the author and the Americas department of the Royal Museums of Art and History of Brussels.

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