# LATE-HORIZON PACKAGING:
# THE INCA, *ARIBALOS*, AND PACKAGING FUNCTIONS

By

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A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

Packaging – Master of Science

2017

# ABSTRACT

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Historically, publications in the field of packaging science have relied on Western supply chains and their use of wheel, boat and market driven exchange to analyze packaging. To provide additional perspective, an in-depth study of the Late-Horizon Andes Mountains and the Inca Empire (roughly 1438 to 1533 AD), the region's dominant power during this time, was performed because it lacked substantial wheel, boat and market driven exchange while still engaging extensively in the movement of goods. Chapter 2 provides a comparison of native packaging before and after Spanish influence in the region, establishing evidence that shifts in packaging are observable with changes in culture. Chapter 3 uses packaging attribute models and packaging value chain analysis to interpret the impact of a package type, *aríbalos*, on the Late Horizon Andes, and demonstrate packaging's impact across cultures. Chapter 4 presents a closer examination of *aríbalos* providing data that the design of *aríbalos* were engineered for user comfort and modeling their mass and circumference. The research indicates the Inca Empire's packaging solutions were optimized to reduce economic costs of packaging construction while increasing efficiency in transportation.

## ACKNOWLEDGEMENTS

The creation of the following research is the result of years of education, assistance, and patience of those who I have been fortunate enough to have been supported by.

Of foremost recognition is Dr. Diana Twede who greeted me in the first days of my graduate studies at the School of Packaging and has provided me guidance in every step since. I am forever changed by our interactions. Your vision for what Packaging can be and influence in shaping the field are, in my opinion, without comparison.

Dr. Rocio Quispe-Agnoli, thank you for all your incredible strength in articulating vision, breadth of knowledge, and assistance in understanding the Inca Empire. Working with scientists is not easy, working with you has been highly educational and enjoyable.

Dr. Gary Burgess thank you for being our source of technical knowledge and helping us structure the quantitative and engineering portions of this thesis. Hope you are getting plenty of opportunities to ride your bike.

Dr. Matthew Helm, my ability to stay healthy and creative throughout this writing process is a result of tools presented by and developed with you.

The faculty and staff at School of Packaging has been incredible to interact with and learn from. A special thanks to Dr. Susan Selke for helping me to enter the field of packaging and teaching me much of what I know. Cimberly Weir for all your hard work for the School and with the PGA. Dr. Bix for all your help and inspiration over the past two years. Dennis Young for your help prototyping. Ron Iwaszkieicz for your advice and council. Aaron Walworth for everything lab related, especially the night before leaving for Chicago. Dr. Auras with advancing graduate life. Dr. Clarke for your help with the PGA. Dr. Kamdem for the lessons taught in Europe. Dr. Almenar for being a friendly source of support.

Thanks to: Dr. Pollard for the introduction and guidance into the world of archeology; Dr. Guyotte for helping me understand what makes great writing; Dr. Narvaez: for the inspiration for subject matter presented is a reflection our interactions and I could not have come-up with this idea without your support; Dr. Myers for helping me articulate facts with observations and teaching me to express in writing with the intensity felt while learning; Dr. Tomasik for teaching me to enjoy empirical work and encouraging me advance with my schooling; Dr. Wheat for the early and continued inspiration; and Dr. Hunt thank you for giving me the confidence to present my conclusions here and re-inspire my thinking with this project.

Thank you my family: mom, dad, Gwen, Jason, and Christina for supporting me during my studies; and friends: Ariel Wang, Chris Wilson, Tony Trier, Paula Perez-Perez,

Patrick and Aleska Belenger, Ian Sheets, Sam Rothwell, Jiyon Lee, Yifan He, Ye Thai, Chancy Zhang, Alyssa Harben, Semra Cavus, Mamata Thatte, Patrick McDavid, Gauri, Sammy Rahimi, Wataru, Paulie Lewart, Colm McNab, and Chris Wang.

I Have relied on everyone to get me here. Thank you again.

Also many thanks for Chris and Allison at the Chicago Field Museum. The finding in Chapter 4 are as much a reflection of your hard work as anyone else's.

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# CHAPTER 1.INTRODUCTION AND BACKGROUND

## Introduction

The Inca Empire's road system encompassed an impressive 40,000 km of roads and stretched 3,800 km from Quito to Santiago (Hyslop, 1984, p. 224). Building an extensive system of *qullqa* – in Quechua "warehouses" - along these roads, Inca administrators oversaw *qullqa* stocking with food and supplies for travelers, soldiers, and laborers performing state-related functions (D'Altroy, 2015, pp. 409–412). In times of famine, administrators also redistributed food to ensure effected communities' survival. A total 7,500 *qullqa* are confirmed to have existed throughout the empire, a particularly impressive feat considering that the empire was less than 100 years old (D'Altroy, 2015 p 379; Jenkins, 2001). Huánuco Pampa, an administrative center, alone contained 30,000 $m^3$ of storage space. Post-contact accounts help with comprehending the Inca Empire's storage efficiency. For example, nearly a decade after the fall of Cuzco (the Inca Empire's capital), 1500-2000 Spanish troops lived off the storage systems of the Hatun Xauxa for 50-100 days consuming around 850 $m^3$ of supplies (D'Altroy, 2015, p 414-415; D'Altroy & Hastorf, 1992). To reference in modern capacity, the Spaniards extracted roughly 11 freight containers of food and supplies from storage.

The modern study of packaging science relies on diverse insights to increase the scope of its empirical lens. Studying the approach of the Inca Empire to moving and storing their goods poses an opportunity examine central tenets of the field and refine unnoticed bias. Inca governance in the Late-Horizon Andes required the management

of the enormous quantities of goods and required the presence of skilled administrators, refined incentives, and vast means of production. The technology required to move and store such a sum of goods using only porters – called "strappers" - and llama caravans implies a high degree of specialized technology vastly different from those commonly observed in traditional Western supply chains.

The primary purpose of this research is to expand the scope of empirical tools available to packaging professionals by integrating cross-cultural comparisons, understanding human-package interactions as behavioral phenomenology greater than marketing functions, and the use of contextual pressures as a way of locating existing packaging solutions into a packaging professional's knowledge base. Secondarily, the research should assist those outside of the field of packaging in understanding the global importance of packaging in building and shaping society and peoples' lives.

By relying on chroniclers' accounts, ethnographic studies, and archeological data, Chapter 2 presents a comparative description of Andean packaging pre- and post-Spanish contact. As ceramics have best survived the 500 years post-contact, the *aríbalo* – a specifically shaped and commonly produced jar during the Late-Horizon under Inca rule - are examined more closely in Chapters 3 and 4. Both reveal insights into the descriptive value of packaging as means of communicating and influencing prevailing social and economic life. A part of this thesis also argues that the current paradigm of the superiority of cubic efficiency through use of straight sided objects, wheels, and boats as likely rooted in Western assumptions of efficiency, and that Inca technology allowed for the efficient bulk transport by foot.

## Background

*Terminology for Studying the Inca Empire*

Reading about the Inca Empire often presents a challenge to those unfamiliar with the region because the word "Inca" appears to lack specific meaning. During the Late Horizon, the word "Inca" would have referred to the ruler of the Inca Empire; a literal interpretation of "Inca Empire" can be thought of as one might say "King Louis's Empire" (D'Altroy, 2015 pp. 176-179) However, the Empire was passed from one Inca to another. Thus, we refer to the ruler of the Inca Empire as the *sapa Inca*. To further complicate matters, the ethnic society the *sapa Inca* came from are often referred to as the "Incas." Such a group also integrated non-Incas into their rank to control the *sapa Inca*'s Empire (i.e. the "Inca Administration"). Where possible care was placed into using the correct terminology, however when studying a 500-year-old subject difficulty often exists in determining the exact originator of an action so the reader is encouraged to remain skeptical of over-attributing causality.

*The Late Horizon Andes*

Present day Peru, western Bolivia, northern Chile, and southern Ecuador collectively comprise the "cradle of civilization" scholars label the "Andean Highlands" or "the Andes" for short (D'Altroy, 2015 pp. 46-58). Evidence of human occupation of the region starts around 11,000 BCE and continues to the present. The "Late Horizon" specifically describes a period from 1476 AD to 1534 AD, which roughly aligns to the Inca Empire's rise and descent as the dominant regional power.

The Late Horizon's is notable for the relative cultural homogeneity created by the Incas as the previously obscure tribe grew aggressively during this time period to encompass much of the Andean Highlands. Prior to the rise of the Inca Empire, many independent cultural groups flourished in the Andes (D'Altroy, 2015 pp 46-58). Cultural diversity continued under the Inca Empire but differed dramatically in that the Inca Empire controlled the flow of goods and imposed taxes. Specifically, the Inca administration leveraged its knowledge of Andean agriculture, transport, and record keeping to stabilize food scarcity and increase the prevalence of rare goods for the many cultural groups they ruled over (Murra, 1980). The Inca peoples benefited handsomely from their expansion and taxation often using substantial force and violence to ensure the sustained functioning of their empire.

*Agriculture and Microclimates*

The Andean Mountains climb quickly reaching heights of 5000 m above sea level at distances of 300-350 km from the ocean (D'Altroy, 2015 pp 35-42). The substantial and dramatic shifts in altitude produce variance in localized climates and a high frequency of microclimates or patches of land differing in the temperature and moisture of adjacent soil. Agricultural patterns reflect the climatic variability with relatively large diversity of plants being cultivated and consumed in the Andean Mountains.

Prior to the Late Horizon, groups mitigated the volatility caused by variability in microclimates by relying on reciprocal exchange with geographically separate groups (Murra, 1980). The social mechanisms that dictated how groups were separated by respectable distances (50-100 km being common) and engaged in exchange remains

contested (Dillehay, 2013; Mayer, 2013; Murra, 1980; Stanish & Coben, 2013). Undisputed though is that the strength of the Inca Empire, in part, resulted from its ability to standardize and impose a version of reciprocal exchange on previously independent communities within the Andes (Murra, 1980).

*Consolidation of Economic Forces and the Need for Expansion*

The Inca Empire's capital was Cuzco - of the same location and name in modern Peru - and its boundaries extended north, south, and west, bounded only to the east by the Amazon (D'Altroy, 2015 pp. 96). Empirical evidence indicates expansion does not appear driven by the acquisition of rare resources or a desire to convert followers to a state religion, rather the Incas appear deeply motivated in the absolute protection of Cuzco - the most sacred of space in the Incas cosmology.

The motivation to protect Cuzco during the Late Horizon altered the regional economy by attempting to stabilize it through consolidating surplus and forcing state-led labor. Prior to the rise of the Inca Empire, the Late-Horizon shows few groups engaging in market exchange and bartering (Murra, 1980). As such, while exchange was expansive in the distance it covered, it was limited to many small exchange networks which did not substantially intermix. The Inca Empire did not assume the role of a direct provider of exchange networks either, rather it forced locally autonomous groups who used to distribute surplus to other groups as an insurance policy to instead provide the surplus to the Inca Empire (D'Altroy, 2015 pp. 358-359).

The distinction here is important because modern economics is based heavily on results-oriented activity, and therefore the Late Horizon is often described as being

more stable and better because the Inca administration enabled more efficient production and distribution. However, the Inca Empire, motivated by the protection of Cuzco, appears to have believed service to it was more important than goods produced. Examples like the building of the parallel paths to the same location and massive stockpiling of goods suggest control of people, not their goods (D'Altroy, 2015 pp. 370 and 409-417). Such evidence does not negate possible economic benefits received by ethnic groups within the Inca Empire, however the tension between benefit received by subjected peoples and those of the Incas should not be confounded in an attempt to suggest voluntary participation of the former or benevolent naivety of the latter.

*Production for the Inca Empire*

Three loci of production were known to exist in the Inca Empire: (1) *Mit'a, (2) Aclla Cuna*, and (3) specialized communities. Perhaps one of the most curious - and known - aspects of Inca society to outside observers was its ability to reach incredible power without the use of currency, although it is debated whether no set-standards of exchange existed (Dillehay, 2013; Mayer, 2013; Murra, 1980; Stanish & Coben, 2013). Instead, the Inca imposed various forms of organized labor service on communities, which translated into the production of goods.

The most widespread form of organized labor extraction was *mit'a* (literally "to take a turn") in which the Inca commanded the completion of a task via ordering the community to send a specified number of people to complete it (D'Altroy, 2015 pp. 396). *Mit'a* duties could include a wide array of activities but some of the more common tasks

were working in Inca fields, building state infrastructure, and serving as a soldier for a season.

Nearly all communities were also required to provide certain people to the state, most notable are the *aclla cuna* (or chosen women) who were young maidens working in state run facilities for the *sapa* Inca (D'Altroy, 2015 pg 301). These young women were socially elevated workers for the Inca state and they were commanded to produce some of the highest-quality woven textiles and make *chicha* (maize beer) for the Inca and *mit'a* labors, and importantly not concubines.

The Inca also employed specialized communities of artisans and individual artisans in state run workshops (D'Altroy, 2015 pp 429-431). These communities were not developed by the Inca, rather the Inca integrated them after conquering such people, often going to great lengths to transplant these communities hundreds of kilometers from their native lands. Specialized communities produced a number of goods ranging from pottery to metallurgy, but always specialized in a narrow range of products and were distinct from other specialized communities.

*The Inca Road and Storage System*

The structure of the road system in the Inca Empire was mostly for wealth finance and the localized transport of staple goods. To describe an economy, social scientists distinguish wealth goods (i.e. nonperishable products offered as gifts and payment to elites) and staple goods (i.e. those people need to subsist and live) (D'Altroy & Earle, 1985). Although the Inca road system was extensive, analysis has revealed that it was built to efficiently transport wealth goods to Cuzco and move them back out

sometimes to locations moderately close to the original location (Jenkins, 2001). The proposed justification for such inefficiency is that the Inca Empire was more concerned with the stability of the Empire than providing for local elites, and a gift from Cuzco would signal both the generosity of the Incas and their power to control exchange, rather than simply presenting the gift. There is a relative absence of evidence showing movement of staple goods between administrative centers and regions (Morris, 1992). Current scholarship therefore suggests the movement of wealth goods using the formal Inca roads and low regional movement of staple goods indicates the road systems were therefore primarily for the movement of gifts to elites. However, along the road and removed from the road were *qullca* (or storehouses) indicating that although goods were not moved substantially on Inca roads, one cannot fully separate what the roads transported and the stability brought by food storage.

*Qullca* are generally either round or square and the forms likely represent discrete and important functions in the Inca economy. Substantial debate exists around whether shape represented discrete categories of goods - it is thought that circular *qullca* held mostly maize while square ones held tubers and other goods - but the general consensus is still absent (Morris, Craig & Thompson, Donald E., 1985). *Qullca* comprised roughly 12% of all Inca infrastructure (Morris, 1992a; Figure 1-1). Further, it has been recently established that the Incas appear to have used a grid system of tiles and *quipus* to allow for the proficient counting and recording of the amount of items present in *qullca* (Urton & Chu, 2015).


*Figure 1-1 Drawing showing eight Inca qullqa or storehouses*

*Quipu's Role in Censuses*

The Inca administrative system was highly proficient and has been documented extensively. Of specific interest to logistics of the Inca Empire were *quipu* or large strands of rope that contained knots at various set locations (D'Altroy, 2015 pp 148-161; Urton, 1997). The color, size, type of knot, direction of twist, and various other factors were used to convey highly detailed biannual census information to the *sapa Inca*. These census were so important the Empire's warehouses had structures built to efficiently count and record inventory (Urton & Chu, 2015). The readers of *quipu* did not rely on the device as a purely mnemonic aid, rather these devices were transported quickly (over 250 km a day) by *chasquis*, which were a system of runners who functioned to carry messages, *quipu*, and sometimes certain foods to and from Cuzco (D'Altroy, 2015 pp 146-161). The effort exerted by the Inca to proficiently assess their current goods – as

indicated by their extensive use of *quipu*, warehouse features, and the creation and support of the *chasqui* system – suggest that administrative timeliness and clarity of information were highly valued.

*Human and Llama Transport of Goods*

Conservative estimates of the Inca road system show that it enabled llamas to travel 20 km/day carrying an average of 20 kg, and porters traveling in a caravan capable of carry roughly 30 kg of cargo up to 20-25 km/day (D'Altroy, 2015 pg 344; Hyslop, 1984). Evidence shows porters in form of state laborers and women performed the majority of transport of goods within the Empire due to their greater resilience and ability to handle the rugged terrain of the Andean Mountains (for similar and opposite reasons it seems likely evidence of wheeled transport remains absent).

*Packaging as a Lens*

The relevance of transport, storage, and ceremony for archeology and ethnohistory indicates interdisciplinary dialogue with packaging science might prove fruitful in the Andes. Packaging analysis of Grecian *amphoras* has already been performed to benefit of Mediterranean archeologists (Hein, Georgopoulou, Nodarou, & Kilikoglou, 2008; Twede, 2002a, 2002b). Package analysis has also aided the field of maritime, marketing, and U.S. history (Twede, 2005, 2012). The Inca *aríbalos* holding *chicha* certainly meets the academic definition of "packaging" as an object which performs protection, containment, communication, and utility functions for another object (Lockhart, 1997). Specifically, the following three hypotheses were examined:

1. Shifts in regional power dynamics, from the Incas to the Spanish rule, create changes in the type of packaging used by subjugated communities from the end of the Late Horizon to early Spanish colonization.
2. A reasonable description of packaging function can be gained by understanding the context a package functions within.
3. The value in a package's design can be explained in terms of physical pressures created between the package, product, and portions of the environment interacting with package.

Chapter 2 will address the first hypothesis by examining primarily the Guaman Poma Chronicles, using descriptions of life during the Late Horizon and post-Conquest periods to build a case that Spanish unfamiliarity with regional needs resulted in the inefficient use of material in package design. Chapter 3 provides a conceptual frame work and an extensive analysis of the *aríbalos* to build a holistic picture of packaging during the Late Horizon. Chapter 4 uses statics and lab data of various *aríbalos* to test whether some of the more specific features of Late Horizon value chains are accounted for with package design. Chapter 5 concludes the thesis with a general synthesis of finding and implication for future research on packaging history and *aríbalos*.

Although packaging history is not a well-established field, the primary focus of this thesis is to propose the application of novel literary, archival, and engineering methods to explore the historical role of packaging. Specifically, a systematic approach was made to first establish the type of packaging which was observed during the period studied (Chapter 2), then understand the entirety of its social and performance functions

(Chapter 3), and to finally extract technical information about potentially unique technology used by the society (Chapter 4). This analysis limits itself mostly to the Late-Horizon Andes, however application of the methods used in other contexts – modern and historic – seem reasonable.

# CHAPTER 2. EXAMINING GUAMAN POMA DE AYALA'S REPRESENTATION OF LATE HORIZON AND EARLY CONTACT ANDEAN PACKAGING

## Introduction

*Guaman Poma de Ayala's Chronicle*

One of the earliest Indian (/Native Peruvian) writers of colonial Peru, Felipe Guaman Poma de Ayala, who lived approximately between 1565 and 1615, is thought to have primarily worked as an interpreter for an extirpator of idolatries and later as an Indian notary (Adorno, 2000). His seminal work is *El primer nueva corónica y buen gobierno* (*The First New Chronicle and Good Government*) finished in 1615 and is also referred to as Guaman Poma's chronicle. *The First New Chronicle and Good Government* is the most extensive, native account of daily and public life of the Andean people during the Inca Empire as well as after the Spanish conquest. Drawing on both the published, Spanish accounts, *quipus*, and oral tradition, Guaman Poma's chronicle provides an 1189-page account of various aspects of Andean life. Of the nearly 1200 pages, a third of them contain drawings of the events and reoccurring happenings of Andean life around the Late-Horizon. Although at points containing partial account of events, Guaman Poma's chronicle is generally accepted as a historically accurate and valued piece of scholarship for those studying the Andes (Adorno 2000).

*Methodical Bias in Studying the Inca*

The critical and historical study of the Inca Empire has often favored a Western understanding of the documentation of Inca knowledge. Two accounts of information on the Incas are referenced substantially by historians: the one written by Spanish priest Bernabé Cobo and by Indian author Felipe Guaman Poma de Ayala. To illustrate the historians' bias towards Cobo's account of events, an analysis of five introduction textbooks on the Incas and their citations and references revealed that Cobo's work is cited 25% more than Guaman Poma's (2-1):

*Table 2-1 Citation differences in works by Cobo and Guaman Poma.*

| Source | Guaman Poma References | Cobo References | % Cobo References/ Guaman Poma |
|---|---|---|---|
| (T. N. D'Altroy, 2015) | 54 | 84 | 22% |
| (D'Altroy & Hastorf, 1992) | 6 | 10 | 25% |
| (Julien, 2002) | 51 | 97 | 31% |
| (Niles, 1999) | 30 | 39 | 13% |
| (Pease, 2010) | 1 | 7 | 75% |
| **Total** | **142** | **237** | **25%** |

Furthermore, many citations of Guaman Poma's work often make reference only to his drawings as a way of illustrating a narrative, without using the factual information provided by such work. The primary issue with such an approach is that one born and raised into a given culture, like the Andean one, will have a better and more object understanding of its less noticeable features – like packaging - than an outside observer. Which is to say, while an outsider – like Cobo - may provide honest

observations, their ability to factually document all aspects of that culture are limited to their ability to observe without assuming. Such a bias is an issue for packaging because the Spanish authors had a tendency to objectively document the various goods and things in a place, and little else. As such, packaging is mentioned sparingly, which makes the little information that is present also potentially inaccurate.

Guaman Poma however provides a wealth of information about storage because he often included it as just a fact of life. This observation does not suggest that some caution is not required. Still, relying on the Andean chronicler's work instead of Spanish authors like Cobo seems safer. This study was therefore built using mostly Guaman Poma de Ayala's *El Primer Nueva Corónica y Buen Gobierno* and, for similar justifications, additional ethnographic research. Archaeological findings about packaging in the Andes and Spanish chroniclers' reports were then used to supplement this data and corroborate.

Although finished about eighty years after the fall of the Inca Empire to the Spanish conquistadors' in 1533, Guaman Poma's chronicle presents two distinct descriptions of life in the Andes: life before and after contact with the Spaniards that correspond respectively to *New Chronicle* (pre-contact) and *Good Government* (post-contact). Observing the changes and similarities in pre-contact and post-contact packaging can enhance our understanding of the unique demands the Andes places on those trying to extract and transport resources from and through the region. In general, a total of eight unique package types are observable before and after the Spanish

conquest of the Incas in Guaman Poma's work. Of the three pre-contact packages, only the sack appears to retain its traditional design and application in the post-contact era.

## Late Horizon Packaging

The material selection for packages in the Andes prior to Spanish contact appear - in pictorial depictions - to have only been constructed of either rope, cloth, or clay. Pre-contact packages can be described broadly as follows:

1. Rope bundles
2. Sacks
3. *Aríbalos*

*Rope Bundles*

The rope bundle appears in three drawings of *New chronicle* which depict situations from pre-contact daily life (Figure 2-1)[1]. In all drawings a rope has been tied around a long and rigid or semi-rigid product. In two of the drawings the rope has been clearly wrapped around the object three times; the third drawing shows two wrappings, and the man's body also covers the anticipated location of the third. Two of the bundles appear to be roughly the same size and from the text we can infer they are carrying either firewood or straw; the rope strap attaches to the tying portion of the rope and allows a bundle to be swung over one's shoulder freeing both hands for walking and reducing the impact with carrier. The third panel (middle panel, Figure 2-1) shows a larger bundle with wheat being carried, which would not have been present in Andes prior to the arrival of the Spaniards. The scene that is being shown here only

[1] Images for document are taken from the digital edition of Guaman Poma Chronicles located in the Royal Library of Copenhagen http://www.kb.dk/permalink/2006/poma/info/en/frontpage.htm

makes sense in a pre-contact context because the headbands observed indicate an Inca royal official. Guaman Poma likely used wheat instead of some other similar native crop like maize to appeal to his intended reader: The Spanish king.


*Figure 2-1 Three drawn panels from Guaman Poma's Nueva corónica y buen gobierno showing rope bundles pre-Spanish contact (1615, pages 227, 318 and 198).*

Interestingly, every reference to firewood this author could locate in Guaman Poma's chronicle (nine in total) also contains a reference to straw. A ubiquitous tying of the two materials suggests that straw and wood played a similar function during the Late Horizon. Such a statement is also corroborated by archeological evidence which found that grass and wood fragments were perhaps stored together (D'Altroy & Hastorf, 1992; Lennstorm & Hastorf, 1992). If one supposes both were used as fire-building material, then one is also implying a hierarchy wherein certain types or sizes or wood held lesser value than those used for building houses and bridges. Whether such smaller pieces of wood were used to build baskets or other types of packaging remains unknown.

Martin de Murúa, another chronicler, wrote two versions of his chronical *Historia general del Piru*, or which the current study uses the earlier version, known as the Galvin manuscript. Of importance to the current analysis, while representing a slightly different take on Andean life, Murúa and Guaman Poma are known to have exchanged ideas and likely Guaman Poma made some of the drawings for Murúa (Adorno & Boserup, 2008). Regardless, the Galvin *Murúa Codices c*orroborate Guaman Poma's Chronicle's (Figure 2-2) use of the bundle package, as the design looks virtually identical – albeit in less detail.


*Figure 2-2 Drawing from Murúa showing a bundle rope bundle (Murúa & Ossio, 2004).*

*Sacks*

Two representations of sacks are shown in pre-contact scenes (Figure 2-3). The first image contains a wealth of information regarding the transport of goods. The large number of people shown here implies that crops were, at times, moved to storage facilities in mass. Also, the sack appears to have two variations, which seem to follow similar patterns. The first uses a rope to hold the bag on one's back while the second is using a piece of cloth. All the sacks appear to be roughly the same length and of a slightly larger diameter than the torso of the person carrying the sack. The straps on both, the rope and cloth, are shown as being placed on the underside of the deltoid and held at mid-chest by means of a knot that requires the carrier to apply an additional downward force to ground. The second drawing differs from these observations in that a single porter (crossing a bridge) is shown while moving goods. The load also appears

lighter as the man is depicted as walking upright and without the use of his hands. Such a sack could have been carrying food for the carrier of the sack, as the headband worn symbolizes a higher status person.

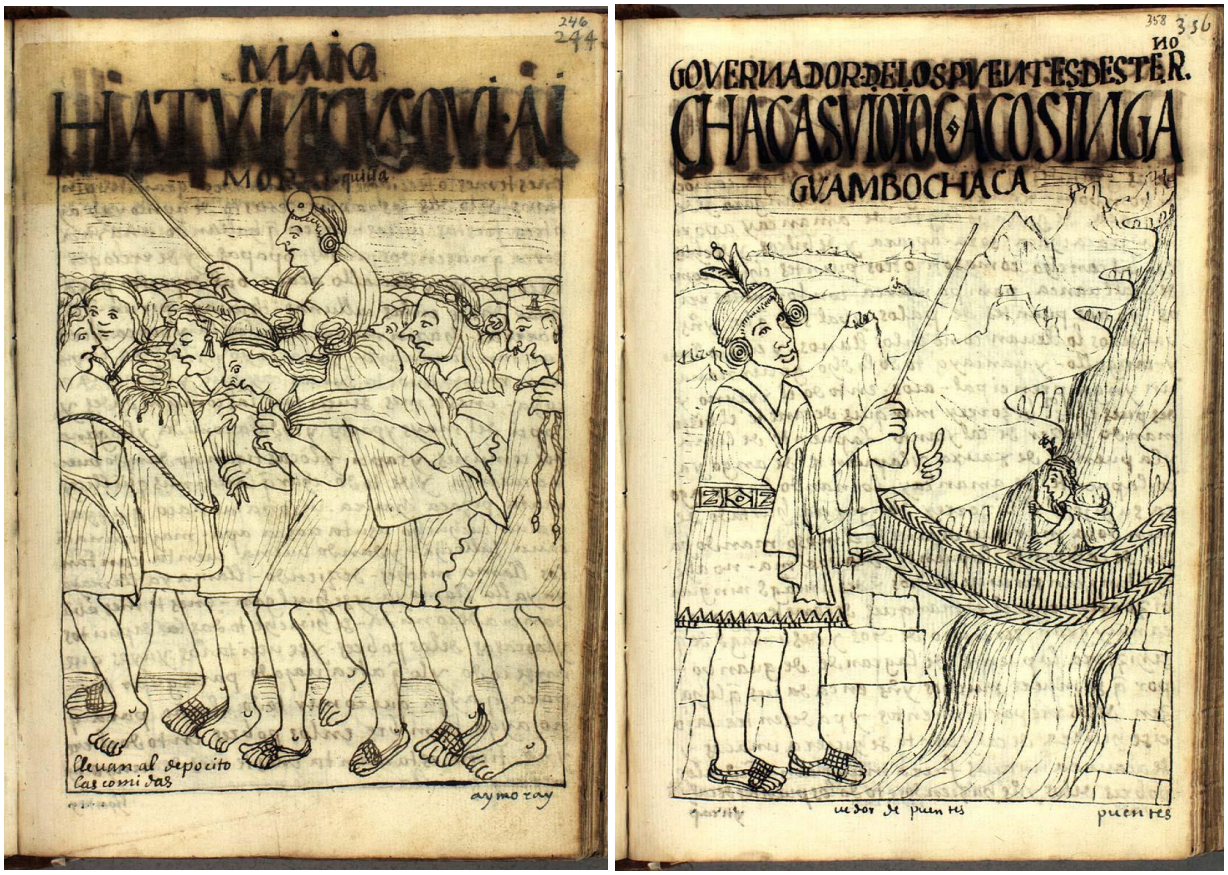



*Figure 2-3 Two drawn panels by Guaman Poma showing sacks pre-Spanish contact (1615, pages 246 and 358).*

John V. Murra has summarized two key points on Andean textiles that are relevant to the current discussion on sacks. First, Cobo had two general classifications of cloth: *awasqa*, "cloth produced for domestic purposes, which was rather rough, indifferently colored, and thick" and *kumpi* "a finer fabric, woven on a different loom" (Murra, 1962). The Western assumption would be that bags made for the Inca peoples would have been made of *awasqa* because it would appear to be less labor intensive,

however there is insufficient evidence make such an induction. Specifically, whether the transport of goods including tubers was – in a similar way to *aríbalo* – part of the ceremonial power structure of the Inca Empire has not been investigated nor seems unreasonable provided the difference in labor is not so great to preclude it. Second, Hernando de Santillan – an official of Spanish government in Chile around 1557 - observed that many bags used for carrying were made of maguey thread (i.e. fique made from various members of the genus *Fucraea*), and Garcilaso de la Vega confirmed this noting that areas that lacked wool and cotton used maguey. This implies that, at least in the highlands, it appears that maguey was likely the choice material for sacks.

Regarding ownership of sacks, a list of material provided to the Spanish by a moderate sized town over the course a few months suggests few sacks were kept by the Inca administration. Of the roughly 150,000 bushels of corn, quinoa, and potatoes given to the Spaniards, only 15 carrying bags and 12 ropes for about 22,000 large ceramic containers were given (T. D'Altroy & Hastorf, 1992)[2]. The large number of ceramics in contrast with cloth bags (despite giving over 200 pieces of cloth clothing and blankets) indicates that delivering crops in bags and giving such bags away was not a custom. This makes sense if we consider that the labor involved in producing a bag was substantial at the time. It even seems plausible that most sacks were worth more than the goods they carried.

[2] Inaccuracy dues to miscommunication, and Indian and Spaniards both being incentivized to not communicate the correct amounts means some caution is required in interpreting the exact meaning of such numbers.

Modern ethnographic research, such as G. Silverman's *A Woven Book of Knowledge*, provides insights into how the cloth for sacks might have been woven. Specifically, given the size and quality (strong enough to carry fairly large quantities of tubers) it seems likely such cloth was made using either "the backstrap loom" or "the four-stake horizontal ground loom" technique. Silverman wove moderate-sized bags for the transport of personal goods using the four-stake horizontal ground loom. The technique for the four-stake horizontal ground loom, as described in current times, is time intensive and full of symbolic meaning (conveying such information as season, time of day, geographic features, and agricultural information). The backstrap loom technique is less symbolic in its topic matter and requires less labor. Whether these techniques were also the two Cobo observed is difficult to determine, although provided the similarities in modern fine cloth to Late Horizon samples, it seems likely *cumpi* textiles were woven using a method similar to the four-stake horizontal ground loom.

The *Murúa Codices* (Galvin) corroborate Guaman Poma's use of these sacks (Figure 2-4) and elaborate some on the carrying pattern. The porter can clearly be seen bent far over, much further than shown by Guaman Poma. Such an account is similar to modern the observations in ethnographic accounts (Valderrama Fernández & Escalante Gutiérrez, 1996).

*Figure 2-4 The Murúa Codices drawings of sacks during the Inca Empire (Murúa & Ossio, 2004).*

*Aríbalos*

Two examples of *aríbalos* are observed in Guaman Poma's depiction of pre-contact Incas (Figure 2-5). Although only two drawings show *aríbalos*, they are perhaps the most well described packaging in the whole chronicle because they provide details about their transport and end-of-life use. The first panel depicts a young girl carrying an *aríbalo*; a head strap holding the jar appears to both support and stabilize the jar. The rope is not held by her hands, but instead a circle was made forming at her forehead, moving back through the handles of the jar, and snagging on the base of a lug on the front of the jar. No lid appears present on the top of the jar. The second panel shows a woman pouring *chicha* (corn beer) into a cup as part of June harvest festivities. The jar

has been placed on her side and she tilts it forward using only the ring finger on the inside of the jar to stabilize it. The rope of the jars is still attached and front of the jar faces upward as she pours.

*Figure 2-5 Two drawings of aríbalos by Guaman Poma (1615, pages 231 and 248)*

The *aríbalo* is a well-documented jar by archeologists when compared to sacks and bundles. Based on ethnographic research and archeological data, the jars appear to have been stored in either holes in the ground or on stone bases (Moore, 1989; Morris & Thompson, 1985). Although likely made for local consumption, the ritual drinking of *chicha* seems to have been mostly at a state level. For example, in La Paya – located in modern Argentina – the majority of *aríbalos* were found concentrated in a state facility

suggesting that the Inca state controlled its distribution (Acuto, 2010). Although the exact mechanisms used to control the supply chain are not known, the association between administrative centers and/or elite households has been noted elsewhere ( D'Altroy & Bishop, 1990; Morris & Thompson, 1985). Similarly, we know *aríbalos* were fairly ubiquitously decorated with simple geometric patterns in a polychrome paint and notable only on the front of the jar which faced outward as a person carried it (Donnan, 1992; Grewenig, 2004).

Similar to a the ceremonial *chicha* consumption shown in the Guaman Poma's chronicle, the *Murúa Codices* show ceremonial use of *aríbalo* (Figure 2-6)

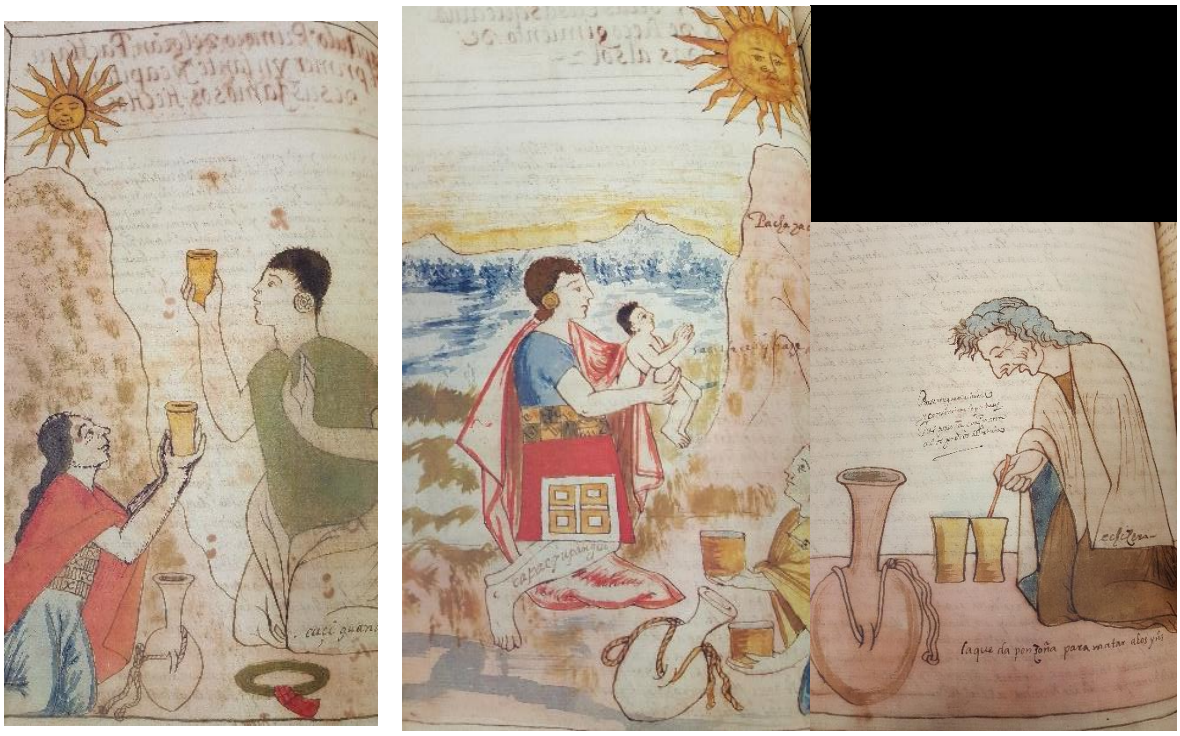


*Figure 2-6: The Murúa Codices drawings of aríbalo during the Inca Empire (Murúa & Ossio, 2004)*

## Early Contact Packaging

The packaging of the Andes, as depicted by Guaman Poma, is notably changed with the arrival of the Spaniards (starting in 1532 and continuing beyond the Guaman Poma's chronicle's publication). While retaining many of the features of traditional packages, the introduction of new designs and packaging materials - namely wood for trunks and leather for *bota* bags (sacks which hold wine)- become a source of expression for Guaman Poma's disdain for particular behaviors of certain Spaniards and their consequences for native peoples of the Andes. The post-contact packaging can be broadly classified as follows:

1. Rope bundles
2. Chest and trunks
3. Leather *Botas*
4. Wine Jars and *Aríbalo*
5. Sacks

*Rope bundles*

Three rope and bundle packages are shown in post-contact drawings (Figure 2-7). Although the package structure of the rope bundle appears similar, a shift in the wrapping pattern is observable. Three of the four bundles shown use a two-loop rope tying system. In the first panel, a man carries a bundle in which the rope is wrapped in a way not presented earlier - involving a winding of the rope around the product - and the bundle on his back is smaller than those observed in the pre-contact drawings. The second and third drawings show rope bundles used in the harvesting and transport of corn utilizing a two wrap system similar to the shoulder strap observed pre-contact.


*Figure 2-7 Three rope bundles shown in the Guaman Poma post-Spanish contact (1615, pages 861, 1148, and 1154).*

*Chest and Trunks*

Two of Guaman Poma's more emotionally potent post-contact drawings depict native porters carrying either a Spanish chest or trunk (Figure 2-8). The drawing of chests and trunks are notable because their use prior to the arrival of the Spanish seems unlikely due to the relative lack of trees that could produce trunk-worthy wood in the Andean Mountains. Further, the trees that did exist could be used for housing, bridges, weapons, or objects of ceremonial significance. The plausible implication is therefore that the Spanish either sourced their packaging externally (either from the Iberian Peninsula or other areas of Spanish colonization) or withdrew precious wood without consideration to native need. The straps used by porters in two of the drawings seem similar in placement to those observed with traditional sacks. The trunk is place on the back and the rope which supports them is placed mid-deltoid.


*Figure 2-8 Three drawings in the Guaman Poma showing chests and a trunk (1615, pages 495 and 541, and 545).*

*Leather Bota Bags*

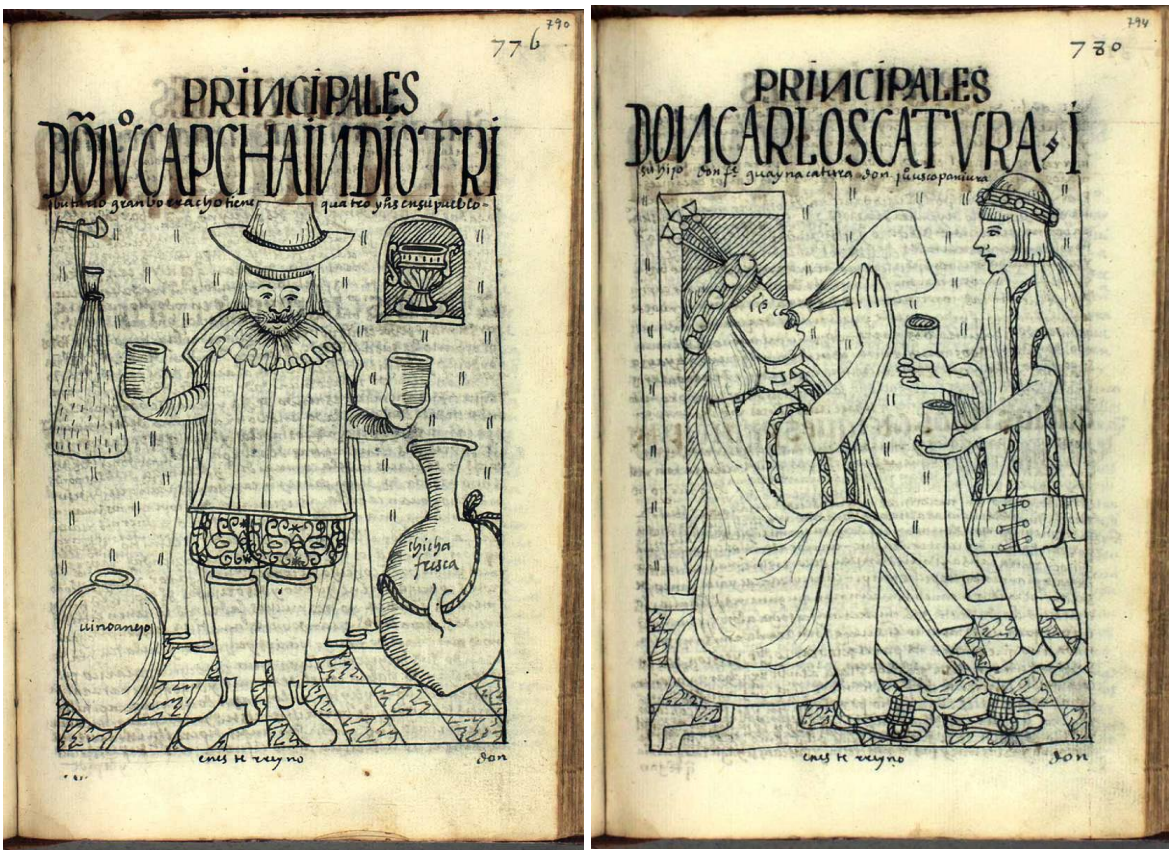
The Spaniards brought with them wine, and carried it in leather *botas* as those depicted five times in Guaman Poma's chronicle (Figure 2-9)[3]. A notable feature of these bags is that unlike *aríbalos* in the pre-contact depictions which show the aríbalo as part of either daily life or ceremonial rituals, all alcoholic beverages displayed in post-contact scenes have consumption of the beverage as a central or secondary theme.


*Figure 2-9 Five leather wine botas by Guaman Poma in post-contact scenes (1615, (pages 509, 545, 617, 790, and 794).*

[3] The author could not find sufficient documentation of when Spanish vineyards become common in Peru. The origin of such wine, how it was initially packaged before being placed in a leather bota (whether in an aríbalo from Peru or amphora, barrel, or other jar from import), and how the transport to bota transfer remain a potential area for further investigation.

Figure 2-9 (cont'd)

Figure 2-9 (cont'd)




*Wine Jars and Aríbalo*

Three long-term storage and transport jars of the Spaniards can be observed in Guaman Poma's drawings as well as a single *aríbalo* (Figure 2-10). Unlike the *aríbalos* mentioned earlier, the wine jars in the first panel have a lid on the top, suggesting that lids were used by the Spaniards and, more notably, lids were intentionally absent on Guaman Poma's earlier descriptions of *aríbalos*. The second panel tells us that the jars were roughly 50 cm tall and serve as a holding vessel for *bota* bag (upper left of photo) to be carried and/or used later. We also know the jar held wine because in this panel, the jar is labeled "wine."


*Figure 2-10 Three panels showing wine jars in the Guaman Poma (pages 538, 790, and 828) and a single aribalo (page 790) (1615).*

*Sacks*

The sacks mentioned earlier in pre-contact drawings (Figure 2-3) remain remarkably similar after the arrival of the Spaniards (Figure 2-11). These drawings show Guaman Poma's vision of the early colonial Andes, so it is perhaps not too surprising some features of pre-contact life resemble how he believes post-contact society should be organized. The depiction on the second panel shows how sacks were carried on llama, with three wrapping of a rope around the body of this animal and a sack, which were then presumably tied. The man in this panel also carried the sack in a similar manner, below the deltoid, as in earlier pictures. The first panel is intriguing because it shows a woman carrying a sack (not shown in pre-contact scenes) that is notably smaller and is carried with a neck strap instead of over the shoulder.

*Figure 2-11 Two drawings of sacks from the Guaman Poma (1615, pages 1157 and 1160).*

## Other references in Guaman Poma's Chronicle

Although pictorial descriptions are perhaps the most useful material for the goal of this investigation on Inca packaging, a number of types of references to packaging are made in *The First New Chronicle and Good Government* that tend to fall into one of three categories:

1. Package drawings of a symbolic nature but without sufficient context.
2. Package drawings too small to accurately categorize.
3. Written descriptions or referencing of packaging.

*Package Drawings of Symbolic Nature without Sufficient Context.*

A *chaski* (an Inca imperial messenger) is shown carrying a basket of snails in this panel (Figure 2-12). Such a package was transported from the coast to the valley of Cuzco, and likely accomplished in a single day. How such a basket compensated for vibration and shock damage is difficult to determine.

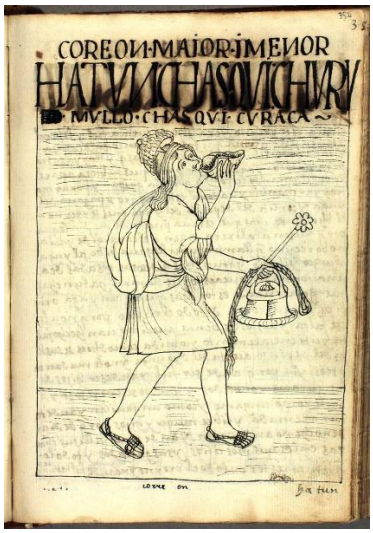



*Figure 2-12 A chaski's carrying a basket as shown in Guaman Poma (1615, page 352)*

Next, two sets of drawings help mark the arrival of the Spaniards in Guaman Poma's work. These panels depict the *sapa* Inca meeting with a Spaniard for the first time (Figure 2-13). The story of this meeting at the Inca's storehouses is known to have been fabricated by Guaman Poma. However, packaging is clearly shown in both panels, most of these appear to be of Spanish origin. The contrasting greatness of the *sapa* Inca with his large warehouses to the Spaniard's small gifts might have been posturing in an attempt to remind the King of Spain how much the natives of the Andean Mountains already gave.


*Figure 2-13 Two panels of the Guaman Poma showing symbolic packaging of some sort (pages 371 and 389, 1615).*

In another drawing we can see a Spanish nun receiving alms from an Indian woman who is turn carries a jug on her back by means of a cloth strap tied to function as a head-strap (Figure 2-14). Little else can be deducted from the accompanying text or picture, however the unique shape suggests a somewhat specific function.

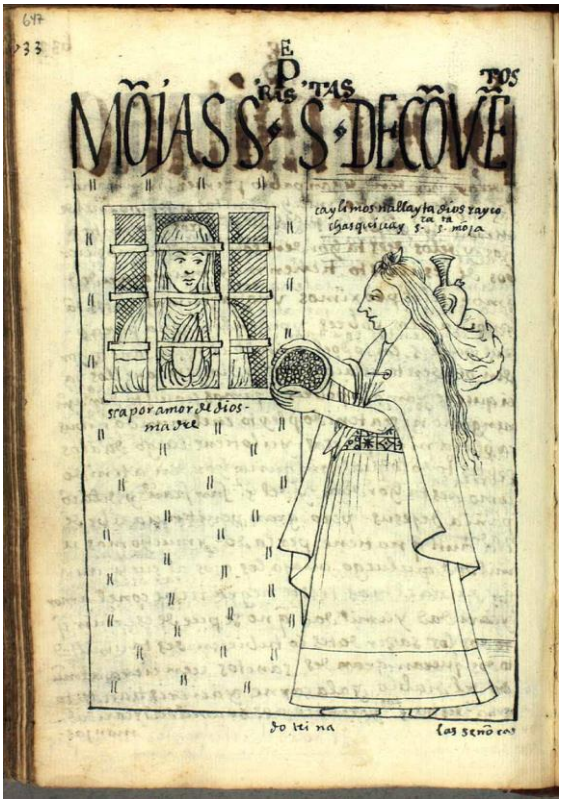


*Figure 2-14 Miscellaneous jar shown in the Guaman Poma (page 647, 1615).*

*Package drawings too small to accurately categorize*

A handful of drawings are shown later in Guaman Poma's chronicle describe the type of trade which takes place in each Andean city at that time. The interesting thing about these drawings is that different types of packaging are clearly being used to show different types of good are being transported in and out of the cities (Figure 2-15). The exact goods being transported and packages used are hard to specifically assess.


*Figure 2-15 Drawings from the Guaman Poma of various cities (pages 1009, 1021, 1031, and 1035, 1615) Different packaging can be observed in each drawing (1615).*

*Written Descriptions or Referencing of Packaging*

On page 194 of Guaman Poma's chronicle, the author writes about the laws of census in the Inca Empire, stating: "A report must be made of the manure for each *chacra*, that there be in their houses much firewood and straw, ducks; they shall have barrels called *cullona* of papas for themselves and to serve the Inca." In this way, the Indian writer tells us that during the Late Horizon, barrels – presumably to store or carry tubers - were commonly used, as they were apparently required for census required by law. The idea of storage barrels is expanded later on in the first set of "Months of the Year" panels with the following description:

> During this month [May], they made sacrifices of more parti-colored llamas. At this time there are other little festivals. They have one if they find a double maize cob or papas. They harvest the crops, take them to their house or to the storehouse to save them in a *cullona* [barrel], *chauay* [storage place], *pirua* [storage bin] (Guaman Poma de Ayala 2009, pg 247).

Here we see that such barrels, in general, are used in both common people's homes and in imperial storage facilities. Furthermore, we find a reference to *pirua* which are "storage bins" and distinct from a storage barrel called "*cullona.*" In addition, the specific meaning of "*chaway*" is somewhat harder to discern, and it could be in reference to a storage or holding area with a defined and measurable shape like those described at Inkawasi by Urton and Chu or a climate controlled environment like those described in Huánuco Pampa (Morris & Thompson, 1985; Urton & Chu, 2015).

## Discussion of General Findings

Perhaps the greatest discernable pattern relating to packaging from comparing the pre-contact and post-contact scenes of the Highlands Andean region depicted by Guaman Poma is that the social, economic, and political systems that create a need for a

specific package are confounded with the value perceptions of a dominant group. For example, when both the Inca and Spanish made alcoholic beverages, a specific package – *aríbalos* or leather *botas* - were used to communicate its content. Guaman Poma clearly demonstrates his belief that Spanish wine is bad for the native population by showing either the mistreatment of natives or their drunkenness in every panel with a leather *bota*. Similarly, the use of wood for chests and trunks communicates the Spanish lack of consideration for resource constraints of the area or desire to resist change by having heavy wooden items carried through the Andes. This happened at the cost of native livelihood. The use of sacks to store and transport crop also signals the importance of weaving in Andean society and among the Incas, as it seems likely that a basket with rope or some other less labor intensive form of package production was available. The overall pattern suggests that packaging reflects the power dynamics and culture in which it was created, and not necessarily the most effective solution for a particular value chain. Whether such idiosyncratic behaviors are sustainable seems less likely. Obviously, however, the sheer political power of the Spanish was sufficient to justify the rather gross economic inefficiency of their packaging. Stated as such, we would expect the package material and design choices of the post-contact period to gradually reflect more traditional Andean packaging over time.

Examining packaging as an expression of power dynamics reveals a number of other subtleties expressed by Guaman Poma in his chronicle. The panel in Figure 2-3 that shows the mass transportation of crops depicts an official directing porters. This official is not carrying a sack which tells us that the hierarchical administrative systems

of the Inca extended to agricultural processes and the transportation of goods. In contrast, Figure 2-11 depicts two versions of sack filling and transportation in which a group of people work together to harvest and move the goods to a storehouse (presumably state-owned). The vision expressed here tells us that Guaman Poma accepted the rule of Spaniards in the Andean region and rather wanted to renegotiate the context in which it took place. That is, Guaman Poma appears to indicate that some degree of subjugation is required in Andean life. Rather it appears, at least to this writer, that part of the frustration or appeal being made results from the Spanish not maximizing the economic output of the region and thus hurting both the Spanish crown and natives.

Further, the depictions of packaging in Guaman Poma's Chronicle and *Murúa Codices* reveal information about identity and daily life. Between the two accounts, three representations show the ceremony in which *chicha* was served. In all three, an *aríbalo* sits in front of the woman serving, a man is positioned taller than her and half pointed towards her and half outward. That is, the *aríbalo* sat between the two characters as part of the ceremony. The specific meaning of this is harder to discern, but knowing how an object we can observe today sat 500 years ago during its intended use provides some meaning to such large and imposing jars. In the panel on page 790 (Figures 2-9 and 2-10) the packaging is quite literally communicating the context in which a split identity is created according to Guaman Poma: the ceremonial drink of the Incas – *chicha* – accompanies the native side on the left, and those of Spaniards – wine - on the right. In between we see an Indian who has been assimilated to the Spanish lifestyle, "Don Juan

Capcha, tributary Indian, great drunkard, and enemy of all Christians." The text accompanying this description speaks of this character's poor treatments of natives as well. In this way, a more in-depth view of post-contact packaging would likely reveal the negation of identity often observed in post-contact scenes (an idea proposed and explored in Larson, 2004).

## Conclusions

Guaman Poma's chronicle demonstrates and represents transitions between pre-Hispanic and post-Hispanic contact quite clearly. Commonly addressed notions of identity, suppression of economic autonomy, and physical and moral hazard to natives are shown in the depictions of packaging. In addition, the observer gets a real sense of Guaman Poma's attempts to propose solutions and remedy changes brought by the Spanish colonization of Peru in positive and constructive manner which included shifts in approaches to packaging. Packaging provides a means for further revealing information about the dynamics which exist within a society. In the next chapter, the idea of "packaging as a lens" is taken further with the in-depth analysis of *aríbalos* pre-contact.

# CHAPTER 3.THE CHICHA VALUE CHAIN AND *ARIBALO* PACKAGING ANALYSIS

## Introduction

Packaging attributes, or the physical portions of a package which create some action within a specific context, are by definition the functional components of a package. Those unfamiliar with the function of a package's attributes often incorrectly speculate functions based on forms familiar to the observer. For example, a Roman amphora's conical-bottom is likely to be perceived by the modern consumer as just a nice shape. However, clear documentation exists that their conical-bottom allowed them to be rolled easily and stacked quiet efficiently in Roman ships (Twede, 2002b). Similarly, the word "*aríbalo*" describing the common Inca ceramic vessel derives from the Spanish perception of the jars' conical-bottom as similar to the Roman amphora, a suggestion which is in hindsight is unfortunate because – due the rocky nature of the Andes and lack of mass ocean transport – it makes little sense to assume *aríbalos* were rolled or transported in mass by ship. That is, amphorae and *aríbalos* have similar packaging attributes, i.e. conical-bottom, but are lacking in similar functions.

If separating packaging attributes from their context risks ethnocentrisms, then a model guiding the contextual interpretation of *aríbalos* attributes' functions seems likely to result in more accurate descriptions of the packaging system. Specifically, modern packaging research was used to create a conceptual model combining packaging function theories and a generic modern packaging value chain, the resulting generic

model tying packaging functions to a value chain was then used analyze *aríbalos* from the Late Horizon Andes's packaging attributes.

*Process Mapping and Value Chain Analysis*

Creating visual representations of the abstract activities of a "process" or "value creation" has provided useful knowledge to business professionals, and when applied to historical analysis creates a more substantial approach to studying the Inca Empire's packaging. Process mapping is a conceptualization technique developed by business professionals around idea that the actions people take within an organization reflect a form of collective knowledge (White & Cicmil, 2016). Process mapping can be used to describe something as large as the structure of a Fortune 500 company to something as small as how an employee screws an individual bolt. However, the most prevalent application is in describing how a business delivers a particular product or service to the final user. Value chain analysis is slightly more complex than process mapping, and contends the valuable knowledge in a process map lay in its ability to identify (1) a manufacturing organization and final user, (2) relevant stakeholders within an exchange, (3) the relationship between parties, (4) the influences on all stakeholders is assessed, and (5) the critical components of the process map (Donaldson, Ishii, & Sheppard, 2006). The current study uses modern packaging research to build a behavioral-based description of packaging functions and where they most commonly interact in a generic value chain. Late Horizon research is then used inform the likely context of each step in the value chain. Finally, deductions, based on context, are made describing how the *aríbalo* likely performed a specific package behavior. This study is

limited to Inca *aríbalos* around the Late Horizon period used for containing water or chicha in state-sponsored activity.

*Aríbalos*

*Aríbalos* are standardized long-necked jars observed throughout the Andes during the Late Horizon period. A typical jar consists of a body, neck, rim, two handles, decoration on the front, a lug on the front, and two ears below the rim (Figure 3-1; Table 3-1). A*ríbalos* account for 42% of all Inca vessels located in the Hinterlands and therefore represent a sizable proportion of Inca ceramic production (Bray, 2003). Unlike the pictorial iconography present on many Andean ceramics, *aríbalos* are marked by their signature pattern of highly repetitive geometric shapes (Malpass, 2009).

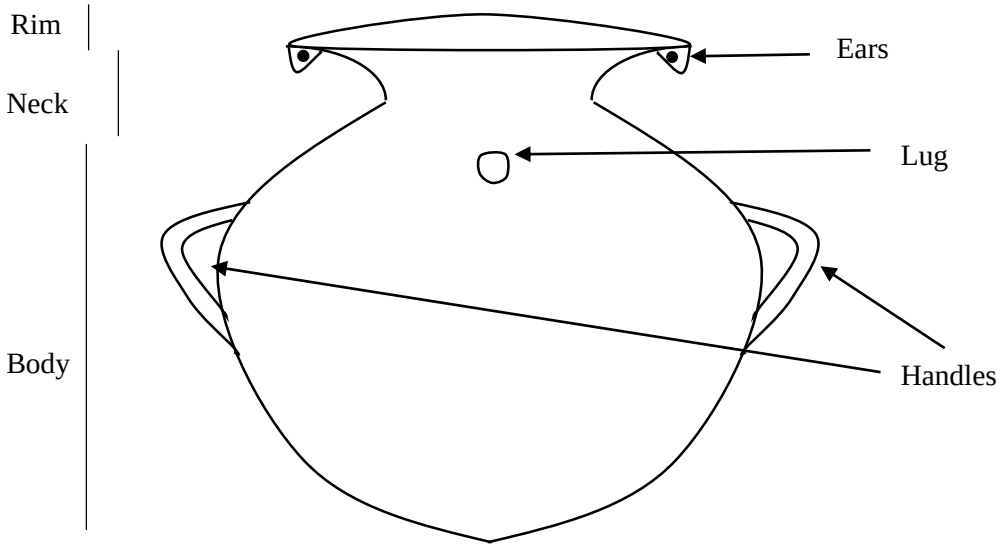



*Figure 3-1 Generalized Diagram of Aríbalo*

*Table 3-1 Examples of aríbalo of various sizes and regions.*

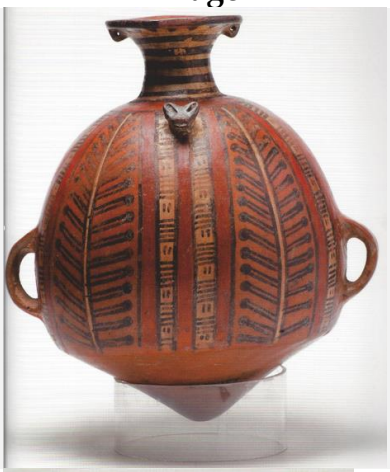
| Source | Image | Source | Image |
|---|---|---|---|
| **(Marsilio, 2010)** |  | (Donnan, 1992) |  |
| **(Marsilio, 2010)** |  | (Donnan, 1992) |  |
| **(*Storage Jar (Arballus)* (2), 15th–early 16th century)** |  | (Sawyer, 1968) |  |

*Table 3-1 (cont'd)*

| | | | |
|---|---|---|---|
| **(*Storage Jar (Aryballos) (1)*, 15th–early 16th century)** |  | (Jones, 1964) |  |
| **(Morris, Craig & Covey, 2011)** |  | (Jones, 1964) |  |
| **(Grewenig, 2004)** |  | (Grewenig, 2004) |  |

*Current Research on Packaging Functions and Value Chain*

An extensive literature review of packaging attributes was made by Simms and Trott (2014). The primary limit to the Simms and Trott model is it reliance on business to business, and business to consumer supply chains. As the Inca Empire had a great deal of exchange and lacked markets such a model requires modification.

Twede identifies seven principles of packaging (Twede, 2013). These seven principles can be thought of as indicators of efficient economic activity required for packaging. The principle functions identified by Twede replaced functional categories used by Simms and Trott because of their similarities and later publication suggest Simms and Trott perhaps did not recognize the theory on packaging they were presenting relied heavily on the work of a previous researcher in the field.

Packaging value chain work has been used to understand the movement of goods and transportation and logistics costs. The works of Hellstorm and Saghir was used to frame the discussion around the packaging value chain as a whole (2007). Similar to Simms and Trott, packaging value chain research has traditionally relied on a fairly market based structure to frame its findings. Therefore, labels were again expanded to more accurately reflect their function in non-market economies.

## Model Creation

*Packaging Functions:*

Simms and Trott provide the following list of packaging functions along with categorical imperatives to provide some guidance in their meaning:

**Protection**: effects on the supply chain, Tamper evident, role of transportation and logistics, product safety and quality, preservation/shelf life of product, and protection from: hazards, mechanical damage, chemical damage, environmental damage, climatic damage, and bacteriological (i.e. biological)
**Containment**: aid customers use of product, and containing and holding product, quality/amount, facilitating convenience in handling, effect on quality, and compatibility and constraints
**Identification**: product identification, labeling, and information (copy/illustrations on use).
**Marketing communication**: supporting marketing communications, supporting promotion of other products, sales/marketing, and product positioning.
**Cost**: transport and storage, and process and use.
**User convenience**: Openability, recloseablity, carrying, dispensing, affecting consumer value, new solutions, consumer convenience, and suitable quantity/format.
**Market appeal**: Consumer and market appeal, branding, reinforcing the product concept, ability to improve sales, and facilitating commercialization.
**Innovation**: Innovation and technology (Simms & Trott, 2014)

Some of the categorical imperatives (i.e. marketing communication and appeal) are stated in trade-based imperatives, which are lacking in the Inca Empire. The list compiled by Simms and Trott was therefore reworked into the following categorical imperatives identified by Twede:

1. Shape and geometry
2. Protection and containment
3. Economics
4. Relationships and organizations
5. Identification
6. Standardization
7. Reuse and recycling (Twede, 2013)

In addition to replacing the categories provided by Simms and Trott with Twede's categories, Simms and Trott's marketing-based terminology for packaging functions were re-written in the form of behavioral descriptions. For example, "consumer" is really a market-based term to describe the "the person who is tasked with distributing the end-product to the final user." For example, a parent might be the consumer of two-liter soda bottles while a child and their friends use it. The "consumer" is therefore behaviorally the person who initiates the removal of a package from an organizationally

controlled packaging value-chain (for this analysis, the Inca administers). For this reason the term "end-user system" was used to denote anything outside of Inca administrative use. Similar logic was applied to other terms. Also, identification and standardization were combined due to their interrelated functions.

- **Shape and geometry**: Carrying, Lifting, Dispensing, Facilitating convenience in handling, End-user system convenience, and Aid end-user system use of good
- **Protection and containment**: Effects on the supply chain, Tamper evident, Openability, Recloseablity, Product safety and quality, Preservation/shelf life of product, and Protection from: hazards, mechanical damage, chemical damage, environmental damage, climatic damage, and biological
- **Economics**: Material Considerations, Technological Considerations, Role of transportation and logistics, Facilitating mass production, Cost of transport and storage, Cost of process and use, and Compatibility with existing transport system
- **Relationships and organizations**: Establishing the good's social concept, Reinforcing the good's social concept, Good's social positioning, Controlling perceptions of good's value, Supporting organizational communications, and Supporting use of other organizational goods, End-user system social appeal, and Ability to entice end-user system action,
- **Identification and standardization**: Good's identification and Suitable quantity/format
- **Reuse and recycling**: Reuse, Recycling, and Disposal

*Functions within a Value-Chain*

Hellstorm and Saghir explicitly identify 11 broad packaging functions taking place in 5 locations (manufacturer, transport from manufacturer, distribution center, transport from distribution center, and retail center) within their model of the packaging value chain (2007). Because their analysis started with filling of a package, three additional steps "package component creation," "empty package component transport," and "package assembly" were added to the of the front current analysis. Also, because consumer use of packaging was not included in their analysis, "end-users systems" was added to the current model (Table 3-2).

*Table 3-2 Packaging Functions within a Value-Chain Modified from Hellstrom and Saghir 2007.*

| ***Location*** | **Packaging Value-Chain Function** |
|---|---|
| ***Package Manufacturer*** | (1) Component Creation |
| ***Goods Manufacturer*** | (3) Assembly<br>(4) Filling Process<br>(5) Warehousing Process |
| ***Distribution Center*** | (7) Receiving Process - 1<br>(8) Storing Process<br>(9) Picking Process<br>(10) Shipping Process |
| ***Distributor*** | (12) Receiving Process - 2<br>(13) Replenishing Process<br>(14) End-User Systems<br>(15) Re-Use, Recycle, and Disposal |
| ***Transport*** | (2) Empty Component Transport<br>(6) Filled Transport - 1<br>(11) Filled Transport - 2 |

*Matching Attributes to Value-Chain Function*

To match packaging functions to steps within the value chain, the logical location, which such a feature would become useful, was determined with a

combination of inductive and deductive reasoning. To provide an example with the packaging trait "Tamper evident," one would expect interests in such a feature after the package was filled and would likely stop caring once the product had been removed from the package. So, in Table 3-3 it is indicated that that "Tamper evident" is an active function in the warehousing process though end-user interactions.

## Aríbalos Packaging Value Chain

The logical flow of the packaging value chain during the Inca Empire took place as follows: (1) *aríbalo* were produced in nucleated works shops, (2) empty *aríbalo* were transported to *chicha* production facilities, (3-5) *aríbalos* were filled with *chicha*, (6) the *aríbalos* were transported to *qullqa* or a similar structure, (7-10) the *aríbalos* were stored and eventually retrieved from a *qullqa* or a similar structure, (11) they were transported to a state sponsored ceremony, (12-15) the *chicha* was consumed at the state- sponsored and the *aríbalo* likely exited Inca administrative control (Figure 3-2).

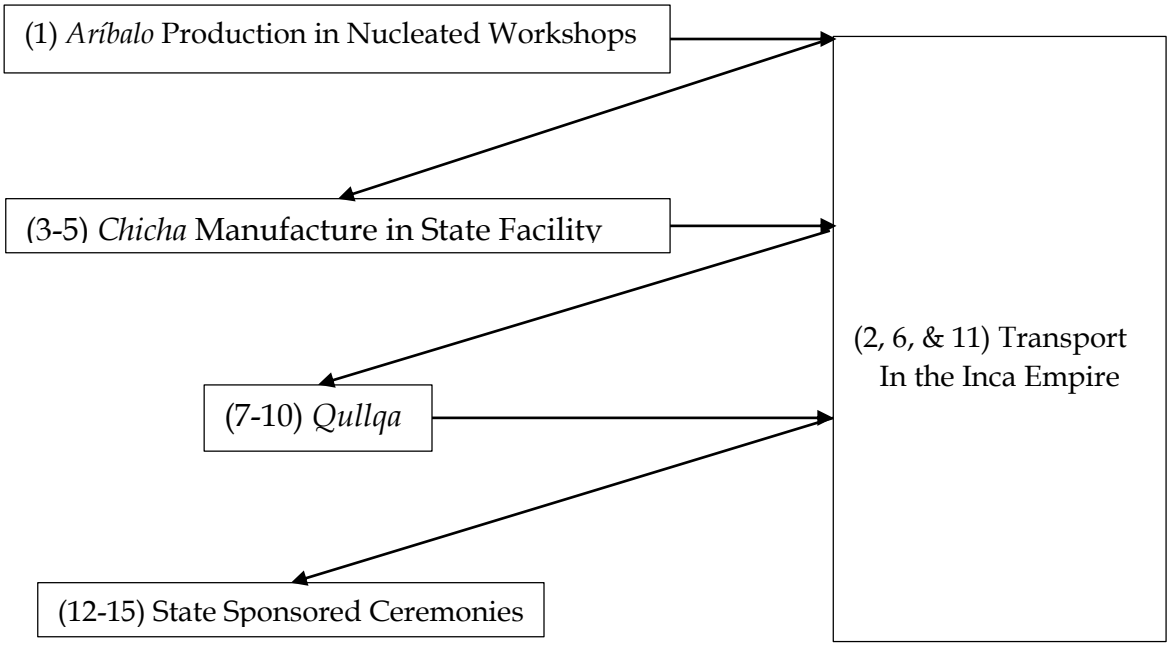



*Figure 3-2 Generalized value-chain model in the Inca Empire.*

A*ríbalos* were produced in nucleated workshops, often with low skill laborers (Costin & Hagstrum, 1995). Production varied by region; for example, the bottles of Cuzco are visually distinct in the patterns from those of outlying regions (T. D'Altroy & Bishop, 1990). The degree of variation is small and therefore indicates such work is the results of, or was overseen by, a state administrator (Costin & Hagstrum, 1995). The production of chicha and the filling of *aríbalo* likely took place in state-run facilities as brewing equipment similar to equipment used today to make *chicha* exists in state facilities (Morris & Thompson, 1985). Evidence of chicha being stored in warehouses of some sort makes sense because there is some evidence that jar holders existed in warehouses and that, given the size of feasts, it would have be stored in some facility

while it fermented, which takes place within the *aríbalo* (Morris, Craig & Covey, 2011; Valdez, 2006).

Transport of *aríbalo* with *chicha* has some documentation; for example the Guaman Poma Chronicles (see Chapter 2) depicts a chicha filled *aríbalo* being transported by a young girl. Further, studies indicate there was a defined logic to how the Inca approached transport (Jenkins, 2001). For a specific investigation into filled *aríbalos* as a transport see Chapter 4 of the current document. The ceremonial consumption of *chicha* has been well documented as a locus of control by the Inca Empire, and it makes sense as the exit point of the value chain (Bray, 2003; Cummins, 2002).

## Analysis of Aríbalo Packaging Attributes

*Shape and geometry*

The curvature, dimensions of features, and distribution of weight in a structure determine how a package is interacted with on the most basic level. The Roman amphora for example was rolled on its point on and off ships (Twede, 2002b). Similarly, a gallon milk jug - despite weighing a moderate amount (roughly 8 lbs) - can be easily lifted, placed for storage, and dispensed because its handle is conveniently located. Consumer frustrations like an inability to open pill bottles or carrying large bags of rice can result from this component of the value chain.

While ergonomics are important throughout the packaging value chain, they become of particular concern during the transport process and during end-user interactions. The ergonomics of a package during transport are notably different from

those of an end-user because they tend to engage different muscle groups, specifically gross motor-skills are required to manipulate a heavier package repeatedly and over longer distances, while fine-motor skills are required for end-user interactions like pouring or removing content from a package. The locations shape and geometry related activities interact with the packaging value chain are located in Table 3-3.

*Table 3-3 Location of shape and geometry related packaging attributes throughout the packaging value chain.*

| ***Package Function*** | **Carrying Lifting** | **Dispensing** | **Facilitating convenience in handling** |
|---|---|---|---|
| *Component Creation* | | | |
| *Empty Component Transport* | X | | X |
| *Assembly* | | | X |
| *Filling Process* | | | X |
| *Warehousing Process* | | | X |
| *Filled Transport - 1* | X | | X |
| *Receiving Process - 1* | | | X |
| *Storing Process* | | | X |
| *Picking Process* | | | X |
| *Shipping Process* | | | X |
| *Filled Transport - 2* | X | | X |
| *Receiving Process - 2* | | | X |
| *Replenishing Process* | | X | X |
| *End-User Interactions* | | X | X |
| *Re-Use, Recycle, and Disposal* | | X | X |

The particulars of transport and end-user interactions with *aríbalos* are the primary focus of Chapter 4 of this thesis, which provides evidence-based dimensional analysis of *aríbalos* showing how they were well-designed for porter-based transport. Such construction differs markedly from more traditional Western styles of bulk transport. Differences are most notable in "carrying" and "lifting" aspect of package function, while the dispensing function appears to be similar to how other large jars

might be poured. The Guaman Poma chronicle, for example shows the jug likely rested on the knee of the individual pouring it, and that at least some people held the *aríbalo* by its top while pouring (Figure 3-3). Ropes placed around the jar allowed it to be carried without hands.

The lug the back of jar increased rope stability during transport by decreasing potential slipping of the rope. The ears of the jar (see Figure 3-1 and Table 3-1) do not hold any clear function or at least none is shown in the illustrations. Potentially a piece of rope or textile might have been strung through it to act as a lid during transport and to catch spilt *chicha* while pouring.

*Figure 3-3 Guaman Poma Chronicle (left pg 248) chicha pouring and (right pg 231) carrying from an aríbalo.*

*Protection and containment*

A package must have the ability to adequately contain and protect the product it holds in order to be of much use. Roman amphoras relied on a set of producer-specific stamps to provide tamper evidence, which is evidence the product contained within a package has not be altered since leaving the supplier (Twede, 2002b). Similarly, many modern packages accomplish proof of original content by providing some difficult to recreate seal on a package which allows an end-user to know the product is likely of a safe and quality origin. Such a device however can make it difficult to open a package and reclose it for later use. Similar transport and user costs are often incurred for traits like increased product protection, shelf life preservation, and product containment.

The presence of tamper evident features also mean transporters of a good must be conscious of potentially damaging such tamper evident features because the product will also likely be viewed as damaged if the seal is damaged. Conversely, an end-user within a secure supply chain can often trust the quality, safety, and perseveration of a good because of related social systems tied to exchange. The results however are similar, some mechanism exists which ensures a good exiting the package is of an understood quality or, in-terms of the packaging value chain, the processes in-between filling and end-user interactions are within acceptable quality parameters. Protection and containment functions are a concern once the package has been filled (Table 3-4).

*Table 3-4 Location of protection and containment related packaging attributes throughout the packaging value chain.*

| *Package Function* | **Tamper evident** | **Openability** | **Recloseablity** | **Protections from damages** | **Preservation/shelf life of product Product safety and quality Containing and holding a good** |
|---|---|---|---|---|---|
| *Component Creation* | | | | | |
| *Empty Component Transport* | | | | | |
| *Assembly* | | | | | |
| *Filling Process* | | | | | X |
| *Warehousing Process* | X | | | X | X |
| *Filled Transport - 1* | X | | | X | X |
| *Receiving Process - 1* | X | | | | X |
| *Storing Process* | X | | | X | X |
| *Picking Process* | X | | | | X |
| *Shipping Process* | X | | | X | X |
| *Filled Transport - 2* | X | | | X | X |
| *Receiving Process - 2* | X | | | | X |
| *Replenishing Process* | X | | | X | X |
| *End-User Interactions* | X | X | | | X |
| *Re-Use, Recycle, & Disposal* | | | X | | |

*Chicha* is an unstable product with a short shelf life of only a few days (Moore, 1989). The sheer size and capacities of the administrative centers like Huánuco Pampa, which is about thirty city blocks and includes a 1 hectarea ceremonial plaza, indicates that state regulated ceremonial *chicha* production and consumption was a considerable logistical feat in which the *aríbalos* played a central part in achieving ( D'Altroy, 2015; Morris & Thompson, 1985).

As the relatively large sherd to whole vessel ratio indicates at many dig sites, Andean ceramics – like all ceramics – are highly vulnerable to breaking (Costin & Hagstrum, 1995; Morris & Thompson, 1985). As argued in Chapter 4 however, part of

reason *aríbalos* are well suited to the Andes are because they rely on people to navigate the difficult the terrain while minimizing the risk of damage to the jars by using the porter as a human shield and cushion. In addition to containing the chicha, the *aríbalo* likely protects chicha from other damages like UV light and environmental contaminants like dirt.

Documentation of a lid, a nearly ubiquitous means of accomplishing a closure, used on *aríbalos* are non-existent. Descriptions in chroniclers' accounts are absent of any indication of lid (see section on pre-contact *aríbalos* in Chapter 2) and the archeological evidence does not appear to indicate that lids were used. Although an easily composted material might have been used to prevent splashing, the likely explanation comes from the process of *chicha* brewing. Ethnographic work indicates wide-mouth jars are used to create a sugary mix in which lids are used to aid in heating (Jennings & Chatfield, 2009). However, the fermentation process begins with the liquid's transfer to *aríbalos*. Specifically, the fermentation process in *aríbalos* is often fast (one to six days) and sometimes the liquids "bubble violently." A lid therefore seems likely to delay such a process or cause a mess. The presence of wide-mouth jars with fitting lids and *aríbalos* absent of fitting lids in archeological sites like Huánuco Pampa confirm that lids were likely not used (Morris, Craig & Covey, 2011).

The apparent absence of lids suggest supply chain security – that is knowing the good being received was the desired good on the part of recipient – was accomplished through other means. Such a topic might be of interest for further investigation because considering the social role *chicha* has and continues to play within the Andes, the ability

to distribute counterfeit *chicha* likely carried substantial economic benefit. For similar reasons, investigations into how product safety, quality, and shelf life were monitored for mit'a labors' ceremonies might reveal insights into the administrative structure of the Inca Empire. One possibility, based on the linked increases in infectious parasites and *chicha* consumption when the Inca Empire brought a group within its domain is that *chicha* quality was not of substantial concern during such ceremonies to Inca administrators (Dorsey Vinton, Perry, Reinhard, Santoro, & Teixeira-Santos, 2009).

*Economics*

The design and implementation of a particular package type has considerations that relate to its ability to be scaled and integrated with existing systems. For example, IKEA – the Swedish home goods store – has been examined by academics and it appears much of the company's design process is driven from its ability to cheaply package and transport goods (Hellström & Nilsson, 2011).

Such considerations are more prevalent at the beginning of the packaging value chain, although their influence on decision-making continues throughout (Table 3-5). The reason such traits tends to be an issue at the beginning of the value chain is because this is when they can be altered and therefore a manufacture can receive the rewards of changing it.

*Table 3-5 Location of economic packaging attributes throughout the packaging value chain.*

| *Package Function* | Economics - Material Considerations | Economics - Technological Considerations | Facilitating mass production | Cost of transport and storage | Cost of process and use | Compatibility with existing transport system |
|---|---|---|---|---|---|---|
| *Component Creation* | X | X | X | | | |
| *Empty Component Transport* | | X | X | | | |
| *Assembly* | | X | X | | X | |
| *Filling Process* | | X | X | | X | |
| *Warehousing Process* | | | | X | | |
| *Filled Transport - 1* | | | | X | | X |
| *Receiving Process - 1* | | | | X | | |
| *Storing Process* | | | | X | | |
| *Picking Process* | | | | X | | |
| *Shipping Process* | | | | X | | |
| *Filled Transport - 2* | | | | X | | X |
| *Receiving Process - 2* | | | | X | | |
| *Replenishing Process* | | | | X | | |
| *End-User Interactions* | | | | | | |
| *Re-Use, Recycle, and Disposal* | X | | | | | |

Packaging in a Western context is often predominately driven by the availability of material, as this has historically related to lower market costs (Twede, 2005; Twede & Selke, 2005). Although analyzing patterns from recent societies and applying them to ancient empires is often dangerous, the available evidence indicates material availability and cost of package conversion (i.e. technological consideration) drove Inca reliance on *aríbalos*.

The production of ceramic vessels is performed throughout the Andes today; as numerous communities continue to tie the production of pots into their annual cycles like one might with the planting crops (Dean, 1993). Such documentation indicates clay is a readily available material for most people in the Andes. The availability of sherds and whole jars identified as Inca provide evidence that this was likely the case during the Inca Empire too (Bray, 2003; Costin & Hagstrum, 1995). Many of the processes used to create *aríbalos* were well established prior to the Incas rise to power as there is clear evidence to similar jars being made prior to Inca conquest of a territory (Costin and Hagstrum 1995).

The combination of an available, often-used material to make pots similar to those already produced indicate *aríbalos* lacked design innovation at its fruition. Such evidence does make sense however as pragmatism is often observed in Inca decision making, and this indicates such thinking extended to decisions regarding packaging. Perhaps the most intriguing aspect of the entire packaging design and material sourcing process is that Inca ceramics, and particularly *aríbalos*, are more standardized than those produced by local communities not under Inca state rule which generally resulted in better and more consistent quality of finished jars (Costin, and Hagstrum 1995). Inca administrative guidelines or systems requiring a lower tolerance in variation, in turn, likely enabled their value-chain to be more consistent. Whether logistical (i.e. related to efficiency) or aesthetic (i.e. power or ceremonial prowess) purposes drove such standardization is not clear, provided the evidence.

*Relationships and organizations*

End-user package interactions are those, which aid in the intended use of a good. These can be thought of as utility features of a package, which either make using the good easier, give prestige to the good, encourage use of the good, or encourage some secondary package function. Modern packaging design is highly motivated by these packaging functions. For example, a "Please remember to recycle." printed on the bottom of a carton would be an example of social appeal. A handle on a milk jug would be an example of end-user convenience. Because the end-user is ultimately the person who creates the value that justifies the rest of the packaging value chain, such interactions should not be over looked or taken lightly. How the sum of such offering are constructed builds on known and implicit institutions and establishes a relationship between the end-user and the organization which sells it. For example the "Please remember to recycle" logo indicates certain perceptions the producing organization desires of those using it (i.e. we want the end-user to recycle).

From a packaging value chain perspective, creating the desired social perception can be intensive and can requires tight regulation of everything from the sourcing of material for the good and package, to the disposal of the package once the good has been depleted. This contrasts with the effects of such controls that matters primarily at the end of the value chain, when the consumer actually interacts with a good (Table 3-6).

*Table 3-6 Location of relationship and organization related packaging attributes throughout the packaging value chain.*

| ***Package Function*** | **End-user system convenience**<br>**Ability to entice end-user system action**<br>**Aid end-user system use of good** | **End-user system social appeal** | **Establishing the good's social concept**<br>**Reinforcing the good's social concept**<br>**Good's social positioning**<br>**Controlling perceptions of good's value**<br>**Supporting organizational communications**<br>**Supporting use of other organizational goods** |
|---|---|---|---|
| *Component Creation* | | | X |
| *Empty Component Transport* | | | X |
| *Assembly* | | | X |
| *Filling Process* | | | X |
| *Warehousing Process* | | | X |
| *Filled Transport - 1* | | | X |
| *Receiving Process - 1* | | | X |
| *Storing Process* | | | X |
| *Picking Process* | | | X |
| *Shipping Process* | | | X |
| *Filled Transport - 2* | | | X |
| *Receiving Process - 2* | | | X |
| *Replenishing Process* | | | X |
| *End-User Interactions* | X | X | X |
| *Re-Use, Recycle, and Disposal* | | X | X |

The end use of *aríbalos* is known to have taken place predominately in ceremonial contexts. Specifically, smaller *aríbalos* were carried by young girls who would assist in the filling of cups. Men and boys drank the chicha from a specialized cup called a "*quero*" (Cummins, 2002). Larger jars also appear to have been carried by and used for serving by women during ceremonies – specifically the *Aclla Cuna*, both of these can be observed directly in Figure 3-3.

The painted decorations on the side of *aríbalos* facing outward (i.e. facing the front of the jar) assisted in the ceremonial use of chicha by enhancing the visual dynamics of the ceremony. As modern ethnography has shown, much of the appeal and meaning in native Andean hinterland ceremonial life derives from the diversity of

stimulating colors and patterns with intersecting and contrasting meanings (Silverman, 2008). In this respect, *aríbalos* can be seen at enhancing its use by helping to create the atmosphere in which the Inca intended it to be used[4].

Specific structural features like the lip and narrow neck also likely provided functional aspects like allowing for a better control of flow rate and a reduction in spills.

Current scholarship indicates prior to Inca arrival both *chicha* and ceramic vessels were available in much of the Andes. The base materials, maize and clay, are widely available throughout the Andes. Maize specifically can be grown productively between 3,100 and 3,500 m in altitude (D'Altroy 2015). Evidence also exists that maize consumption played an important dietary role in lower altitude communities prior to Inca arrival (Dorsey Vinton et al., 2009). Modern ethnography supports the idea that mechanisms of reciprocal exchange centering around *chicha* consumption predated the Inca and continued long after their fall (Jennings & Chatfield, 2009; Murra, 1980).

Interestingly, the Inca Empire managed to take these commonly available materials and increase the value of the same end product and similar package. Or, to phrase more bluntly, we have evidence from shifts in diets of subjected communities that the Inca Empire controlled chicha consumption in these communities. Meaning, they either had to control the flow of maize or chicha carrying *aríbalos*. The logical conclusions from such evidence is that the Inca implemented a limited distribution model, or the process by which an organization tightly controls the availability of a

[4] As a cautionary note, provided the variability in designs and sizes of *aríbalos*, it seems unreasonable to assume that all *aríbalos* were used for ceremonial purposes in end use. However, evidence does not exist for other end uses at time of publication and therefore is not elaborated in this investigation.

good to ensure value. Limited distribution is employed in businesses by distributing to a select number of trusted locations and standardizing the minimum price of the good. It seems likely provided the emphasis of *chicha* in ceremony, and the relative ease such goods were accessed before and after the Inca Empire, that the most logical explanation was that communities desiring to produce chicha and ceramic vessels capable of holding it were systemically prevented from obtaining key ingredients.

Although control of maize seems more likely than clay because it requires substantial time to be grown, has a short shelf-life, and can be located/grew a fewer spots than clay can be found, packaging specifically seems well suited to explaining how prestige value was added to chicha. Dig sites which have acquired *aríbalos* within local communities, as opposed to ceremonial and storage centers, often find them associated with elite housing (D'Altroy & Bishop, 1990). Archeologists have often suggested with such findings that the vessels presence signal political alliances which resulted the Inca being able to extract labor. One possible means by which local elites might have accomplished such a task is by acting as local distributors of chicha. Such a suggestion is bolstered by recent ethnography demonstrating the structure of political relationships is intimately tied with chicha consumption in the Andes (Jennings & Chatfield, 2009).

*Identification and Standardization*

Today, much of packaging's "function" is viewed as a means of achieving marketing goals for a particular product line. It is the ability of the supply chain to create a standardized enough good that a consumer can consistently identify it correctly

that forms the foundation of controlling perceptions. The supply chain is further involved in an object being efficiency grouped and retrieved from storage facilities, in that an object must sufficiently communicate the type of good, origins, quality, quantity, and remaining shelf life. The ability to identify the contents held in a package and whether it's of suitable quality and format are really matters of supply chain reproducibility and therefore important throughout the packaging value chain (Table 3-7).

*Table 3-7 Location of the packaging attributes related to identification and storage throughout the packaging value chain.*

| ***Package Function*** | **Good's Identification** | **Suitable quantity/format** |
|---|---|---|
| *Component Creation* | | X |
| *Empty Component Transport* | | X |
| *Assembly* | | X |
| *Filling Process* | | X |
| *Warehousing Process* | X | X |
| *Filled Transport - 1* | X | X |
| *Receiving Process - 1* | X | X |
| *Storing Process* | X | X |
| *Picking Process* | X | X |
| *Shipping Process* | X | X |
| *Filled Transport - 2* | X | X |
| *Receiving Process - 2* | X | X |
| *Replenishing Process* | X | X |
| *End-User Interactions* | X | X |
| *Re-Use, Recycle, and Disposal* | | X |

Recent evidence indicates Inca storehouses used a grid like system to estimate the amount of goods present (Urton & Chu, 2015). Currently only a limited number of digs have shown such a grid pattern. Although grids have not been found for *aríbalos*, stone chicha holders have been found at the storage sites of Huánuco Pampa (Morris,

Craig & Covey, 2011). Such information indicates the Inca had mechanisms identifying goods and counting them, which likely means Inca administrators also had a way of counting *aríbalos* perhaps using holes/sunk-pits, which would likely not appear in the archeological record.

*Reuse, Recycling, Disposal*

Once a product has been removed from a package, the final destination of the package can signal a bit of information about the dynamics within a society and the values of the society. If reuse is intended, it likely indicates the intentional production of a higher-quality packaging material for that purpose and therefore continuous interactions with a group of people. Recycling indicates limited resources or an attempt to reduce resource consumption by the production facility or some group regulating its production; indicating an attempt to continue to extract value from the package post-use. Meanwhile, disposal represents the use of cheap package material without trust that the material can be regained. The location of reuse, recycling, and disposal attributes in the packaging value chain can be located in Table 3-8.

*Table 3-8 the location of the packaging attributes reuse, recycling, and disposal throughout the packaging value chain.*

| ***Source*** | **Twede** |
|---|---|
| *Package Function* | Reuse<br>Recycling<br>Disposal |
| *Component Creation* | |
| *Empty Component Transport* | |
| *Assembly* | |
| *Filling Process* | |
| *Warehousing Process* | |
| *Filled Transport - 1* | |
| *Receiving Process - 1* | |
| *Storing Process* | |
| *Picking Process* | |
| *Shipping Process* | |
| *Filled Transport - 2* | |
| *Receiving Process - 2* | |
| *Replenishing Process* | |
| *End-User Interactions* | |
| *Re-Use, Recycle, and Disposal* | X |

The available evidence indicates reuse was the preferred method post-use by the Inca Empire. Such a conclusion seems reasonable because the archeological data has presented many fully intact *aríbalos* (Bray, 2003; Costin & Hagstrum, 1995; Morris, Craig & Covey, 2011). Disposal would have likely resulted in more jars being shattered, as ceramics can be easily broken and would not have been associated discarded within housing and storage units. Ceramics are not a recyclable material. Further, the limited distribution model used by the Inca for *chicha* would anticipate both reuse in the households of local elite and the creation of higher quality ceramics, which the archeological data support.

## Discussion of Inca Packaging Value Chain and Attribute Analysis

Combining packaging value chain and attribute theories, a model was created that allowed for the interpretation of *aríbalo* features in their logical context. The study revealed evidence of all the features of modern packaging were well accounted for by chroniclers', ethnographic, and archeological evidence. The Inca Empire did use *aríbalos* as more than a method for simply moving *chicha* from its production facility to ceremonies. The functions of a moderate range transport vessel are structurally present and make sense within context of the Late Horizon. The material selection processes, location of reuse, quality of construction, and intended features for the *chicha* consumer all indicate the Inca Empire strategically used packaging as a means of transforming a moderately sought after commodity into expression of state power and means of retaining it.

Although the methods used in this study are a bit precarious because they rely on extrapolated intention by acknowledging only features which appear logical in a Western theory, they are far superior to current commentaries on the *aríbalos* which simply suggest it was a jar that played an auxiliary role in Andean life under the Inca Empire (Bray, 2003; Cummins, 2002). Viewing the logistical accomplishments of Inca *aríbalos* as auxiliary to its social function ignores the complexity revealed in this value chain analysis. More to the point, the anticipated long-term nature of relationships between the Inca Empire and its subject peoples is demonstrated by the administrative care put into such a package's design and construction. The current analysis demonstrates substantial evidence that *aríbalos* were engineered to fit and perform

optimally within the context for which it was created. Specifically, given the sum of the data discussed it is abundantly clear that *aríbalos* enabled the bulk movement of a valuable fluid in a way that signaled the fluids social function in an environment lacking in wheel-based transport and retail settings.

Modern package designers looking to create packages for environments without wheels or ships for bulk transport – i.e. those requiring a person to carry them - might consider using some of technical features of *aríbalos*, which is the subject of Chapter 4.

# CHAPTER 4. *ARIBALO* MASS AND VOLUME: A CASE STUDY IN PACKAGING DESIGN

## *Introduction*

Although *aríbalo* research lacks the ability to reveal precise methods employed to carry Inca packaging, the application of statics to the attribute analysis performed previously enables this study to reveal insights into *aríbalo* engineering, which in-turn explains the plausibility of various carrying methods. Central to this analysis is the assumption that the *aríbalos* form follows the function of balancing an carrying a fluid load. This study relies on dimensional analysis of *aríbalos* from museum samplings and archival data, then extrapolates system masses and volumes.

## *Methods for Carrying Aríbalos*

Methods used to carry *aríbalos* vary by size of *aríbalo* and the age and sex of the person carrying it. In the literature, an individual author often favors one of three carrying methods, which vary in location of rope handles and the *aríbalo*'s position on the back. Those writing on the matter agree that the rope was strung through the handles and held by some means in the front of the carrier.

The first description from Bingham's 1912 expedition provides little information regarding deduction of the method. The Bingham method involves a porter holding the rope mid-deltoid and pulling down on a knot around the sternum (Figure 4-1). The method closely resembles sack carrying by men as described in the Guaman Poma's chronicle and strapper carrying methods in current times.

*Figure 4-1 (Left) Proposed aríbalo carrying method proposed by Bingham in 1912, (Middle) Pg 246 of Guaman Poma's 1615 chronicle carrying a sack in a similar method, and (right) Jennings and Chatfield's 2009 ethnographic observations of a modern day strapper carrying a Inca aríbalo.*

The second method comes from recent ethnographic research (Figure 4-2). Here a head strap appears to keep the *aríbalo* from rotating, while the sacrum holds most of the weight; arms appear to balance the force in the rope and prevent neck stain. This method resembles other non-academic documentation of mid-sized *aríbalo* in modern times.

*Figure 4-2 (Left) Ethnographic research on ceramic production showing a possible means of aríbalo carrying (Dean, 1993) and (Right) tourist photo of aríbalo from blog post (Luis, 2016).*

The third method comes from Guaman Poma's chronicle (Figure 4-3). Here the rope rests on the forehead, distinct from previous versions in its use of thoracic vertebra. Notable, the drawing shows a "five year-old" girl so clearly it depicts a smaller jar than the previous two descriptions of carrying methods. A similar method is shown performed with a textile and non-aríbalo jar later in the chronicle.

*Figure 4-3 Description of aríbalo carrying method proposed in el primer nueva corónica y buen gobierno by Felipe Guaman Poma de Ayala (Guaman Poma de Ayala, 1615)*

*Modeling Packaging-Human Dynamics*

Attempts at modeling of the spine indicate the human spine handles vertical compressive forces better than lateral movements, which tend to amplify effecting forces (Reeves & Cholewicki, 2003). Meaning, the spine supports downward forces easily, and fails earlier when presented with twisting or lateral forces. Functionally this should lead to a package design that minimizes twisting forces that cause injuries and unneeded energy expenditure. Given the general importance of efficient transport in the Inca Empire and the fragility of the spine, the current analysis examines whether,

through conscious effort or trial and error, the Inca optimized *aríbalo* design to reduce twisting. Diagramming of balanced forces reveal this to be the case.

Specifically, the three *aríbalo* carrying methods outlined above involve balancing 3 forces exerted by a strapper on a jar. The forces result from (1) pulling on the handles via a rope, (2) pushing on the portion of the jar which rests on their back, and (3) gravity (Figure 4-4).

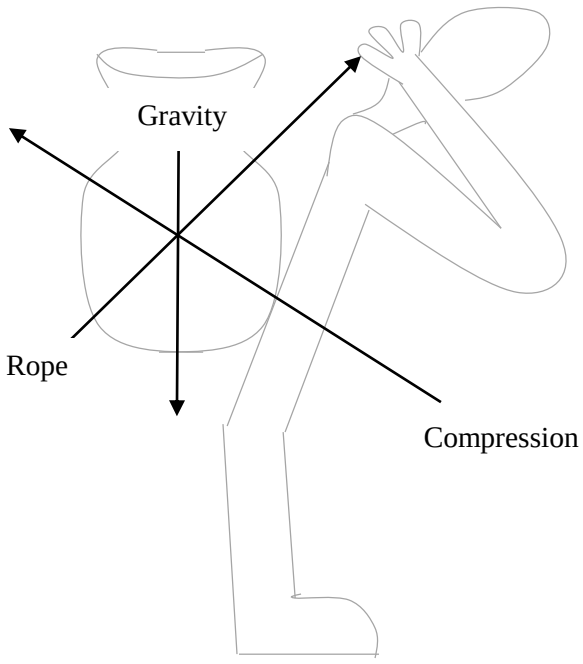



*Figure 4-4 Simplified Force Diagram of Porter Carrying an Aríbalo*

In order for the aríbalo to remain motionless in its upright position, the back and rope forces must intersect on a vertical line through the center of the aríbalo. The gravitational force acts along this line. If the construction is such that this does not happen, the aríbalo will tip forward or backward. Friction between the aríbalo and back may prevent uncomfortable tipping.

Figure 4-5 shows the forces acting on an aríbalo that is poorly designed. The aríbalo's handles were placed in a location such that the rope and back forces do not intersect on the center weight line and the aríbalo therefore tends to tip forward (i.e. away from the strapper towards the ground and spilling its content). A back or frictional force could counter-act the tipping force however, considerable discomfort would arise.

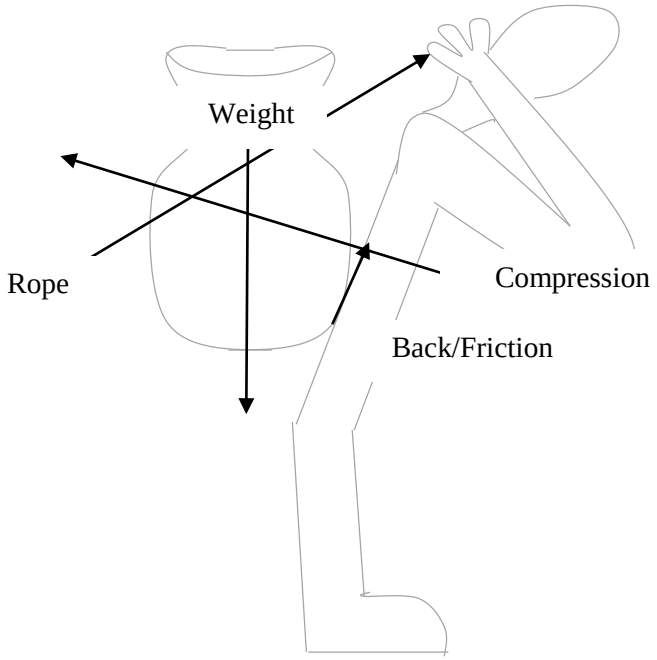



*Figure 4-5 Hypothetical misalignment of forces if handle and jar-to-back placement resulted in non-intersecting forces, where the force of friction for a motionless jar is equal to the force created by misalignment.*

Knowing this, a reasonable conclusion is that the only variable requiring adjusting is the location of the handles and rope. The best design will have intersecting forces located on the center line. This will eliminate the friction there. This can be done by changing the handles' locations and/or the point at which the aríbalo contacts the carrier's back. Figures 4-1, 4-2, and 4-3 present a consistent theme for the rope: a knot or

closed loop system was used. Once the angle and force required were determined (likely with the help of a second person supporting the *aríbalo*) a knot could be tied, thus applying a constant tension from the rope. A strapper from this point forward did not require exceptional abilities to balance or to be particularly strong, rather they just had to ensure the knot or head strap stayed at roughly the same location relative to the *aríbalo*.

Having established that *aríbalos'* design allowed it to easily balance fluid loads. The goal of this remainder of this chapter will focus on benchmarking *aríbalos* to modern packaging designed for mass transport of water. To formally state such a hypothesis:

**$H_1$**: The maximum capacity of people carry a fluid in an *aríbalo* is greater than modern single unit fluid packages carried by people.

## Methods

*Lab Data Collection - General Procedure*

With help of archive staff on Wednesday March 9th, 2016 at the Field Museum of Chicago, IL the researcher selected 12 whole *aríbalos*, and 1 aríbalo neck, and 18 sherds for analysis. A photograph of the sample and the Field Museum's identification number documented samples used. A series of sample specific measurements (explained in respective sections below) were made.

*Lab Data Collection – Whole Aríbalo*

Whole *aríbalos* selection considered *aríbalo* suitability based on their size (the 12 largest vessels available at the time) and general quality (i.e. lacking large chips

missing). A HoMedics® 531 HealthStation® (accuracy +/- 0.22 kg) scale was used to measure sample weight. A measuring tape (accuracy +/- 0.05 cm) was used to determine the distance between: (1) base to rim, (2) base to lug, (3) base to top of handle, (4) based to bottom of handle, (5) circumference below lug, (6) circumference above handles, (7) circumference around handles, (8) circumference below handles, (9) the inner and outer top rim, (10) thickness of handle, (11) displacement of ear from rim, and (12) size of ear opening. For samples with limited feasibility of certain measurements (for example, a lack of ears on an *aríbalo*), the final analysis still included the available measurements relevant to the analysis performed.

*Lab Data Collection – Sherds*

Sherds selection criteria focused on identifying samples either used or from similar ware to *aríbalo* based on their likelihood of originating from *aríbalos* (minimal orientation), thickness (based on *aríbalo* measurements, samples thickness greater than 0.4 cm), and ability of methods used to calculate density (i.e. no more than 5 corners). An UpScale/ Rite Weight pocket scale (accuracy +/- 0.3 g) was used to measure the mass of sherds. An iGaging Digital Protractor (accuracy +/- 0.1 degree) was used to measure angles formed. A digital caliper (accuracy +/- 0.1 mm) was used to measure the thickness at each corner along with the distance between one corner and the next.

*Lab Data Collection – Neck and Rim*

This study also included measurements of a large neck and rim because of relative scarcity of large *aríbalo* samples, using the aforementioned tools for mass, base

to rim distance, ear opening size, out and inner rim difference, mid-neck circumference, and top opening diameter.

*Archival Data Collection - Whole Aríbalo*

To further gather samples for dimensional analysis, this study used ARTstor (Digital Library of images from museums) using the terms "*aríbalo*" and "Inca jar" with a date restriction set to 1400 AD to 1560 AD. Samples appearing in general shape and labeled as some synonym of "*aríbalo*" qualified for further investigation into whether the sample originated at a creditable institution and was denoted as being "Inca" in origin. Achieving the four criteria resulted in inclusion for analysis. In addition to ARTstor samples, this study made use of a select number of previously located large vessels from art history and archeology publications.

*Data Analysis - Sherds*

The following progression of equations was used to calculate the density of three-sided samples (Figure 4-6), where SAE = Surface Area Estimate[5] (based on an adjacent sides and angles), D = Distance, θ = Angle, T = thickness, V = volume, and m = mass:

[5] Two surface area estimates were averaged, instead of all three, because they produced similar estimates (i.e. deviation within 1% of the either samples' total weights).

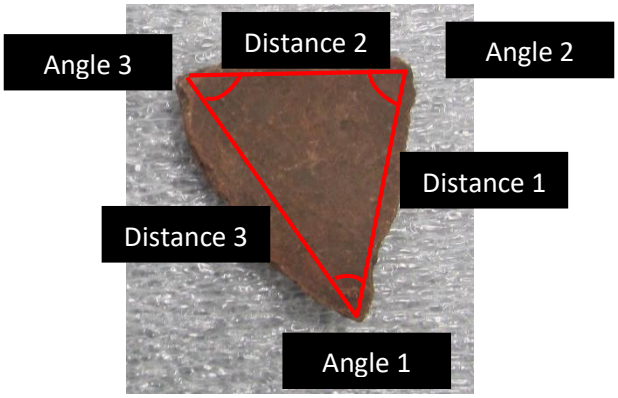



*Figure 4-6 Example of distance and angle numbering used*

$$\textbf{Eq 1}.SAE_1 = \frac{D_1 * D_3 * Sin(\theta_1)}{2}$$

$$\textbf{Eq 2}.SAE_2 = \frac{D_1 * D_2 * Sin(\theta_2)}{2}$$

$$\textbf{Eq 3}.SAE_{avg} = \frac{\left(SAE_{3-edge,1} + SAE_{3-edge,2}\right)}{2}$$

$$\textbf{Eq 4}.T_{avg} = \frac{T_1 + T_2 + T_3}{3}$$

$$\textbf{Eq 5}.\boldsymbol{V} = SAE_{avg} * T_{avg}$$

$$\textbf{Eq 6}.D = m/V$$

The following progression of equations was used to calculate the density of four-sided samples (i.e. calculating the area of a quadrilateral using the Bretschneider's formula) where S = semi-perimeter length, D = distance of side[6], and θ = angle on the quadrilateral between the sides labeled (i.e. $\theta_{12}$ = between sides 1 and side 2):

$$\textbf{Eq 7} = \frac{D_1 + D_2 + D_3 + D_4}{2}$$

[6] Similar to in the three-side samples, the side closest to the researcher (decided arbitrarily) was counted as side 1 and counted up counterclockwise around the sample.

$$\boldsymbol{Eq\ 8} = SAE_1$$

$$= \sqrt{\left((S - D_1) * (S - D_2) * (S - D_3) * (S - D_4)\right) - \frac{D_1 * D_2 * D_3 * D_4 * (1 + (Cos(\theta_{12} + \theta_{34})))}{2}}$$

$$\boldsymbol{Eq\ 9} = SAE_2$$

$$= \sqrt{\left((S - D_1) * (S - D_2) * (S - D_3) * (S - D_4)\right) - \frac{D_1 * D_2 * D_3 * D_4 * (1 + (Cos(\theta_{23} + \theta_{14})))}{2}}$$

$$\boldsymbol{Eq\ 10} = T_{avg} = \frac{(T_1 + T_2 + T_3 + T_4)}{4}$$

Then, Eq 3, 5, and 6.

The final analysis excluded five-sided sherd density measurements because the calculations for surface area for irregular pentagons rely heavily on secondary measurements (i.e. diagraming images) and introduced too much secondary error into calculations using the available tools. Microsoft Excel was used to aggregate and calculate sherd density averages and standard deviations.

*Data Analysis – Aríbalo Dimensional Analysis*

While maintaining original proportions, whole *aríbalos'* photos (lab and archival) were resized to roughly fit on an individual piece of paper. On a printed version of the photo, pen dots were added to mark the *aríbalo*'s center point location (near the top, middle, and bottom of the jar, Figure 4-8). A vertical line was drawn in the center. Next, horizontal lines were drawn at roughly equal vertical intervals across the bottle. For each *aríbalo*, a record sheet was used to track the following measurements: the length of vertical line segments (i.e. the height of a segment), the length of each horizontal line

(i.e. diameter at a segment), and the vertical distance from the *aríbalo* bottom of each horizontal line (relative placement of lines).

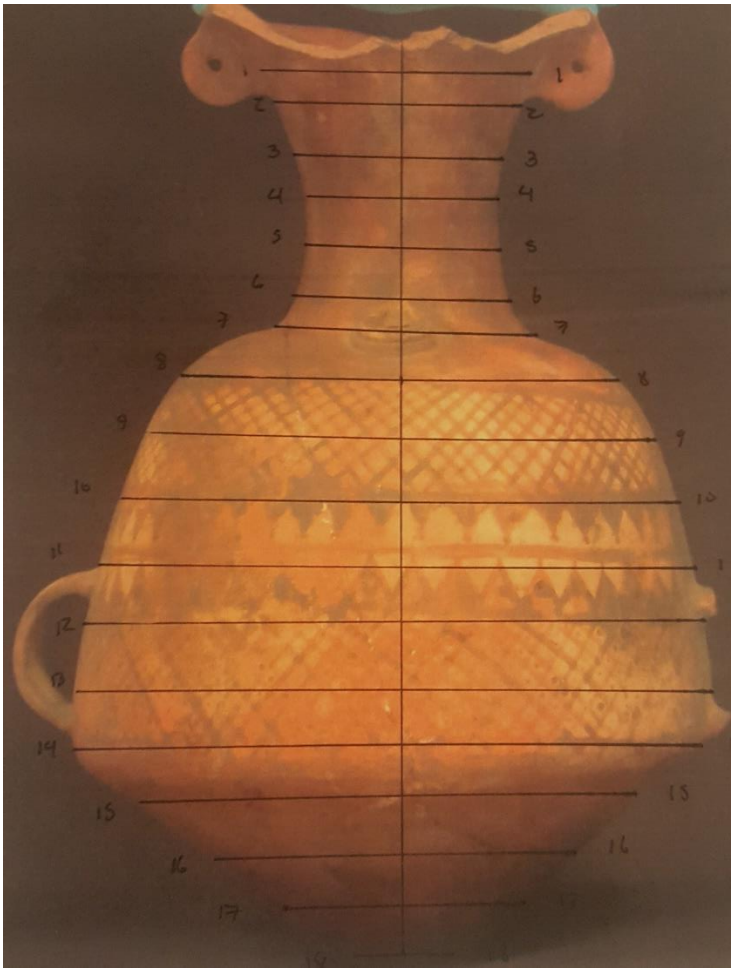


*Figure 4-7 Example of dimensional analysis performed on aríbalos.*

Microsoft Excel was used to aggregate data for analysis. Using the vertical length and an averages of the diameter created a band for analysis. To scale the data from paper to measured size, paper measurements were multiplied by a conversation factor created by the base to rim height (from either the lab research or the stated height in archival) divided by the total *aríbalo* height on the sheet of paper.

The following equations were used to calculate *aríbalo* mass where B = band height and R = radius (taken by dividing the average diameter in half)[7]:

$$\textbf{Eq11}: \mathrm{V}_{aribalo\ wall\ section} = \pi * B * (R^2_{outer} - R^2_{inner})$$

$$\textbf{Eq12}: \mathrm{V}_{aribalo\ wall\ total} = \sum \mathrm{V}_{aribalo\ section_{n1+n2\ldots Nx}} * T_{aribalo}$$

$$\textbf{Eq13}: \mathrm{m}_{aribalo} = \mathrm{V}_{aribalo\ total} * D_{avg\ all\ sherds}$$

The difference between measured and calculated mass was determined, where Err = deviation between calculated to measured mass and ABS = absolute value:

$$Err = ABS\ \left(\frac{(m_{aribalo\ calculated} - m_{aribalo\ measured})}{m_{aribalo\ measured})}\right)$$

Similarly, to calculate the volume of the fluid the *aríbalo* held (note: to account for fluid volume, the total volume factored out the *aríbalo*'s wall-volume):

$$\textbf{Eq15}: \mathrm{V}_{aribalo\ fluid\ section} = \pi * B * R^2_{Inner}$$

$$\textbf{Eq16}: \mathrm{V}_{aribalo\ fluid\ total} = \sum \mathrm{V}_{aribalo\ section_{n1+n2\ldots Nx}}$$

*Data Analysis - Archival Aríbalo*

Samples were measured using the same dimensional analysis procedure performed for the lab samples. The analysis used a thickness of 0.65 cm for an *aríbalo* under 50 cm in height and 1.00 cm for *aríbalo* over 50 cm. The neck and the rim analysis relied on similar techniques to those used with the *aríbalos*.

[7] Radius outer was determined by scaling the diameter measurements taken on paper. Radius inner was calculated by removing the thickness of the aríbalo (determined experimentally) from the radius outer (calculated).

## Results

*Density of Sherds*

A total of 14 of 18 sherd samples measured qualified for use in the final analysis (average = 2.1 g/cm$^3$, SD = 0.30). Table 4-1 outlines the complete findings, while Figure 4-9 provides a visual representation of sample deviation from the mean.

*Table 4-1 List of Calculated Density of Sherds from Field Museum with Average and SD Listed at Bottom. Variation is equal difference between the average for all density measurements and density of the sample.*

| *Sherd Sample* | Field Museum Identifier | Density (g/cm3) | Variation |
|---|---|---|---|
| *1* | 241810.8 | 1.858 | 0.281 |
| *2* | 241810.14 | 1.961 | 0.178 |
| *3* | 241810.22 | 1.597 | 0.543 |
| *4* | 240354.13 | 2.068 | 0.072 |
| *5* | 240354.22 | 2.754 | 0.614 |
| *6* | 240354.27 | 2.326 | 0.187 |
| *7* | 240354.29 | 1.967 | 0.172 |
| *8* | 240354.3 | 2.008 | 0.131 |
| *9* | 240357.1 | 2.516 | 0.377 |
| *10* | 240357.8 | 2.188 | 0.049 |
| *11* | 240357.1 | 2.238 | 0.099 |
| *12* | 240357.11 | 2.449 | 0.309 |
| *13* | 240357.13 | 2.020 | 0.120 |
| *14* | 240357.15 | 2.001 | 0.138 |
| | Average | 2.139 | |
| | Standard Deviation | 0.298 | |

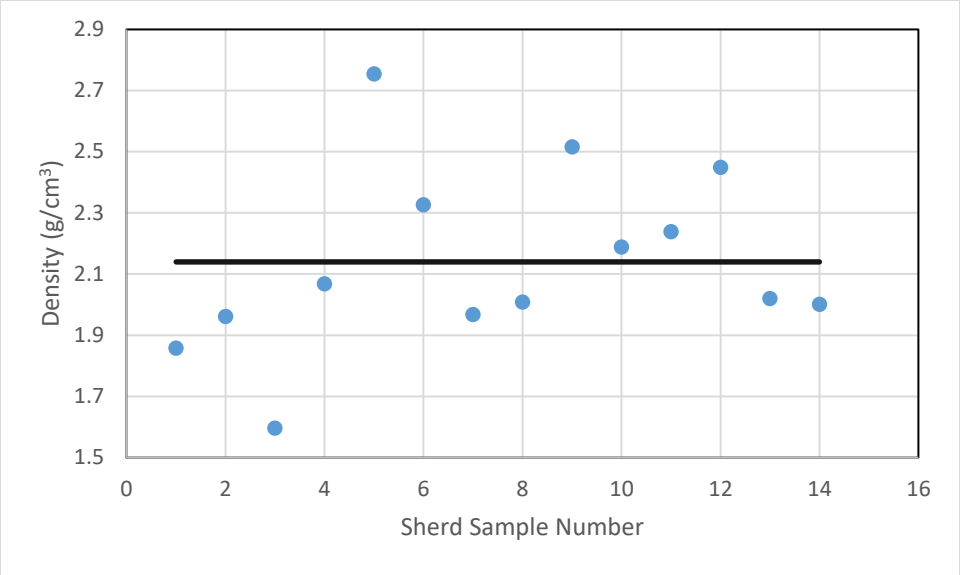



*Figure 4-8 Sherd Samples Collected at Field Museum Calculated Density Deviation from Average Calculated Density*

*Lab Aríbalo Samples – Method Validation for Mass and Circumference*

The reliability of an analytical tool, like the dimensional analysis employed, relates to its ability to predict empirical observations. As whole *aríbalo* dimensional analysis predicting mass and circumference lack previous investigation, validating the technique requires a comparison of predicted and measured values.

If the analytical technique currently being examined were used in a field study, then a reasonable estimate of density of an *aríbalo*'s material would likely be available in the form of sherds at the same location. However, because we are not certain of the *aríbalo*'s studied density, allowing for a reasonable fitting the mass of an *aríbalo* to an appropriate density more accurately reflects the accuracy of the technique on a limited sample population. To fit the data, a filter chose the value closest to one-seventh of actual jar weight, within 1 SD from the mean density to represent its fitted value (Table 4-2). Overall findings using unfitted averages reasonable represented the empirical

observations (average 16% deviation from measured weight) and fitting the averages provided an additional 8% gain (8% deviation from measured weight). Notably, some samples differed by quite substantial margins from their actual weight (namely samples 3 and 11). The calculation's reliance on a single thickness measure likely amplified small misalignments between a jar's density and the experiment's density average. Sample 3 deviates substantially in thickness (1.2 cm) when compared to the other sample weighing roughly 2 kg (average = 0.68 cm thick). Similarly, the two other large *aríbalo* samples (Sample 12 and the Rim/Neck) measured greater thicknesses (respectively 1.0 cm and 1.8 cm) to the smaller neck present in the large *aríbalo* samples like 11 (0.6 cm).

*Table 4-2 Measured Weights and Calculated Weights Using dimensional Analysis of Whole Aríbalo of the Field Museum.*

| SAMPLE | MEASURED WEIGHT (KG) | CALCULATED WEIGHT UNFITTED (KG) | DEV | CALCULATED WEIGHT FITTED (KG) | DEV |
|---|---|---|---|---|---|
| **1** | 2.18 | 2.19 | 0.01 | 2.19 | 0.01 |
| **2** | 4.99 | 4.97 | 0.00 | 4.97 | 0.00 |
| **3** | 5.08 | 8.28 | 0.63 | 7.13 | 0.40 |
| **4** | 2.18 | 2.25 | 0.03 | 2.15 | 0.01 |
| **5** | 2.81 | 3.24 | 0.15 | 2.79 | 0.01 |
| **6** | 1.91 | 2.32 | 0.22 | 2.00 | 0.05 |
| **7** | 1.63 | 2.11 | 0.29 | 1.82 | 0.11 |
| **8** | 2.27 | 2.23 | 0.01 | 2.23 | 0.01 |
| **9** | 1.54 | 1.28 | 0.17 | 1.46 | 0.05 |
| **10** | 1.91 | 1.99 | 0.04 | 1.90 | 0.00 |
| **11** | 16.24 | 10.89 | 0.33 | 12.40 | 0.24 |
| **12** | 20.77 | 20.97 | 0.01 | 20.97 | 0.01 |
| | | *Avg Dev* | 0.16 | *Avg Dev* | 0.08 |

Circumferences measurements, relative to those anticipated by the calculations, modeled the data with moderate accuracy (4% average deviation from measured circumferences; Table 4-3).

*Table 4-3 Differences in Aríbalos Empirical and Calculated Circumferences Using dimensional Analysis*

| *Sample* | *Measured Center Circumference (cm)* | *Calculated Circumference (cm)* | *Dev* |
|---|---|---|---|
| ***1*** | 68.1 | 72.5 | 0.0640 |
| ***2*** | 99.6 | 107.9 | 0.0836 |
| ***3*** | 95.5 | 101.5 | 0.0628 |
| ***4*** | 70.6 | 73.3 | 0.0381 |
| ***5*** | 82.6 | 87.8 | 0.0632 |
| ***6*** | 71.6 | 69.8 | 0.0245 |
| ***7*** | 70.2 | 70.4 | 0.0035 |
| ***8*** | 90.2 | 91.6 | 0.0159 |
| ***9*** | 59.7 | 60.3 | 0.0108 |
| ***10*** | 66.3 | 70.7 | 0.0667 |
| ***11*** | 160.8 | 162.8 | 0.0125 |
| ***12*** | 175 | 181.6 | 0.0374 |
| | | *Avg Dev* | 0.0403 |

*Aríbalo Samples – Mass and Volume*

Using dimensional analysis to determine mass and volume of both lab and archival data, the mass of *aríbalos* analyzed ranged from 0.58 kg to 21.09 kg, while maximum volume ranged from 0.81 L to 109.93 L (total *aríbalo* masses at various fill levels found in Table 4-4). The average *aríbalo* below 50 cm in height massed at 2.41 kg and held 7.59 L of fluid; the average above 50 cm massed at 16.8 kg and held 78.6 L of fluid. Mass and volume means based on height of an *aríbalo* differ significantly ($p < 0.001$).

*Table 4-4 List of Calculated Total Masses at Various Fill Level for Dimensional Analyzed Aríbalo*

| **Empty (kg)** | Bottom Handle (Kg) | Top Handle (Kg) | Base of Neck (Kg) | Max (Kg) |
|---|---|---|---|---|
| 0.58 | 0.80 | 1.07 | 1.36 | 1.39 |
| 0.69 | 0.81 | 1.13 | 1.32 | 2.19 |
| 0.87 | 1.25 | 1.83 | 2.40 | 2.46 |
| 1.00 | 1.49 | 2.16 | 2.78 | 2.84 |
| 1.28 | 2.02 | 3.26 | 5.16 | 5.53 |
| 1.99 | 3.07 | 5.16 | 8.52 | 8.73 |
| 2.11 | 3.23 | 5.51 | 9.06 | 9.33 |
| 2.19 | 3.42 | 5.51 | 9.02 | 9.52 |
| 2.23 | 5.27 | 9.71 | 14.48 | 14.69 |
| 2.25 | 3.85 | 6.71 | 9.60 | 9.90 |
| 2.32 | 4.11 | 5.90 | 8.75 | 8.85 |
| 2.35 | 5.07 | 7.05 | 9.80 | 10.00 |
| 3.15 | 5.61 | 9.16 | 13.77 | 14.03 |
| 4.97 | 8.39 | 16.94 | 22.19 | 22.75 |
| 8.28 | 12.57 | 18.09 | 27.53 | 27.88 |
| 10.89 | 31.05 | 56.38 | 92.52 | 96.02 |
| 14.14 | 22.65 | 44.54 | 65.23 | 68.38 |
| 15.42 | 26.89 | 40.98 | 72.72 | 77.04 |
| 17.27 | 32.03 | 46.87 | 79.95 | 85.65 |
| 17.97 | 29.14 | 51.36 | 86.34 | 92.34 |
| 20.97 | 43.23 | 89.21 | 126.71 | 130.90 |
| 21.09 | 59.45 | 78.11 | 112.87 | 117.58 |

Performing a multivariate regression analysis using height and maximum circumference as explanatory variables yielded a significant model ((F, 2, 19) = 148.94, $p < 0.001$; $R^2 = 0.9400$). Height explained a bit of the observed trend with a coefficient of 0.202 cm/kg ($p > .001$) while maximum circumference's effect lacked significance ($p = 0.104$). Investigating the relationship further, a plot of height against mass with linear trend resulted a coefficient of 0.275 cm/kg with an intercept of -6.211 kg ($R^2 = 0.9308$; Figure 4-10).

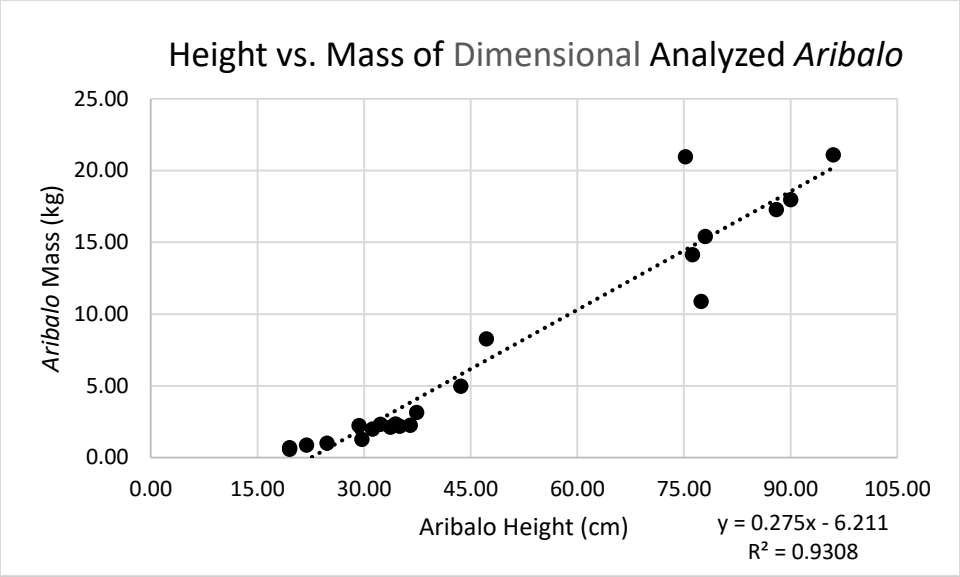



*Figure 4-9 Results of Dimensional Analyzed Aríbalo from Samples Collected from Archived Collections and the Field Museum of Chicago (R=0.9308).*

Provided the clustering at the ends of the explanatory variable data, the analysis separated samples less than 50 cm in height from those greater than 50 cm in height. Further, the large deviations from the dimensional analysis's anticipate the weight of one sample to its actual weight (see Sample 3 Table 4-2) caused it to be excluded it from multivariate modeling of small *aríbalos*.

The multivariate regression analysis of the mass of *aríbalos* less than 50 cm, using height and maximum circumference as explanatory variables, yielded a significant model ($(F, 2, 11) = 47.56$, $p < 0.001$; $R^2 = 0.8963$). Mass for *aríbalos* less than 50 cm equals -2.855 + 0.1166 (height) + 0.017213 (maximum circumference) where height and maximum circumference measure in centimeters. Meaning, the mass of *aríbalos* under 50 cm in height increases 0.1166 kg for each centimeter of height and 0.017213 kg for each additional centimeter of maximum circumference. Further, using the equation to calculate *aríbalo* mass of samples measured in the lab yielded an average deviation of

12.9% (SD = 6.56%) from the regression's anticipated value. The multivariate regression for the *aríbalo* over 50 cm lacked significance.

A multivariate regression analysis of *aríbalo* volume with height and maximum circumference as explanatory variables yielded a significant regression equation ($F(2, 19) = 110.44$, $p < 0.001$); $R^2 = 0.9207$). Volume equals -44.93 + 0.5331 (height) + 0.4786 (maximum circumference) where height and maximum circumference measure in centimeters. Meaning, an *aríbalos'* maximum volume increased 0.5331 L for each centimeter of height and 0.4786 L for each additional centimeter of maximum circumference. Both height and maximum circumference significantly predicted maximum volume.

## Discussion

*Sherd Density*

The variation observed (2 SD = 27% of average = 2.139 $g/cm^3$, i.e. 0.596 $g/cm^3$) in sherd density indicates attempts to model *aríbalo* mass and volume need to account for the possibility of deviation. In the current analysis, the observed mass of the whole *aríbalo* confirmed the dimensional analysis accurately predicated 75% of jars masses within 5% of the range anticipated by the densities above. However, future applications of the dimensional analysis likely require greater precision. Measuring ceramics sherd density of the same origin as the whole ceramic containers likely reduces differences between the two because ceramics of the same origin standardize better for regional clay variation and production technique. The current analysis attempted to rely on large regional (Andean) and production (created by the Inca Empire) samples to control for

randomness. However, the broad range of calculated densities indicates a need for greater precision.

*Mass and Volume*

*Aríbalos* analyzed ranged in the moderate to large size. Moderate sized vessels (i.e. those less than 50 cm in height and among the 12 tallest available at the Field Museum) weighed from 0.58 kg to 5.08 kg while larger vessels ranged from 14.14 kg to 20.09kg (note: the heaviest moderate sized vessel and the lightest large vessel deviated from their calculated masses, reporting ranges therefore used their more accurate real mass, using dimensional analysis values for tests of significance remained consistent throughout the analysis). The observed increase of nearly 10 kg between the largest, small sized vessel and smallest, large vessel appears common, as larger sampling (n = 728) using height and diameter found similar distributions (Bray, 2009).

Volume measurements ranges paralleled mass findings with moderate variation observed in *aríbalos* ranging from 0.81 L to 19.60 L in total volume. Similarly, large *aríbalos* made a substantial jump to range from 61.62 L to 109.90 L in maximum volume. As noted in results section, both the mass and volume differ significantly for samples above and below 50 cm in height.

*Insights in Inca Mass Transportation*

An initial investigation into how forces for *aríbalo* transport functioned revealed equal plausibility of the three methods proposed for carrying *aríbalo*.

The strap-over-deltoid method described in Figure 1, likely corresponds to a large vessel classified in this document as greater than 50 cm in height. Such vessels

weighed a substantial amount when filled and thus required a professional porter to transport.

The second method described in Figure 2 likely correspond to moderate sized vessels –less than 50 cm in height in this analysis – carried by non-professional porters and the *allca cuna*. Descriptions of the *allca cuna* serving *chicha* in moderate sized *aríbalo* exist in *The Guaman Poma Chronicles* descriptions of ceremonial life (see Chapter 2).

Smaller vessels range from the smallest analyzed in this data set to those between 5 and 20 cm in height. Small children, such as the child shown in Figure 3, likely found transporting such a vessel as a means of contributing to Inca Empire ceremonial life. Determining the specific method employed likely requires further spinal modeling analysis on a case-by-case basis (Reeves & Cholewicki, 2003).

Investigating if the average professional porter tolerates carrying a full *aríbalo* presents an opportune chance to further these findings in an applied context. The total weights for the largest *aríbalos* ranged from 68.38 Kg to 130.90 Kg with a median of 92.34 Kg. The corresponding fill levels of over 75 L are even more intriguing because they far exceed the largest, unitized water transport packages currently used (i.e. 5 gallon jugs) by a single person not assisted with wheel. However, the total weights estimated exceed the weight barring capacity for most adults. Modern specialists – i.e. strappers - in the transport of goods still exist in Cuzco, Peru today and offer an opportunity to gather insights into the biomechanics which enabled the Inca to potentially accomplish such a technological accomplishment (Valderrama Fernández & Escalante Gutiérrez, 1996).

# CHAPTER 5.CONCLUSION

## Review of Material Presented

The preceding Chapters 2, 3, and 4 presented original research created with the intent of furthering the fields of packaging science and the Late Horizon Andeans via the empirical investigation of three often overlooked aspects of modern packaging: the role of cultural shifts on packaging changes, packaging attributes and the packaging value-chain's ability to inform of the cultural role of packaging, and the relationship between structural technology and human comfort.

Chapter 2 examined, by means of Guaman Poma's chronicle along with complimentary sources, shifts in package design and material construction before and after a change in the regional dominant power. Drawing from native texts explicitly describing a movement away from a few limited package types whose materials were widely available within the local regions to a diversity of packaging forms under Spanish rule. Evidence of the negative impact such changes had on local populations was also clear from the descriptions accompanying shifts in packaging.

Further investigation into the localization of the package design and material section are made might reveal a great deal about how value is placed on materials within a region. Further, as use of the Spanish trunk suggest too, direct application of non-familiar packaging forms to a region also carries a risk of system inefficiency, as it likely made little sense for a logistics or material sourcing perspective to use a package primarily optimized for a square space.

Chapter 3 combined a package attribute analysis with a packaging value chain analysis. Combining the two techniques was performed in order to further investigate how the Inca might have accomplished such logistical feats as those described in the ceremonial literature on the Inca Empire. Such a technique revealed substantial evidence of a highly tailored packaging solution that might be useful to experts the Late Horizon because *aríbalos*, and perhaps other packages, can be recognized as having a broader social function.

Conversely, modern packaging analysis lacks such a technique. While both packaging attribute analysis and packaging value-chain analysis have existed for some time, an explicit method for linking such activities has not. Functionally such a model already exists in industry and the academy because comprehensive list of packaging attributes are informed from key components of the value chain. However, the explicit linking of such components to specific aspects of a value-chain remained undeveloped prior to model proposed.

Further research into attribute value chains would likely reveal means in which the logistical efficiency of new and existing packaging solutions could be improved with less trial and error because such a comprehensive model explicitly acknowledges that a package's value chain and attributes are functionally context specific. Which is to say, the context of a packaging value-chain is not the same across geo-political regions and therefore the packaging attribute requirements should not be expected to share contexual similarities. When moving into new markets and trying to solve a logistical

feat, then it might be advantageous for packaging professional to recognize such a difference.

Chapter 4 examined the structure of *aríbalos*. Analysis indicated *aríbalos* structure minimized user discomfort. *Aríbalos* were examined for both mass and volume in order to determine roughly how large they were in-case the information might be of use to archeologists. Previous literature also suggested *aríbalos* were mostly carried empty however, evidence in the balancing of forces for all jars was given indicating that the construction of *aríbalos* were likely such that they could be carried by one person full. The idea of *aríbalos* being well designed and fairly precisely crafted products enhances our communal respect for the technological feats of non-Western societies.

**Concluding Remarks**

Often, packaging as a field resorts to marginal utility analysis for assessing the likelihood of a successful outcome. Such techniques have proven largely successful in optimizing the construction of traditional Western supply chains (i.e. largely dependent on square unitized loads). Many modern problems facing packaging engineers and the global community are not truly matters of greater efficiency; rather they are investigation into how to tailor solutions to a more localized market.

The hope in providing the aforementioned studies is start a conversation about how and why efficient packaging to one group might be viewed as inefficient to another. Chapters 2 examined such a shift, while Chapters 3 and 4 more closely investigated the underlying efficiency of such a package within the proper context. Obviously using an *aríbalo* in a modern Western value-chain would be inefficient.

However, inferring that it was therefore poorly designed within the context it was meant to be used lacks in approach what is needed to resolve many current packaging issues. Provided the frameworks developed packaging engineers might be able to reduce their time and cost in developing packaging solutions enabling a more sustainable, socially aware, and profitable movement and transport of goods.

# WORKS CITED

## WORKS CITED


Acuto, F. (2010). Living Under the Imperial Thumb in the Northern Calchaqui Valley, Argentina. In *Distant Provinces in the Inka Empire: Toward a Deeper Understanding of Inka Imperialism* (pp. 108–150). Iowa City: University of Iowa Press.

Adorno, R. (2000). *Guaman Poma: Writing and Resistance in Colonial Peru*. University of Texas Press, Austin/Institute of Latin American Studies.

Adorno, R., & Boserup, I. (2008). The Making of Murúa's Historia General del Piru. In *The Getty Murúa: Essays on the Making of Martin de Murúa's "Historia General del Piru," J. Paul Getty Museum Ms. Ludwig XIII 16*. Los Angeles: Getty Research Institute.

Bray, T. (2003). Inka Pottery as Culinary Equiment: Food, Feasting, and Gender in Imperial State Design. *Latin American Antiquity*, *14*(1), 3–28.

Bray, T. (2009). The Role of Chicha in Inca State Expansion. In J. Jennings & B. Bowser (Eds.), *Drink, Power, and Society in the Andes* (pp. 108–132). Gainesville, FL: University Press of Florida.

Costin, & Hagstrum, M. (1995). Standardization, Labor Investment, Skill, and the Organization of Ceramic Production in Late Prehispanic Highland Peru. *American Antiquity*, *60*(4), 619–639.

Cummins, T. (2002). *Toasts with the Inca: Andean Abstraction and Colonial Images on Quero Vessels*. University of Michigan Press.

D'Altroy, T., & Bishop, R. (1990). The Provincial Organization of Inka Ceramic Production. *American Antiquity*, *55*(1), 120–138.

D'Altroy, T., & Hastorf, C. (1992). The Architecture and Contents of Inka State Storehouses in the Xauxa Region of Peru. In T. LeVine (Ed.), *Inka Storage Systems* (pp. 259–286). Norman: University of Oklahoma Press.

D'Altroy, T. N. (2015). *The Incas* (2nd ed.). Singapore: Blackwell Publishing Ltd.

D'Altroy, T. N., & Earle, T. K. (1985). Staple Finance, and Wealth Finance, and Storage in the Inka Political Economy. *Current Anthropology*, *26*(2), 187–206.

Dean, A. (1993). *Ecology and Ceramic Production in an Andean Community*. Wheaton, Illinois: Cambridge University Press.

Dillehay, T. D. (2013). Economic Mobility, Exchange, and Order in the Andes. In K. Hirth & J. Pillsbury (Eds.), *Merchants, Markets, and Exchange in the Pre-Columbian World* (pp. 283–308). U.S.A.: Dumbarton Oaks.

Donaldson, K., Ishii, K., & Sheppard, S. (2006). Customer Value Chain Analysis. *Research in Engineering Design*, *16*(4), 177–183. https://doi.org/10.1007/s00163-006-0012-8

Donnan, C. (1992). *Ceramics of Ancient Peru*. Hong Kong: Pearl River Printing Company.

Dorsey Vinton, S., Perry, L., Reinhard, K., Santoro, C., & Teixeira-Santos, I. (2009). Impact of Empire Expansion on Household Diet: The Inka in Northern Chile's Atacama Desert. *PLOS One*, *4*(11), e8069.

Grewenig, M. M. (2004). *Inca Gold: 3000 Years of Advanced Civilisation Masterpieces from Peru's Larco Museum*. Weltkulturerbe Volkinger Hutte.

Guaman Poma de Ayala, F. (1615). *El Primer Nueva Corónica y Buen Gobierno*. Retrieved from http://www.kb.dk/

Guaman Poma de Ayala, F. (2009). *First New Chronicle and Good Government : On the History of the World and the Incas up To 1615*. (R. Hamilton, Trans.). University of Texas Press.

Hein, A., Georgopoulou, V., Nodarou, E., & Kilikoglou, V. (2008). Koan amphorae from Halasarna – investigations in a Hellenistic amphora production centre. *Journal of Archaeological Science*, *35*(4), 1049–1061. https://doi.org/10.1016/j.jas.2007.07.009

Hellström, D., & Nilsson, F. (2011). Logistics-driven packaging innovation: A case study at IKEA. *International Journal of Retail & Distribution Management*, *38*(9), 638–657. https://doi.org/10.1108/09590551111159323

Hellstrom, D., & Saghir, M. (2007). Packaging and Logistics Interactions in Retial Supply Chains. *Packaging Technology and Science*, *20*(3), 197–216.

Hyslop, J. (1984). *The Inca Road System*. New York: Academic Press.

Jenkins, D. (2001). A Network Analysis of Inka Roads, Administartive Centers, adn Storage Facilities. *Ethnohistory*, *48*(4), 655–687. https://doi.org/10.1215/00141801-48-4-655

Jennings, J., & Chatfield, M. (2009). Pots, Brewers, and Hosts: Women's Power and the Limits of Central Andean Feasting. In *Drink, Power, and Society in the Andes* (pp. 200–231). Gainesville, FL: University Press of Florida.

Jones, J. (1964). *Art of Empire: The Inca of Peru*. New York, New York: Drum lithographers, Inc.

Julien, C. (2002). *Reading Inca History*. University of Iowa Press.

Larson, B. (2004). *Trials of Nation Making: Liberalism, Race, and Ethnicity in the Andes, 1810-1910*. Cambridge University Press.

Lennstorm, H., & Hastorf, C. (1992). Stores and Homes: A Botanical Comparision of Inka Storehouses and Contemorary Ethnic Houses. In T. LeVine, *Inka Storage Systems* (pp. 287–323). Norman: University of Oklahoma Press.

Lockhart, H. E. (1997). A Paradigm for Packaging. *Packaging Technology and Science*, *10*(5), 237–252. https://doi.org/10.1002/(SICI)1099-1522(199709/10)10:5<237::AID-PTS395>3.0.CO;2-#

Luis, M. (2016, February 13). Aribalo Inca en pleno uso [Word Press]. Retrieved from jaroma2305.wordpress.com/

Malpass, M. A. (2009). *Daily Life in the Inca Empire* (2nd ed.). Westport, Connecticut: Greenwood Press.

Marsilio. (2010). *Inca: Origins and Mysteries of he Civilisation of Gold*.

Mayer, E. (2013). In the Realm of the Incas. In K. Hirth & J. Pillsbury (Eds.), *Merchants, Markets, and Exchange in the Pre-Columbian World* (pp. 309–317). U.S.A.: Dumbarton Oaks.

Moore, J. (1989). Pre-Hispanic Beer in Coastal Peru: Technology and Social Context of Prehistoric Production. *American Anthropologist*, *91*(3), 682–695.

Morris, C. (1992). Huánuco Pampa and Tunsukancha: Major and Minor Nodes in the Inka Storage Network. In T. LeVine (Ed.), *Inka Storage Systems* (pp. 151–175). Norman: University of Oklahoma Press.

Morris, C., & Thompson, D. E. (1985). *Huanuco Pampa: An Inca City and its Hinterland*. New York, New York: Thames & Hudson Ltd.

Morris, Craig, & Covey, A. (2011). *The Huánuco Pampa Archaeological Project: The plaza and palace complex.* (Vol. 1). Anthropological papers of the American Museum of Natural History.

Murra, J. (1962). Cloth and Its Functions in the Inca State. *American Anthropologist*, *64*(4), 710–728. https://doi.org/10.1525/aa.1962.64.4.02a00020

Murra, J. (1980). *The Economic Organization of the Inca State*. Greenwich, Conn: JAI Press.

Murúa, M., & Ossio, J. (2004). *Códice Murúa: historia y genealogía de los reyes incas del Perú del padre mercenario Fray Martín de Murúa : códice Galvin.* Madrid: Testimonio Compañía Editorial.

Niles, S. (1999). *Shape of Inca History : Narrative and Architecture in an Andean Empire*. University of Iowa Press.

Pease, F. (2010). *The Incas*. Pontificia Universidad Católica de Perú.

Reeves, P., & Cholewicki, J. (2003). Modeling of the Human Lumbar Spine for Estimating Spinal Loads, Stability, and Risk of Injury. *Critical Reviews in Biomedical Engineering*, *31*(1&2), 73–139.

Sawyer, A. (1968). *Mastercraftsmen of Ancient Peru*. New York: Solomon R. Guggenheim Foundation.

Silverman, G. (2008). *A Woven Book of Knowledge: Textile Iconography of Cuzco, Peru*. Salt Lake City: The Univeristy of Utah Press.

Simms, C., & Trott, P. (2014). Conceptualising the management of packaging within new product development. *European Journal of Marketing*, *48*(11/12), 2009–2032. https://doi.org/10.1108/EJM-12-2012-0733

Stanish, C., & Coben, L. (2013). Barter Markets in the Pre-Hispanic Andes. In K. Hirth & J. Pillsbury (Eds.), *Merchants, Markets, and Exchange in the Pre-Columbian World* (pp. 419–434). U.S.A.: Dumbarton Oaks.

*Storage Jar (Arballus) (2)*. (15th–early 16th century). [Ceramic].

*Storage Jar (Aryballos) (1)*. (15th–early 16th century). [Ceramic].

Twede, D. (2002a). Commercial Amphoras: The Earliest Consumer Packages? *Journal of Mircomarketing*, *22*(1), 98–108. https://doi.org/10.1177/027467022001009

Twede, D. (2002b). The Packaging Technology and Science of Ancient Transport Amphoras. *Packaging Technology and Science*, *15*, 181–195. https://doi.org/10.1002/pts.597

Twede, D. (2005). The Cask Age: the Technology and History of Wooden Barrels. *Packaging Technology and Science*, *18*(5), 253–264. https://doi.org/10.1002/pts.696

Twede, D. (2012). The birth of modern packaging: Cartons, cans and bottles. *Journal of Historical Research in Marketing*, *4*(2), 245–272. https://doi.org/http://dx.doi.org/10.1108/17557501211224449

Twede, D. (2013, January). *The History of Shipping Containers: Principles of Packaging Technology*.

Twede, D., & Selke, S. (2005). *Cartons, Crates, and Corrugated Board* (1st ed.). U.S.A.: DEStech Publication, Inc.

Urton, G. (1997). *The Social Life of Numbers: A Quechua Ontology of Numbers and Philosophy of Arithmetic by Gary Urton*. Austin, Texas: University of Texas Press.

Urton, G., & Chu, A. (2015). Accounting in the King's Storehouse: The Inkawasi Khipu Archive. *Latin American Antiquity*, *26*(4), 512–529. https://doi.org/10.7183/1045-6635.26.4.512

Valderrama Fernández, R., & Escalante Gutiérrez, C. (1996). *Andean Live: Gregorio Condori Mamani and Asunta Quispe Huamán*. University of Texas Press.

Valdez, L. (2006). Maize Beer Production in Middle Horizon Peru. *Journal of Anthropological Research*, *62*(1), 58–80.

White, G., & Cicmil, S. (2016). Knowledge acquisition through process mapping: Factors affecting the performance of work-based activity. *International Journal of Productivity and Performance Management*, *65*(3), 302–323. https://doi.org/http://dx.doi.org/10.1108/IJPPM-01-2014-0007