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Andean Fermented Beverages

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Abstract

Latin American indigenous tribes used the fermentation processes as means of food processing and preservation. In the Andean regions of Latin America where the Inca empire had its civilization, the production of beverages was among the major practices that involved a natural fermentation processes. For the Inca's population, the production of alcoholic beverages was important because they played an essential role in their spiritual beliefs., These drinks were considered to have a high symbolism because of the Incan cosmovision. The present chapter describes the traditional fermented beverages of pre-Columbian cultures of the Andean region of South America. Spontaneous fermentation processes were used as a way of alcohol production by using native (in pre-Colombian time) and Old World crops (in post-Colombian time). By allowing an aqueous mixture of fruits or vegetables to ferment, a great variety of alcoholic beverages with a low to a moderate alcoholic content (2–12%) were obtained. Such substrates are rich in fermentable sugars and/or polysaccharides. In some cases preliminary steps such as chewing, germination or roasting were carried out to allow the process to easily occur and also to obtain assorted drinks. This chapter elaborates on the raw materials used, including: Manioc or Çassava, Banana, Sugar Cane, Sweet Potato, Rice, Cacao, Carob Beans, Maize and others. Maize production was of great importance, and for this reason, food crop also became an ingredient beverage manufacturing and this elaboration method was spread along the entire Andean region. Thus the most important and well known drink in this region was a Maize beer or maize-based beverage, called *chicha*. In Andean Latin America all chicha-like beverages with similar production methodology were called *chicha* as well. Nowadays many of these beverages are still being artisanally produced and consumed although they may have undergone changes in their composition and chemical characteristics due to the incorporation of new raw materials and elaboration methodologies. The main objective of this chapter is to introduce an improved knowledge of these traditional Andean fermented beverages, highlighting those coming from the Northwest region of Argentina. A revision of the processes involved in their manufacture will be useful in understanding

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biochemical changes associated to the action of native microorganisms on raw materials. Traditional and new technological procedures involved in their manufacture are discussed. By increasing and updating the available knowledge from a technical and scientific point of view it is expected to make a helpful contribution for those who are interested in traditional fermented foods.

Introduction

Food fermentation techniques are one of the oldest methods discovered by humanity for the purpose of food modification and preservation. These techniques probably emerged as a spontaneous phenomenon and were subsequently improved and developed as a complex practice applied by native people to many of the raw materials for food production and preservation. Cheese, bread, wine and beer are some of the oldest fermented food products produced by earlier civilizations and these foods are clear examples of the high grade of development that these techniques reached in the past. These products have also been strongly linked to culture, tradition and to the evolvement of the human race (Battcock and Azam-Ali 1998).

Fermented beverages like beer and wine are evidence of this association as they were very frequently related to power and religious acts. Empires from the cradle of civilizations all over the world like Sumerians, Babylonians and Assyrians in Asia, the Chinese empire in Asia and the Inca and pre Inca civilizations in America have a developed knowledge of brewery techniques. Mead from honey and beer from barley (*Hordeum vulgare* L.) were the most common fermented beverages in the Old World and were the most common fermented beverages and they had their counterparts in the highlands of the Andean mountain range. A considerable variety of drinks were produced from fruits, tubers, seeds, grains and cereals in the fertile valleys of Andean region. Most of these were alcoholic beverages and they played a key role in the organization and expansion of the Inca Empire.

Nowadays, most South American traditional fermented beverages are still artisanally produced. The production process has remained unchanged, but with notable variations in some regions. These modifications are related to the purpose of the drink, the available raw materials, depending on the geographical location, climate conditions and the skills of the people involved in the production of these traditional beverages. Many of these practices have fallen by the wayside and many others have persisted but have changed due to the introduction of food crops from the old world along with modifications introduced by Spaniards. This chapter introduces improved and systematic knowledge of alcoholic fermented beverages from the Andean region which have been in existence since pre Inca and pre Colombian times, with special mention of some from the Northwest region of Argentina. A revision of processes involved in their manufacture will be useful to understand changes associated with the action of native microorganisms on raw materials. Traditional and new technological procedures involved in their manufacture are commented upon. By increasing and updating the available knowledge it is hoped that this will be a helpful contribution for those who are interested in traditional fermented foods from South America.

Developmnet of Fermented Beverages Production: An Ovwerview

Fruits and vegetables are thought to be the first foods consumed as fermented products. Early hunter-gatherers could have collected and eaten fresh fruits during times of abundance but they could also have consumed rotten and fermented fruits at times of scarcity. This habit led to a developed taste for certain fermented fruits and also for the alcohol produced by spontaneous fermentation (Battcock and Azam-Ali 1998). China is believed to be the birthplace of fermented vegetables. These food products were prepared by the action of molds such as *Aspergillus* sp. and *Rhizopus* sp. to make fermented foods (Battcock and Azam-Ali 1998). This included the development of an amylolysis fermentation method, in which fungi broke down the polysaccharides in rice (*Oryza sativa* L.) and millet (McGovern et al. 2004). Archaeochemical, archaeobotanical, and archaeological evidence support the fact that the preparation of fermented beverages dates back to nearly 9,000 years ago in China (McGovern et al. 2004). There is also reliable information supporting the theory that fermented drinks were being produced over 7,000 years ago in Babylonia (now Republic of Iraq), 5,000 years ago in Egypt, 4,000 years ago in Mexico and 3,500 years ago in Sudan (Dirar 1993; Battcock and Azam-Ali 1998).

Mead, wine and beer were the first alcoholic fermented beverages produced by indigenous people in human history. Production of wine and mead was simple in comparison to beer making. Certainly, mead was the first alcoholic fermented drink because honey (the most antique fermentative substrate) and water were readily available. The process was easily feasible by just allowing a mixture of these ingredients to stand and ferment (Haehn 1956).

Inhabitants of *Mesopotamia* already knew the manufacturing process of beer according to cuneiform findings (2,700 years ago) which clearly describe the process. In the 5th century A.D. (1,500 years ago) there existed in Babylonia skilled brewers who prepared malted grains from barley. This process was described on cuneiform inscriptions as follows: barley is soaked, allowed to germinate, dried and ground to obtain flour and make bread which is baked in a clay oven. Separately, a portion of malted grains is dried under the sunlight and milled. Then, the bread together with the malt and water are blended, and allowed to macerate for several days. Finally, a clear liquid is filtered and transferred to pots for the final fermentation. This process was found to be very similar to the elaboration of fermented beverages in Latin American Andean countries.

The literature describes the existence of at least twenty different types of Babylonian beers and an export trade of beer to Egypt. Egyptians implemented the browning techniques for producing a stout or dark beer and they flavored such beers it with fruits. In the 7th Century A.D. the Arabs introduced beer to Spain and prepared with malt bread along with the addition of cinnamon (*Cinnamomum verum* J. Presl), rue (*Ruta graveolens* L.) and marjoram (*Origanum majorana* L.). Greeks and Romans had wine as their preferred beverage but during the Germanic expansion, beer became an important beverage in Middle and Western Europe after the Germanic conquest of Greece and Rome 1,600 years ago (Haehn 1956).

The early inhabitants of Latin America had their own brewing techniques. Findings of microscopic archeological remains of starch and phytoliths from maize (*Zea mays* L.) in ancient pottery in Northwest Argentina, reinforces the evidence that brewery practices could have been carried out by South American natives 4,000 years ago

(Lantos et al. 2015). Brewing tools and vessels were found on the north coast of Peru where pre Inca civilizations like Moche (1,900 years ago) and Chimu (1,000 years ago) had their empires (Hayashida 2008). There is no accurate data to exactly when fermented drinks began to be produced in Andean Latin American lands but archaeological studies support the theory that even prior to the Inca expansion and establishment in South America, aboriginal peoples from Northwest Argentina already had knowledge of complex processes for the production of drinks in large amounts (Leibowicz, 2013). Identification has been based on the presence of brewing tools and vessels (for milling, cooking, fermentation), by products (e.g., strained mash), and features (e.g., hearths, pits for germinating grain) (Hayashida 2008).

Fermented beverages constituted a fundamental part of indigenous meals, which were produced by native American peoples. With the Incan civilization, technologies such as drying and fermentation achieved a exceptance for food conservation and modification. It is remarkable that these techniques were especially developed in the South American highlands along the Andean mountain range. The Indigenous peoples of South America were skilled farmers and owners of an advanced knowledge in practices for soil cultivation. The aboriginal agricultural systems were noteworthy and allowed them to produce a large quantity of diverse fruits and vegetables which were the main constituents of the Inca diet (Browne 1935).

The production of different meals and dried and fermented products was possible due to the fertile and cultivable soils of the lowlands and highlands of South America, which resulted in the production of an astonishing variety of vegetables. Different varieties of maize and potatoes (*Solanum tuberosum* L.) were domesticated in this region and they became an important staple food along with tubers and other crops such as the now acclaimed quinoa (*Chenopodium quinoa* Willd.) and amaranth (*Amaranthus* spp. L.). Such richness in the food crops available resulted in the development of indigenous techniques for food conservation such as the freezing and fermentation.

Fermentation became a complex process that was applied to many vegetables in the Andean lands which in turn led to the manufacture of different fermented beverages in Latin America that received the common or general name of *chicha*. This term in discussed later in this chapter. Andean Aboriginals fermented most of what they grew in the Andes. In the Andean regions of Latin America that were ruled by the Inca Empire, the manufacturing of beverages was among the main practices involving spontaneous or wild fermentation processes. The production of alcoholic drinks played an important role in their spiritual beliefs and they were considered to have a level of high symbolism because of the Incan beliefs. The spontaneous fermentation was used as a mean of alcohol production on the basis of native (in pre Colombian times) and Old World crops (during post Colombian times). In certain cases this process was refined and became a complex technique. These processes led to the obtainment of alcoholic beverages with a low to moderate alcoholic content (2–12%). Substrates rich in sugar and/or starch such as manioc or cassava (*Manihot esculenta* Crantz), banana (*Musa paradisiaca* L.), sugar cane (*Saccharum officinarum* L.), sweet potato (*Ipomoea batatas* (L.) Lam.), rice, cacao carob beans (*Theobroma cacao* L.) and maize were and are still being used for the elaboration of traditional fermented beverages. In some cases, preliminary steps such as chewing, germination or roasting can be carried out to allow the processes to occur easily and to create assorted drinks. Considering that maize production was of great

importance, this food crop also gained importance due to the fact it was the main ingredient in beverage manufacturing. Along the Andean Region the most important and well known drink was produced: *maize chicha*. There existed other chicha-like beverages in Andean Latin America whose production processes followed a similar methodology and they also received the same name.

Indigenous fermented beverages played key roles in human culture towards the development of fermentation technologies. These products were always considered to be healthy because of their nutritional values and sensorial attributes. They helped in the establishment of agriculture and food processing techniques (McGovern et al. 2004). These indigenous technologies have passed from parents to progeny for thousands of years and they are still in use. Certainly, some fermented products and practices not only survived the passage of time but were also tested for different conditions and changes in the region they belong to (Battcock and Azam-Ali 1998).

Vegetable Material Employed For Fermented Beverages Production in Andean Latin America

Beverages from Andean Latin America were prepared from a considerable variety of edible fruits and vegetables. Alcoholic drinks could be obtained from roots, tubers, seeds, fruits, leaves and even animal body parts, in a few cases (León and Hare 2008). Watery vegetables and fruits served as main substrates in the lowlands of Andean countries due to their proximity with the Amazonian jungle. Cereals, Andean crops, grains and seeds were used in the highlands. Spanish colonizers introduced new food crops to Latin America which were also included in the production of fermented beverages. The diversity of drinks found in Latin America is also attributed to the different ways of preparation and the intended purposes for which it is to be used, since meals were considered foods to feed the body and soul.

Aboriginal peoples from Andean Latin America take advantage of the broad biodiversity of edible food plants available in Andean lands for the production of alcoholic beverages. In the highlands, grains and tubers were used while in the tropical Andean regions sugary fruits and starchy tubers were added to common preparations.

The variety of beverages was immense, though the most popular was an alcoholic drink made on the basis of *Jora*, germinated or sprouted maize. There is another important drink called *masato,* prepared from vegetables, such as the tuber cassava. This beverage is well known in tropical areas and in low-lying regions of Andean countries where the growing of this tuber is feasible. This was the first drink that the Spaniards learnt about from the Andean tribes after arriving in Latin America. Fermented beverages in Andean Latin America were commonly prepared from cereal-like grains such as quinoa and kañiwa (*Chenopodium pallidicaule* Aellen.). Fruits from *molle* (*Schinus molle* L.) and *algarrobo* (*Prosopis* sp. L.) trees were employed for the production of fermented and non-fermented drinks, especially in the southern countries of the Andean region. The tuber oca (*Oxalis tuberose* Molina) was also an ingredient in the manufacturing of chicha. Another well-known beverage was one made with peanuts (*Arachis hypogaea* L.) and it was probably the second most important beverage after maize beer. In the tropical Andes fermented beverages included mainly apples (*Malus domestica* Borkh.), loquat (*Eriobotrya japonica* (Thunb.) Lindl.), pineapple (*Ananas comosus* (L.) Merr.) and cactus pear (*Opuntia* sp. Mill.,) among others (de Leon Pinelo 1636).

The Spanish arrival in America brought several plant materials that were incorporated later in the traditional production methodologies along with the native Andean crops. Most of the new ingredients for drinks were almost all spices such as cloves (*Syzygium aromaticum* (L.) Merr & Perry), cinnamon, citrus (*Citrus* L.), anise and sugar cane, among others. Additionally, cereals like wheat (*Triticum* L.), rice and barley were incorporated passively, but Andean crops already had a strong tradition of use. Sugar cane became an important ingredient in the production of several fermented beverages since it allowed to produce sweet drinks and permitted the production of highly alcoholic drinks and to accelerate the process of fermentation. *Panela* is a solid bar of unrefined sugar cane and can be found in the literature of fermented beverages production with Spanish names like *rapadura*, *chancaca*, *papelon* or *piloncillo*. Nowadays, the production of Andean drinks includes traditional ingredients from Andean America and those that were introduced from the Old World.

Diversity of Beverages in Andean Lands

As previously mentioned, the Spanish term *chicha* is a general name given to traditional or aboriginal Andean Latin American beverages. These may be alcoholic or non-alcoholic drinks. In most cases this term is associated with the popular maize beer which was found to be the most important alcoholic beverage of the region, since pre Inca times and even after the Spanish conquest. The production process of South America´s beer is reviewed and discussed in the coming sections of this chapter. *Aloja* was another term for beverages used in Latin America and they were normally prepared from fruits. *Aloja* was the common name of certain beverages ranging from non-alcoholic to mildly alcoholic. In northern South America and Andean deserts of Peru this term especially alludes to the beverage made from *algarroba* or *molle* fruits. Comparatively, *aloja* does not have a complex production process and it requires few ingredients and less time in processing. It is a weak drink; chicha, on the other hand, needs more preparation time, more ingredients and entails a complex process for its manufacture. Chicha can be thick in consistency, but still aqueous. This generalization needs to be taken as a general concept since in Latin American fermented beverages were and are still being produced in similar ways.

Native people in Andean countries prepared a beverage based on the bright red or pink fruits from a Peruvian native tree called molle. This tree is an evergreen, and tolerant of the dryness which is endemic in the arid zones from the northern South America to the central Argentinian and Chilean deserts. The beverage prepared with molle fruits was simple and only fruits and water were necessary. It was described as “sweet, agreeable and excellent in the treatment of oedema”. For the production of this drink around 250 g of fresh seeds yielded 20 L of *chicha de molle* (Goldstein and Coleman 2004). Technically, fruits of *Schinus molle* are drupes and are ready for chicha production when the resin pockets are fleshy and sweet due to the high level of concentrated sugars. For preparing the beverage, the fruits are boiled with water in a ceramic pot for about half an hour. Cinnamon sticks and cloves are added to flavoring the water. Then the clay pot containing the water is removed from the heat. This decoction will have turned sweet but once cooled, some tablespoons of sugarcane can be added. The overnight mixture is strained through a sieve into a ceramic pot. The pot is covered with a wet cloth and the liquid The pot is covered with a wet cloth

and the liquid is allowed to ferment for 10 days in a cool and shaded room (Goldstein and Coleman 2004; de Leon Pinelo 1693).

In Peru another chicha is prepared with assorted fruits. This drink includeds apples, loquat, pineapple, cactus pear and others. It was only considered a refreshing drink if it was not fermented. The preparation of this drink is made from fruits and also included rice, grated potatoes and carrots (*Daucus carota* L.), black grapes (*Vitis* L.), sugar cane, loquat and pineapple husks. All these ingredients were grated and well mixed. The mixture was then allowed to macerate for about 20 days and an acidic, slightly sweet liquid was obtained through straining the mixture through a sieve. This sweet liquid could be consumed immediately or an alcoholic version could be obtained through fermenting the drink for an additional number of days. At certain intervals, unrefined sugar cane was added until the drink reached the desirable alcoholic content (León and Hare 2008)

Chicha de manguey or chicha de cabuya a beverage made from *manguey* (*Agave americana* L.) and produced from the sap of manguey. To produce this drink a stalk of this plant is perforated and the draining liquid was collected and allowed to ferment spontaneously, it was normally consumed without the fermentation step; in certain cases the sap could be boiled prior to drinking. This beverage was regarded as having medical attributes. In Mexico this beverage was called *Pulque* (de Leon Pinelo 1636).

Peanuts were also employed by the native Andean peoples to prepare a beverage called *chicha de mani* which was quite popular. In its original version, this beverage was prepared only with peanuts, but after the Spanish conquest more ingredients such as rice, sesame seeds (*Sesamum indicum* L.), cinnamon, anise, cloves and digestive or aromatic herbs were added to the traditional recipe. To prepare this drink, peanuts were roasted and ground. Then, the spices were boiled in water and the peanut flour was added. This mixture was simmered and the decoction obtained was cooled. The broth obtained was allowed to sediment, the fermentation was spontaneous and it could take up to three or four days. It was rich in fat from the peanuts (de Leon Pinelo 1636).

In the Andean highlands, ground barley was also employed to obtain a fermented beverage. To prepare this alcoholic drink barley flour was browned and then boiled in water, was cooled and allowed to ferment. Sediment from other *chichas* was used as a starter culture to provide yeasts to the new drink and thus, accelerate the process.

Cassava was also used for the elaboration of a non-alcoholic beverage, a popular drink in the Amazonia region called *massato*, which was different from the alcoholic version. Cassava roots were peeled, washed and cut. It was parboiled in water and more water and honey were added. It was consumed as a refreshing beverage (de Leon Pinelo 1636).

Indigenous peoples in Latin America had no written language before the Spaniards arrival to South America. *Quechua* and *Aimara* were the most important and widespread spoken dialects and fermented beverages were named with different terms aside from *chicha*. In manuscripts of Spanish explorers the voices *aqa*, *acca* or *akka* referred to the fermented beverages of indigenous peoples and their pronunciation belongs to the *Quechua* language. In a similar way the voice *kufa* was attributed to the *Aimara* language (Nicholson 1960; Gastineau et al. 1979).

After the Spaniards arrived and colonized the region from Central to South America fermented beverages were collectively named as *chicha*. Some theories

claim the explorers named the beverage *chicha* as an abbreviation of the expression *chicha co-pa*, in which the part *chichah* means maize, and *co-pah* means drink (Pardo and Pizarro 2005). Another hypothesis about the origin and meaning of the word *chicha* refers to the preparation of this beverage. Thus, the name *chichia-tl* could mean "to ferment" and "water" and another interpretation says that *chichial* means "with saliva" (Nicholson 1960). The Spanish advance towards South America spread the name *chicha* which replaced local denominations and even the aboriginal terms of *mudai* and *palcu* for Chilean fermented beverages which were falling into disuse. Thus, the term *chicha* was assigned to every fermented beverage prepared in a similar way, but became popular and assigned to the *chicha* made from maize and cassava which were heavy and popular drinks. The Spaniard word *aloja* was attributed also to fermented and non-fermented beverages prepared mostly from fruits, (*algarrobo* mainly) and with a weaker consistency (Pardo and Pizarro 2005; León and Hare 2008).

The South American Beer: The Manufacturing of *Chicha De Maiz*

The manufacturing of maize beer is a long-lasting and complex process that requires several steps and days to obtain the alcoholic beverage. It is not a single-step spontaneous fermentation but involves the degradation and consecutive extraction of starch and sugars, which are then worked on separately and reunited again in the last step. The production of chicha also results in the acquisition of several edible by-products. Some of these are very useful and appreciated because of their nutritive value. While some products are employed for animal feeding, others can still be used to obtain other beverages which may be alcoholic or non-alcoholic (Cutler and Cardenas 1947). The Fig. 12.1 shows the production procedure for *chicha de maiz* in the Northwest Argentina.

The first stage for this procedure is the selection of the maize kernels. The quality and variety of maize beers depends on several factors among which the maize cultivar employed in production is one of the most important. Traditionally, this step was carried out by women skilled in the production of chicha which are known as *chicheras*. Several versions of *chicha* can be obtained according to the variety of maize utilized in the production of this drink. Since in the Andean region many cultivars of maize can be grown, a considerable diversity of maize beers can be produced.

Rigid kernels from a local variety of maize called *quellu sara* were used to produce an alcoholic drink in Peru. The cultivar *kulli* which had a deep purple colour was employed to elaborate a dark chicha. Another chicha was prepared with leaden-coloured grains from the variety *oqe* (León and Hare 2008). Bolivian *chicheras* preferred kernels from the *chuspillo* cultivar to prepare their alcoholic drink. This variety is cultivated with the only purpose of beer production because it is very sweet and with a many-rowed cob. The *kulli* cultivar is also used in Bolivia for the production of a burgundy coloured chicha. The kernels of this maize are appreciated for their colour, which can vary from reddish to a dark purple and they have a high content of anthocyanins (Cutler and Cardenas 1947). In the north of Argentina two local varieties are utilized in the production of chicha: *maíz criollo* and *maíz abajeño* (Otero and Cremonte 2009).

Once the maize kernels were selected they can be treated in different ways (grinding, browning, sprouting, etc.) and thus, even more varieties of maize chicha can be produced.

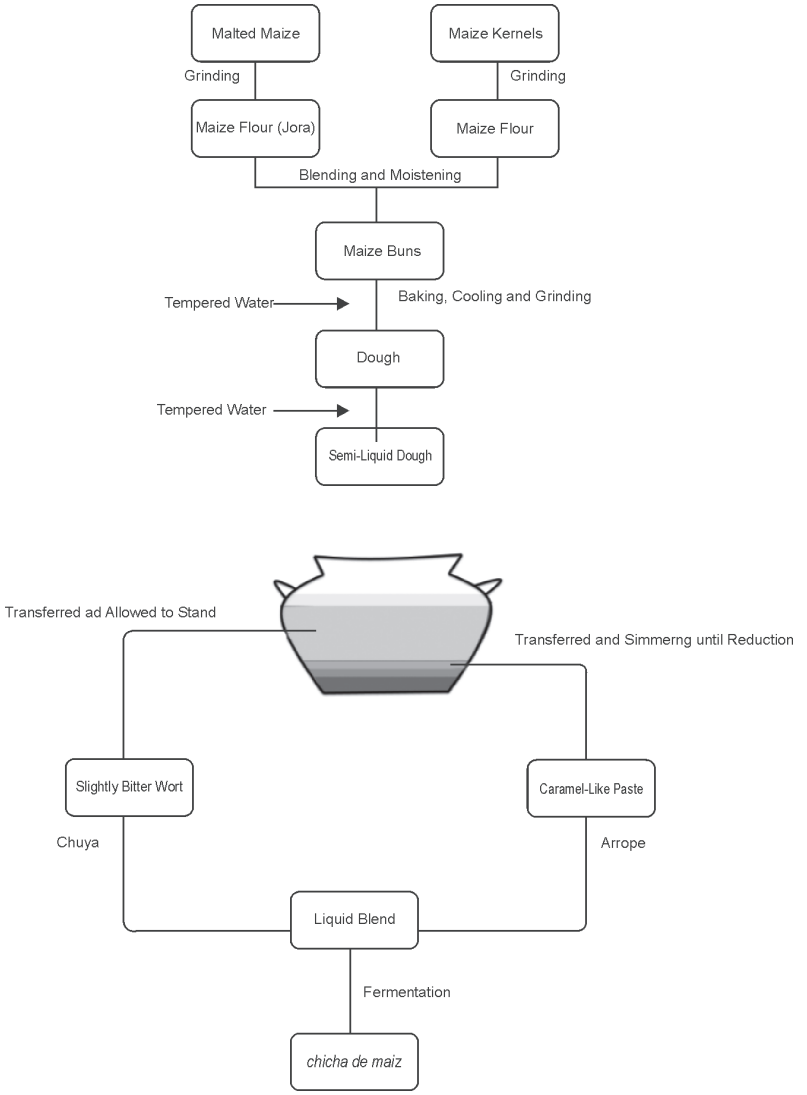

FIGURE 12.1 Flow Chart of ***chicha de maiz*** making in the northwest Argentina. This procedure is the confluent of both Spaniards and indigenous cultures.

At the beginning of the process maize kernels can be malted, browned and even chewed (with a previous slow baking). Some of these steps are preliminary to obtaining a flour (León and Hare 2008).

Malted cereals have been traditionally used in beer manufacturing because they have a high content of enzymes for starch degradation and hydrolysis into fermentable sugars. Malt does have a good enzymatic activity and can still be useful if even more starchy cereals are added (Ward 1989). In the Andean highlands of Peru malted kernels of maize were called *Jora* or *sora* and the beverage produced with the malted grains of maize was called *chicha de Jora* or *chicha de sora*. The germination is interrupted

when the radicle reaches approximately 2.5 cm in length (León and Hare 2008; Cutler and Cardenas 1947). The flour obtained after grinding this maize is called *pachuccho* and is sold in some markets. It can be stored for six months (Nicholson 1960). In Bolivia, both the germinated maize kernels and the flour obtained are called *huiñapu* or *wiñapu*. The enzyme α-amylase is synthesized during germination or malting which produces the hydrolysis of starch by breaking the α-1,4 glycosidic bonds. Another enzyme, the β-amylase, is already preformed in the kernel before the sprouting and contributes to the degradation of maltose into single units of glucose. The resultant hydrolysis products of starch are sugars like maltose and glucose which are available for subsequent fermentation (Bewlyseed 2001; Biazus et al 2009).

The browning technique in maize kernels produces a partial release of single sugars from starch (Tonroy and Perry 1975). Additionally, this reduces the level of toxic and anti-nutritional compounds such as the hydroxycinnamic acid and tannins present in maize (Ayatse et al. 1983).

The practice of chewing/salivating and spitting out food as a preliminary step in the production of beer was very common among Latin American brewers. In the Andean highlands this custom was called *mukeado* and the alcoholic drink obtained through this tradition received the name *chicha mukeada*. The purpose of chewing and/or salivating maize kernels or maize flour was to produce a partial hydrolysis of carbohydrates. This action was attributed to the amylase enzyme found in saliva. Currently, the chewing practice has fallen into disuse but it is still implemented by minor Andean tribes. In the following sections, viewpoints on this ancestral practice are given. Nowadays, *chicha* tend to be prepared from a dough from maize flour instead of *mukeado* or the chewing of kernels. The dough mentioned is called *moyapo* and the chicha produced by using this substrate is known as *chicha de masa* (Otero and Cremonte 2009).

The next step after the selection and treatment of maize kernels is the grinding for the production of maize flour. In ancient times a half-moon shaped stone over a flat stone were used as a mortar and was employed for the grinding and the production of maize flour (Cutler and Cardenas 1947). Nowadays, this method may be still in use but mechanical or electrical mills are the most widespread devices used to grind the grain (Otero and Cremonte 2009). Some *chicheras* do not ground the grains until they are reduced to a fine powder or flour, instead they grind the kernels into small particles of maize. They argue that *chicha* will be clear and more palatable with this degree of grinding (de Mayolo 1981).

In order to elaborate *chicha de masa,* a firm dough is prepared with at least two varieties of flour and the addition of previously boiled water. Then, the dough is baked in a clay oven at a high temperature (Otero and Cremonte 2009), during this process starch is partially hydrolyzed. The reducing sugars produced take part in the Maillard and browning reactions. The browning phenomenon is important because it induces changes in colour, flavour and in the nutritive value of baked food products (Purlis 2010). Maize flour has been characterized as having a high reactivity toward the Maillard reaction and to the formation of favourable compounds (Rufian-Henares et al. 2009). This step is important in the manufacture of *chicha de masa* because it initiates the desirable compounds in flavour and colour. The Maillard reaction is responsible for the typical brown colour of chicha (Elizaquivel et al. 2015).

After the obtention of a baked bun, the next step is the extraction of fermentable substrates. The extraction of carbohydrates is carried out in special ceramic potteries

(Fig. 12.2). Carbohydrates and others nutrients become soluble by macerating the cooked maize bread in water in a clay pot called *virque* (Fig 12.2A). This stage can be performed by different methods including the soaking of the bread, by decoction or by combining both methods (Ward 1989). Preliminary, the baked dough can be dis aggregated by hands or ground (Otero and Cremonte 2009).

The soaking step needs warm or tempered water (70 ºC) that has been previously boiled. Boiling water is not used since it produces an undesirable viscous paste (Cutler and Cardenas 1947), additionally, water at the boiling temperature inativates the amylolytic enzymes. Temperatures between 63–65 ºC are favourable for the activation of enzymes found in cereals and for starch degradation (Ward 1989). The substrate in maceration is continuously stirred with a large wood spoon (Fig. 12.2B) until a homogeneous slurry is obtained. Then the semi-liquid preparation is allowed to decant for few hours after which a multilayer wort can be noted. The disposition of these layers inside the *virque* is due to differences in density, solubility and grinding level of the initial substrate compounds (Fig. 12.1). Each layer has utility and none of these are discarded. Two layers are the most important for the production of chicha. One is the maize wort, locally known as *chuya* and the other is a jelly-like layer called *arrope* which is composed mainly of starch and a minor portion of single sugars. Each of these two layers is transferred into separate clay pots and given a different treatment after which they will be blended again to form the *chicha*. First, the upper layer *chuya* is transferred to a narrow-mouth ceramic vessel or *cántaro chichero* (Fig. 12.2C) and is allowed to stand for the duration of three or four days until it becomes acid (Otero and Cremonte 2009). In some cases this maize wort can be boiled for about three hours and then is cooled (Cutler and Cardenas 1947). In this vessel the lactic acid fermentation is carried out and the pH value drops up to 3.7; this step, the wort acidification, is optional and some brewers may not allow the wort to become acidic (Cutler and Cardenas 1947; Elazequivel et al. 2015). On the other hand, the jelly-like layer called *arrope* is placed in a wide-mouthed pot or *olla arropera* (Fig. 12.2D) and boiled down until it becomes thick and with a caramel-like or brown colour. At this point a two-fold increase in starch, maltose, sucrose and glucose occurs (Elazequivel et al 2015). Finally, the two most important components of *chicha de masa* are blended. The naturally acidified wort and the caramel-like paste of starch are mixed at different proportions to turn from a weak to highly alcoholic *chicha*. Immediately after the two layers are blended, *chicha* starts to bubble and when this phenomenon ceases the production gas declines and the process is considered to be complete (Cutler and Cardenas 1947). As the environmental temperature may vary according to the geographical region and season, the time of fermentation may also vary. In some circumstances, the fermentation is completed in just one or two days (Cutler and Cardenas 1947) or it can last up to one month or more (León and Hare 2008). This last stage of the process is called *the maturing of chicha*. If it is necessary to accelerate the process, sugar cane bars (locally know as *chancaca* or *panela*) can be added to the vessel pot or hot coals can be placed under the ceramic vessel to warm up the fermentation. Thus, sucrose and warmth will help the yeasts to start the fermentation and the production of alcohol.

The final pH of this fermented beverage has been recorded as 3.5 (Elazequivel et al. 2015) and the alcoholic content of the *chicha de masa* can reach values of 4–6% (Aguado et al. 2006). This amount varies amongst the diversity of *chichas* found in the Andean lands from 2% in a weak chicha up to 12%. The average percentage of

alcohol for *chichas* prepared in Cochabamba in Bolivia has been recorded as 5% or less. A well made *chicha* is an attractive drink, clear in color, effervescent and similar in taste to cider. According to Antunez de Mayolo (1981) a half-cup of a heady *chicha* is enough to produce exhilarating effects.

FIGURE 12.2 Chicha pottery employed in Northwestern Argentina. A: ***virque***; B: ***large wood spoon***; C: ***cántaro chichero***; D: ***olla arropera***.

In certain cases, superficial foam taken from a mature *chicha* or the sediment inside the vessel is used to accelerate the process of fermentation in a new *chicha*. Both, the superficial foam and the remnant sediment, are rich in yeasts and can be used in the produccion of maize bread. The yeasts with a high capacity of ethanol production (15–22 ºGL) ascend to the top layer in the pot and can be separated with the foam. In turn, yeasts with a moderate capacity of alcohol production (8–15 ºGL) descend to the bottom layer of the vessel (Ward 1989). It is well known that even the yeasts found in the pores of ceramic vessels were enough to initiate the process of fermentation with no addition of foam or sediment (Cutler and Cardenas 1947).

Microbial fermentation in Indigenous Beverages

Indigenous fermented food products are the result of fermentative processes that might be carried out by the microorganisms already present in the raw material that allows the fermentation to begin spontaneously, or it can be induced by the inoculation of starter cultures taken from previous traditional fermented foods or drinks. Normally, these fermented products are produced by more than one type of autochthonous microorganisms, that work together or in a sequenced mode leading to what is known as the microbial succession.

The first species of microorganisms that colonize the substrate grow until they are self-inhibited by their own by-products. At this point, other organisms present begin to get active until they cannot tolerate the new environmental conditions created by their own metabolism. Bacteria will initiate the work and yeasts will continue until molds take over the substrate, but normally molds do not play a significant role in the desirable fermentation of fruit and vegetable products. The genera *Leuconostoc* and *Streptococcus* grow first and ferment the substrate at an increased rate to other close related species. Often, these genera are the first group of bacteria to colonize a substrate of fermented fruits and vegetables (Battcock and Azam-Ali 1998).

Many Latin American fermented beverages have been characterized as having a sour, spicy and sweet taste with a low to moderate alcoholic content and this is the result of two main types of fermentation: the one that produces the acidic taste because of the action of lactic acid bacteria (LAB) and the other that produces alcohol. Ethyl alcohol is produced mostly by yeasts of the genus *Saccharomyces*, particularly *Saccharomyces cerevisiae* and it also can be produced in small amounts by some LAB. If present, some *Acetobacter* species can synthesize acetic acid from ethanol oxidation. These main products of the microbial metabolism are produced on the basis of available simple sugars (Battcock and Azam-Ali 1998).

A common factor in the production of most fermented beverages is the use of yeasts to convert sugars into ethanol. Approximately, 96% of the fermentation is carried out by strains of *Saccharomyces cerevisiae* or related species. Ethyl alcohol is synthesized through the Embden-Meyerhof-Parnas pathway (EMP) by which the piruvate produced through glycosylation is metabolized into acetaldehyde and ethanol. The global reaction is:

$$\text{Glucose} + 2\ \text{ADP} \rightarrow 2\ \text{Ethanol} + 2\ CO_2 + 2\ \text{ATP}$$

During the process of beer manufacturing yeasts metabolize sucrose, fructose, maltose and maltotriose, in this order. Sucrose is hydrolyzed by a microbial extracellular invertase. Maltose and maltotriose are hydrolyzed inside the yeast by the enzyme α-glucosidase. Most of *Saccharomyces* strains are unable to hydrolyze starch and dextrin. For this reason, the use of starchy raw materials requires the action of enzymes like α and β–amylases found in malt or produced during malting. Many strains of *Saccharomyces cerevisiae* can produce ethanol up to 12–14%. At these high values of alcoholic content the rate of growth is strongly affected and the process of ethanol production is inhibited by itself. Often, values of pH between 3.0 and 6.0 are favourable for the growing of yeasts and for the fermentative process. At pH values lower than 3.0 the growing rate decreases remarkably. Temperatures between 15 ºC and 35 ºC increase the rate of fermentation and the level of compounds like glycerol, acetone, acetaldehyde, pyruvate and ketoglutarate in the wort (Ward 1989).

The Role of Saliva in the Production of Andean Drinks

The chewing practice was a common tradition of Inca and pre-Inca civilizations for the production of foods. It was performed for the production of natural sweeteners from maize stalks. Maize stalks were chewed for a time and the resultant mixture of sap with saliva inside the mouth was spat out to produce a sweetener (Gade 1975; Browne 1935). Peruvian brewers chewed cassava as a preliminary step in the

production of the beverage *masato* (de Leon Pinelo 1636). The chewing of maize was a common practice of Andean and Amazonian tribes of South America. Indeed, it was a paid activity when large amounts of *chicha* were necessary to be produced for feasts and religious acts (León and Hare 2008).

The custom of chewing roots, fruits and grains for the production of fermented beverages was a widespread technique among the indigenous peoples from the Andes. Explorers found this method being practiced in both small tribes and in more structured communities. Several edible vegetables were chewed for the production of fermented beverages in South America. Maize was the most important food crop chewed in the highlands of Peru, cassava in the lowlands of Ecuador, cassava and maize in central Brazil, maize and sweet potato in the Brazilian coast, carobs from *algarroba* and *tusca* (*Acacia aroma* Hook. & Arn.) and fruits from *chañar* (*Geoffroea decorticans* (Gillies ex Hook. & Arn.) Burkart), in the semi-arid lowlands of Bolivia, Paraguay and Argentina. This practice is well described by Culter and Cardenas 1947 and, in the authors opinion the teeth played a minor role in this practice. The researchers, in their study of chicha-making in Bolivia, describe the process as follows: Once the maize flour is obtained from ground kernels a small portion is moistened with water and rolled into a medium–sized ball which is placed into the mouth. The flour ball is kept inside the mouth and is thoroughly worked with saliva until a uniform paste is formed. After this, the salivated paste in moved forward with the tongue and taken out of the mouth with the fingers. The salivated flour ball is called *muko* and can be dried under the sunlight and stored. The production of *muko* and *chicha mukeada* was abolished by Spaniards because they considered this practice to be unacceptable (León and Hare 2008).

Culter and Cardenas (1947) preferred to call this technique salivation instead of mastication or chewing because they considered these last terms should be used only when fibrous vegetables such as algarroba carobs, cassava or sweet potatoes were employed in the production of fermented beverages and the fibrous pulp needs to be disaggregated to produce the drink.

This quirky methodology, which was a distinctive feature of Andean tribes, was supposed to help the fermentation process. It was believed that the action of saliva is to produce a partial hydrolysis of carbohydrates found in starchy vegetables through the salivary amylase enzyme, but according to Pedersen et al (2002), this enzyme has an important but minor role in the gastrointestinal digestion because of its low concentration in saliva.

The Microbial Succession in Chicha

Indigenous beverages are a varied group of traditional fermented foods that still need a deep and comprehensive study of their microbial ecosystems. There are few studies accurately describing the microbiomes present in these indigenous foods. The microbial composition is the result of different factors such as the autochthonous microorganisms present on raw materials, the environmental microorganisms, human mediated factors and the ancestral practices which have led to the local domestication of certain microorganisms.

While most studies on the microbial composition of traditional drinks relied on the traditional culture method of the final products (Cox et al. 1987), recent studies

have adopted a methodology based on the study of each step in the production of fermented drinks. The study of microbial changes with a stage by stage methodology has resulted in the knowledge of common patterns of fermentation along the procedure to produce indigenous drinks.

Maize chicha was studied by Eliazequível et al. (2015) at different stages of production for the evolution of LAB. At the beginning, plate counts for lactic acid bacteria (LAB) were recorded to be of 10^4–10^6 colony forming units (CFU) g^{-1} in flour and 10^8 during the buns making. Since maize chicha was produced by procedures that included cooking or baking, most of the initial microbial community was lost at this stage. Hence, the remaining microorganisms in the substrate, the environmental microorganisms and human factors played an important role in the reconstitution of the microbial ecosystem. After this reconstitution, the acid fermentation began and counts for LAB rose up to values of 10^9 CFU g^{-1}. Some LAB produced small amounts of ethanol, but the main production was carried out by the yeasts that initiated the second phase in this fermentation. Thus, the level of LAB decreases again (10^3–10^5 CFU per mL) due to the inhibition caused mainly by ethanol, the production of lactic acid (2.0–4.5 g%) and the reduction in available single sugars.

The fermentative phase that produces alcohol involves the metabolism of yeasts. Lopez-Arboleda et al. (2010), by using PCR-restriction fragment length polymorphism (RFLP) it was found that the most abundant species in maize chicha were *Sacharomyces cerevisiae* (15%), *Pichia guilliermondii* (18%) and *Candida tropicalis* (18%). Before the fermentative phase, isolates belonged to the species *Candida tropicalis, Pichia guilliermondii* and *Pichia kluyveri.* When the production of alcohol and carbon dioxide took place, these species along with *Pichia fermentans*, *Sacharomyces cerevisiae* and *Hanseniaspora gulliermondi* metabolized sugars to produce more alcohol. After the bubbling phase, yeasts found were *Candida tropicalis*, *Sacharomyces cerevisiae*, *Pichia fermentans* and *Hanseniaspora gulliermondi*.

The bacterial diversity associated with acid fermentation has been investigated by Elizaquível et al. (2015) in maize *chicha* in Northwest Argentina. Pyro-sequencing methodology was able to detect a higher number of species than those found by traditional culture methods. Species from the genera *Enterococcus*, *Lactococcus*, *Streptococcus*, *Weissella*, *Leuconostoc* and *Lactobacillus* were the most predominant in maize *chichas*. The genus *Lactobacillus* was found as the group with high diversity in species, while the genera *Enterococcus* and *Leuconostoc* were the second group in importance.

In samples of chicha from one village the diversity of species included mainly *Lactobacillus plantarum, Lactobacillus rossiae*, *Leuconostoc lactis* and *Weissella viridescens*. On the other hand, samples from the village at a distance of five kilometers away from the first evidenced the presence of species like *Enterococcus hirae*, *Enterococcus faecium, Leuconostoc mesenteroides* and *Weissella confusa* as being predominant. The microbial ecosystem of chicha from both villages at a very close distance was different. Similar conclusion was reached by Colehour et al. (2014), who found that there existed differences in the microbiome associated to cassava chicha from different villages, even in those that were separated by short geographical distances. Both authors attributed this difference in genera of LAB to the elaboration procedure and human mediated factors, since the same beverages were prepared in a similar way but with slight variations.

Benefitial Aspects Related to Andean Fermented Beverages

Many indigenous fermented beverages are still poorly studied and they are thought to own beneficial properties, which have not been deeply studied from a scientific point of view (Marsh et al. 2014). This is the case of many fermented drinks from Latin America which lack of factual information about the beneficial properties attributed to its consumption. Some of these beneficial traits are known because they were orally transmitted from parents to progeny and they were always perceived as good for health since pre Incan times.

From the nutritional point of view it is well known that beneficial effects attributed to the microbial activity on the nutritional value of fermented foods are related to the conversion of single sugars into acids, alcoholic compounds, the reduction of anti-nutritional factors and the presence of potential probiotic bacteria (van Hylckama Vlieg et al. 2011). Some maize varieties may have different content of anti-nutritional factors such as phytates, condensed tannins, α-amylase inhibitors and lectins (Ejigui et al. 2005). Additionally, some metabolites that inhibit or limit the growing of pathogenic bacteria in food products are produced during the LAB fermentation. During the fermentative process the gross composition of fermented food products does not change significantly. However, the water-soluble fraction of nutritional compounds improves remarkably. During the fermentation single proteins, polypeptides and aminoacids are released from conjugated proteins. Bacterial activity increases notably the level of free aminoacids and water soluble carbohydrates during fermentation (Gaden 1992).

Fermentation improves the nutritional value of products produced from maize. There is an increase in the content of Vitamin A, Vitamin B_{12} and amino acids like arginine and methionine (Steinkraus 1997; Chelule et al. 2010). Steinkraus (1997) reported that maize *chicha* is rich in vitamins from the B complex with an increase in the levels of riboflavin.

The consumption of *chicha* was always considered as safe and was a common habit in Andean lands because water sources employed for consumption were always associated with illnesses and to parasitism. It is believed that the Incan never drank from water sources but in the form of *chicha* after but, and the regular intake could have reached up to a litre and half per day. Maize *chicha* was an everyday beverage since most of the Andean meals were produced on the basis of dehydrated vegetables. There existed beverages with different alcoholic content, from the non-alcoholic maize *chicha* to the highly alcoholic drinks prepared for celebration. *Chicha* was not recommended to be consumed by people suffering from skin disorders and was known as being effective against respiratory diseases when it was consumed warm and with the addition of leaves of coca (*Erythroxilum coca* Lam), especially for throat and bronchial affections. Due its acidic trait, *chicha* was employed by some Andean physicians for the treatment of parasitism and tuberculosis (Leon and Hare 2008). Another property assigned to this drink was the diuretic effect, and as a stimulant effect for the supply of breast milk and the anti-inflammatory activity of *chicha* sediment. Numbing properties in rituals were attributed to maize *chicha* if barks of the tree ishpingo [*Ocotea quixos* (Lam.) Kosterm] or sap from succulent plants (Cactaceae) were added. (Cactaceae). Molle *chicha* was considered as a diuretic beverage as long as it was not fermented (de Mayolo 1981).

According to Marsh et al. (2014), on several native communities, the reason for consuming fermented beverages is related to their beneficial effects. It is believed

that these effects are due to the synergistic action of several factors such as the raw materials used, the microbial community and the metabolites produced by them. However, further research is necessary to clarify this topic.

Latin America Fermented Beverages Today

The term *chicha* in Latin America has always been associated to a traditional or indigenous beverage which may be an alcoholic or non-alcoholic drink. It can be produced from a single ingredient or by combining several ones. Whether roots, cereals, tubers, nuts or watery fruits were used, beverages are found to be very diverse. Spices can be added to give a special flavor and sugarcane is always employed in the elaboration. Thus bars of unrefined sugar cane became an important ingredient. The proportion and type of raw materials used in the elaboration varies according the geographical region. In Venezuela the expression *chicha* is commonly used for a beverage made of rice and milk that does not involve a fermentative process. It is a sweet and refreshing beverage sold in public markets. In the Andean states Tachira, Merida and Trujillo in Venezuela, *chicha* is made from maize flour, pineapple´s juice and skins, which are fermented with the maize wort. Cloves, cinnamon, and guava (*Psidium guajava* L.) are normally added. In Colombia a similar *chicha* is still traditionally made and sold in bars and restaurants. It can be an alcoholic drink or not. The spices employed in Colombian fermented beverages are peppermint leaves, marjoram and orange tree leaves. In the tropical regions of Ecuador *chicha* de yucca or cassava is a popular beverage prepared in rural communities and by aboriginal peoples. Cassava is harvested by hands, washed, peeled and crushed. Then, a sweet carrot´s puree (*Arracacia xanthorrhiza Bancr.* 1826) is added with the intention to accelerate the natural fermentation process. This last step can be done at different degrees and thus, a slightly sweet and acidic beverage can be obtained. At the beginning of the process the drink is sweet but acquires a yeasty smell as the days pass by. The beverage has a milky appearance. In the Ecuadorean hills *chicha de jora* is elaborated and sweetened with *panela*. In the Andean region of Ecuador a *chicha* made from quinoa, panela and pineapple juice is still traditionally produced. Cloves and allspice (*Pimienta dioica* (L.) Merr.) are also ingredients for this beverage. Peru has a vast diversity of *chichas.* At present, a non-alcoholic beverage is sold as *chicha morada*, which is produced artisanally and the process of its production has been industrialized for export overseas. This drink is found in markets as a ready to drink beverage or can be prepared from a powdered formula. Alcoholic *chichas* in Peru are prepared mainly with maize but they also can include other fruits and vegetables, especially in rural regions. With the black or purple maize cultivar, called *guiñapo,* a purple and sweet *chicha* is elaborated. The white *chicha* is made with several grains such as maize, cereals and spices. *Chicha* de cacao is elaborated during cacao harvesting season. *Chica de jora* can be the base for the elaboration of other kind of drinks. Smashed strawberries can be added to *Chicha de jora* and the drink *frutillada* is obtained. It can be added also with *chicha de maní* which is rich in oil. Bean flour, browned barley and quinoa can become ingredients in *chicha de jora*. In Peru *jora* is produced, packaged and commercialized overseas. Companies such as Inca´s Food and Arezzo produce and export bottled chicha. These products can be found even on the Amazon.com web site. Peru is the main and most important producer of *chicha*. Markets for *chicha* are found in Europe and in the United States in which this preparation is sold as a ready to drink beverage or as a

seasoning due to its acidic taste. In Bolivia the most traditional and well known *chicha* is the maize *chicha* made from *jora*. Bolivia has an export trade of bottled *chicha* to the United States, Spain, Italy and Sweden. The production is still artisanal but in few cases the process has been fully industrialized. There are regulations that standardize physical-chemical and microbiological parameters in bottled *chicha*. In Argentina *chicha* is still an artisanal and traditional drink prepared mainly by northwestern communities. The production is carried out for traditional celebrations such as the carnival, the day of Dead and in the veneration of goddess Pachamama. *Chicha mukeada* is not allowed by regulatory law but is allowed to be prepared only with beer yeasts. The *chicha* prepared in northwest of Argentina has modifications introduced by Spaniards in some stages in the process. In this region the most traditional *chicha* is prepared on the basis of maize *criollo* and *jora*. Another well-known traditional fermented beverage found in the Northwest of Argentina is the *aloja. Aloja* is prepared from carobs from the tree called *algarrobo*. In central Chile, *chichas* are prepared from fruits, especially grapes and apples.

Acknowledgments

We would like to thank Ana Lúcia Barretto Penna, Luis Augusto Nero and Svetoslav Dimitrov Todorov for the invitation to participate in this book and for promoting the knowledge of traditional foods from Latin America.

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