Pre-Hispanic Periods and Diet Analysis of the Inhabitants of the Quito Plateau (Ecuador): A Review

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Abstract: In all of the different historical periods during its development, the pre-Hispanic inhabitants of the Quito plateau and its valleys used the flora and fauna for food and the development of their society. The objective of this study is to review the chronological periods that correspond to the territory of the current city of Quito, as well as the possible diet, and the toxic substances to which the inhabitants could be exposed. The main archeological sites in the territory of Quito are as follows: (1) 11000–1500 BC (Preceramic): El Inga-Rancho Bajo; (2) 1500–500 BC (Formative): Rancho Bajo-Cotocollo-Tajamar; (3) 500 BC–500 AD (Regional Development): Jardín del Este; (4) 500–1500 AD (Integration): La Florida–Rupípanba-Chillogallo-Chilibul and; (5) 1500–1534 AD (Inca period): Quito, which is today’s historic center and urban area. The probable main vegetable foods that were consumed were corn, potato, quinoa, beans, chili, and oca, while the main meat foods were rabbit, guinea pig, deer, guanaco, and llama. The possible toxic substances to which the inhabitants could be exposed by consuming contaminated foods were glycoalkaloids (α-solanine and α-chaconine), tropine alkaloids, and heavy metals. The analysis of biomolecules in archeological remains is feasible, and some physicochemical analytical techniques are capable of using small samples. Moreover, the possible application of spectroscopic methods, supported by quantum chemistry, in order to predict the occurrence of molecules in the past cannot be ruled out.

Keywords: pre-Hispanic Quito; ancient food; ancient toxins; archeological remains

1. Introduction

Archeology began to be regarded as a scientific discipline in the nineteenth century, although it existed much earlier; however, with the development of stratigraphy, it changed significantly [1]. Archeologists’ understanding of past events is complemented and enhanced by other disciplines, including chemistry, biology, physics, medicine, genetics, and materials science [2,3]. In recent decades, experts in food science and technology have worked with archeologists in order to try to objectively understand the diets and the foods that were consumed by prehistoric populations. The evaluation of paleodietics not only allows us to learn about the diets of past societies, but also, by knowing what people ate, the potential benefits of different diets, the productive and the environmental features...
of that time (exploitation of resources), the possible causes of death or pathologies due to the ingestion of toxins, and possible nutritional problems that are related to a lack of micronutrients or macronutrients can be understood [3,4].

Archeological research has been conducted across Ecuador, providing valuable insights into the aspects of domestic life, the customs, and the dietary habits of the past inhabitants [5]. Many of these studies have provided subjective and objective paleodiet data that have deepened the qualitative and quantitative understanding of the possible consumption of certain vegetables and meats. The chemical analysis of artifacts from the past may help us to answer research questions related to the diets of the ancient inhabitants of the territories that, today, are part of Ecuador, with a special focus on the period before the arrival of the Europeans to the American continent.

Based on the investigations that were carried out by Bell (1965); Ugalde (2019); Ugalde and Dyrdahl (2021); Vásquez (1999); and Villalba (1988), it was determined that the territory that is currently occupied by the city of Quito was home to the following settlements at different times: El Inga and Rancho Bajo in the Preceramic period (11000–1500 BC), Cotocollao in the Formative period (1500–500 BC), Jardín del Este in the Regional Development period (500 BC–500 AD), La Florida, Rumipamba, Chillogallo and Chilibulu, and the Integration period (500–1500 AD) [6–10]. It should be noted that the chronology of these historic periods is diverse, and sometimes confusing, due to the diversity of the criteria, including different periods for each geographical region (coast, highlands, and the east). Specifically, the highlands (also known by the Spanish words Andes or Sierra) were divided into North, Central, and South (which belonged to the Northern Andes) [11–13]. In general, no research specifically describes the chronological periods of what is now the territory of Quito and its valleys, except for the work of Serrano (2017) [12].

In this context, concerning Ecuador, and especially Quito, there is little information that allows the understanding of the evolution of food consumption behavior and the availability of food over time. Several paleoethnobotanical studies have explored the different Andean food plant crops based on their phytoliths, allowing the understanding of some plant foods that were likely consumed in the region [14,15]. There is also evidence of the domestication of the native animals in Andean cultures; domestic animals were introduced to Ecuador through overland trade routes in the second and first millennia BC and, presumably, they were only available to the “elite” people [16]. There are only a few investigations with a chemical approach in the Ecuadorian Sierra that have focused on the analysis of the biomolecules occurring in archeological utensils that were intended for food use. Such an approach allows us to determine whether the animal and vegetable traces that have been found within these utensils were food sources or not.

In this regard, this article aims to review which periods correspond to the plateau of Quito and its valleys, based on archeological evidence. In addition, this article includes the analysis of the possible foods consumed by the pre-Hispanic inhabitants of Quito in order to interpret the existence of possible toxic substances in food, to which inhabitants may have been exposed. In addition, the article aims to find new ways to investigate the biomolecules that are found in ancient utensils in order to establish objectively the archeological evidence in the food field.

In the following sections different topics related to food and archeology will be addressed. Through different investigations, the chronology of the time periods on the Quito plateau, in the province of Pichincha, will be identified together with the foods and possible toxic substances that may have been associated with the diet of Quito’s pre-Hispanic inhabitants. This article also discusses if biomolecules in the human diet remain over time in food related archeological utensils or artifacts without undergoing denaturation, and the techniques that can be used to determine what these biomolecules are.

2. Pre-Hispanic Chronology of Human Settlements in the Quito Plateau

The history of the human occupation of the Andean region has been the subject of many studies, and there has been an extensive debate on how to classify the chronology
of events [17,18]. This work is focused on the Quito plateau and its valleys, which are located in the current province of Pichinchā. Quito and its valleys, due to their geographical characteristics, were an attractive location for human settlement. This extensive plain had several lagoons that made the region adequate for intensive agriculture. The main lagoons are Inaquito (Añaquito) and Turubamba, both of which flow into the Machángara river, and Postrera or Huayna Cápac, which is located near Cotocollao and flows into the Pomasqui valley [19]. Over time, this territory has endured strong volcanic activity, causing the population to decline and settle in other, safer places. However, when the environmental conditions improved, the inhabitants tended to return to the plateau.

2.1. Preceramic

The habitation of what is now Quito began in the so-called Preceramic period (approximately 11,000–10,000 BC), in the early Holocene, when communication routes with the Ecuadorian Andes appeared after the retreat of the glaciers. This provided the conditions for the support of rich vegetation in both the plateau and in the valleys. According to the Villalba (1998) radiocarbon dating study on the Quito plateau, this period may have extended until the appearance of the first settlements, such as Cotocollao, around 1500 BC [7]. For the earliest site that has been reported for this period, some researchers have investigated the antecedents of the site El Inga. This site was located in the site that is known as Iñal hill today, which is located east of the current city of Quito, at 2520 m.a.s.l. Lithic artifacts, such as knives, flakes, fishtail arrowheads, and bone artifacts, have been found at this site. These instruments were made mainly from basalt and obsidian (from raw materials that were obtained from the Quiscatola hill, the Yanaurco Chico hill, and the Mullumica sector), and the oldest date from around 9000 BC [6,20,21].

Cueillar (2013) classified the Preceramic period as early (10000–6000 BC), middle (6000–3000 BC), and late (3000–2000 BC) [11]. Specifically, in the Quito plateau for the Preceramic period, the first settlement that has been registered (where the first sedentary population group was found) was in Rancho Bajo, which is located in a neighborhood that is northeast of Quito called El Condado. This site is located between the El Condado and San Antonio ravines [9]. Ugalde (2019) located this site in the late Preceramic and, according to the data that were obtained in the excavations, it can be assumed that there was a settlement there at least a millennium before entering the Formative period [8]. This finding has been important for Quito, as it demonstrates that Cotocollao (Formative period) was not the first sedentary settlement, the preceramic period plants were domesticated, and the inhabitants were not only hunters and gatherers [22].

2.2. Formative

After the Preceramic period came the Formative period, and there are several references of this period with different periods. For example, Stahl (2010) described the periodization of pre-Columbian cultures in the Ecuadorian Andes and classified the Formative period into early (3500–1500 BC), middle (1500–1000 BC), and late (1000–500 BC) [16]. According to Serrano (2017) (modifying the findings from Meggers (1966), Ecuador’s ancient peoples and places) and Zeidler (2008), the Formative period was between 3500 and 500 BC [12,23]. In order to find a closer correspondence to the Formative period in the Quito plateau, we cite the research by Solorzano (2008), which indicates that the Formative period represents the Neolithic period [24]. The use of this name in Latin America represents the period when pottery first appeared (which was one of the transformative elements in the development of humanity), agriculture was introduced, and societies ceased to be nomadic. For this reason, the Neolithic/Formative period has been chronologically classified in Ecuador according to several investigations with radiocarbon studies, such as Porras (1980), Valdez (2003), and Zarrillo (2012), and other investigations that refer to studies with radiocarbon dating, such as Athens (1978), del Pino and de Terán (2005), Falcón (2019), Rostain and Saulieu (2019), and Solorzano (2008), between 4000 and 500 BC. It has been divided according to
the cultures and settlements as follows: early Formative: *Valdivia* culture on the Ecuador coast, middle Formative: *Machalilla* culture, which was an evolutionary consequence of *Valdivia* culture, and late Formative: settlements on the coast, including *Chorrera* culture, which expanded from the current province of Los Ríos. The settlements in the highlands include the following: *Cotocollao*, which was on the Quito plateau and surrounding valleys, *Las Orquideas*, which was part of the larger *Los Soles* in the city of San Antonio de Ibarra, *La Chimba*, which was located north of the province of Pichincha near the cities of Cayambe and Otavalo, Narrio-Chaullabamba, which was in the current provinces of Cañar and Azuay (the precursor of Cañari culture), and *Catamayo*, which was in the current Catamayo canton, in Loja province. In addition, the Amazonian settlements include the following: the *Mayo Chinchipe* culture, which was located in the province of Zamora Chinchipe (this culture represents the first evidence of the history of the Amazon), the *Upano* culture, which developed at the foot of the Andes in the *Upano* valley, the *Pastaza* culture, which was located at the foot of the Tungurahua volcano between the Chambo and Putate rivers, and *Chiguaza*, which is an archaeological site in the valley of the Chiguaza river in the region of the Sangay volcano [19,24–29].

In this work, we take the archaeological sites of *Rancho Bajo*, *Cotocollao*, and *Tajamar* as the reference for the Formative period because these are the first references to Quito and its valleys and are considered to be the earliest sites based on radiocarbon dating, which will be detailed below. *Tajamar* was located in the northern sector of the Quito plateau, in the current Pomasaqui valley [30]. According to the current investigations of Ugalde and Dyrdahl (2021), the site of *Rancho Bajo* existed in the transition from the Preceramic to the Formative period, while the most important settlement was *Cotocollao*, which existed between 1500 and 500 BC [9]. Evidence of settlements has also been found in *Rumipamba* (a site that is within the urban perimeter of the Metropolitan District of Quito, in the Altamira parish) [31,32]. The inhabitants of *Cotocollao* remained there until that period because, in their final years, the eruption of the *Pululahua* volcano had great implications for the region [33].

Villalba (1988) also proposed that the town of *Cotocollao* grew from 1500 to 500 BC, in which the inhabitants lived in rectangular houses with stoves for food preparation. The houses were built in the middle of streams and near several natural lakes, allowing for the exploitation of lake resources, such as totora, sand, silt, and clay. Finally, Villalba (1988) determined the years of the Formative period for the *Cotocollao* site (and the Quito plateau) as follows: early Formative (1500–1100 BC) and late Formative (1100–500 BC) [7]. During the late Formative period, settlements appeared in Tababela (around the current site of Quito airport), Toctiuco (which was located in the foothills of Pichincha), and an intense occupation in Tajamar [30,34].

### 2.3. Regional Development

Next in the timeline came the Regional Development period, in which the population growth in each region of Ecuador was caused by an increase in knowledge of agricultural production, allowing for the greater trade of products between the regions. As with the other periods, different dates have been suggested for this period. According to Buys (1994) and Sánchez (2017), the Regional Development period was between 300 BC and 500/600 AD. They based these dates on radiocarbon dating and on the cultural and artistic innovations in each settlement, which were important features of this period [32,35]. In general, little is known about this period in Quito since the eruptions of the Pululahua, Atacazo, Cotopaxi, and Pichincha volcanoes affected the inhabitants. Crops were lost, the water sources were contaminated, and the flora and fauna disappeared, all of these factors resulting in population displacement and the destruction of the site at Cotocollao. The majority of the inhabitants abandoned the Quito plateau for an indefinite amount of time and emigrated towards the northern highlands. With this it can be assumed that, during the period of Regional Development, the Quito plateau remained largely abandoned [10,32].
In order to establish the period of Regional Development in the Quito plateau and Pichincha, we can cite the research of archeologists Serrano (2017), Solorzano (2008), and Stahl (2010), who agree that this period was from 500 BC to 500 AD on the Quito plateau. This period is represented by the archaeological site of Jardin del Este, which is located in the Cumbayá valley (which is a parish that is located in the valley of the current city of Quito) [12,16,24]. In general, the ceramic objects that have been found at this site for this period were greatly influenced by the coastal regions, and especially by the Guangala and La Tolita cultures, and by the cultures and sites of the highlands, including Caranqui, Yaruquí, Urcuquí, Cochasquí, and Cayambe. Figurines and utensils from the Tolita and Jama Coaque cultures have also been found, revealing a high level of exchange with the coastal cultures [36].

2.4. Integration

The final millennium in the development of pre-Columbian societies, art, and culture is called the period of Integration, in which there was a demographic increase due to improved agricultural techniques [32,37]. Communities with established geographical boundaries began to form in different parts of the Andean region. These small territories, called ayllu and kurakazgos, had ceremonial centers and rulers known as Kuracas (caciques). Based on ethnohistoric data, the kurakazgo (territory) that was established in Quito and its valleys was Quito [38]. This is the period that has been studied the most, and for which there is the most scientific evidence, with both archeological evidence and written accounts by Spanish chroniclers. For this reason, the dates that have been established by different scholars are from 500 to 1500 AD [12,16,32], although some researchers, such as Solorzano (2008), have argued that the period was between 500 and 1540 AD [24].

According to del Pino and de Terán (2005), Falcón (2019), Molestina (2006), and Porras (1980), the most important Integration period settlements that have been found in the Quito plateau are as follows: Tajamar, Chillogallo (located in the Turubamba valley, south of Quito), Chilibulo (located at the foot of the Ungüi hill, next to the Chochos and La Raya streams and near Magdalena parish, south of Quito), Chaupicruz and La Florida (places that are located in the old Chaupicruz farm, north of the current city of Quito. In some investigations, La Florida has been dated to the end of the Regional Development period, but most of the evidence for this society has been found in the Integration period), and the most important was Rumipamba [19,29,30,39] (which has been located in several archaeological periods (Formative and at the end of Regional Development). For this study, it has been considered that more evidence has been found in the Integration period, according to the Constantine reports that were carried out in Rumipamba [31,40].

An important feature of these settlements is that they shared similar funeral manifestations and the system of materials that were used for burials, which suggests that they were part of the same closely interrelated ethnic group, but with some political and economic autonomy [41]. The merging of these groups was mainly due to the geographical and geological advantages that the Quito plateau had to offer (farmland that was not vulnerable to flooding, water from streams, nearby forests for hunting, and good summer roads to facilitate trade with other regions), leading to the development of and the interactions between the human settlements [39,42]. Other sites in Quito during this period are Rumicucho, which was located in the parish of San Antonio de Pichincha, and El Quinche, which was located east of the city, the latter of which had Caranqui filiation [34].

2.5. Inca

Finally, according to radiocarbon evidence from the research of Connell, Anderson, Gifford, and Gonzalez (2019), Ogburn (2012), Foote (2010), and the manuscripts of the chroniclers of the time, the pre-Hispanic chronology ends with the Inca conquest [43–45]. Contrary to the common misconceptions about Ecuador’s history, the Incas were not in the territory of Ecuador for long, and they cannot be considered ancestors of the Quito plateau because of the relatively short duration of their colonization, a process that was marked by resistance from
local inhabitants and many bloody battles. Despite this resistance, the lordships of the Andes were annexed to the Inca empire, bringing new forms of government to the region [32]. On the Quito plateau, the Incas built several military fortresses and created a road network over the existing aboriginal roads, establishing a communication system with the other territories [46]. One strategy that helped the Inca empire to spread was the insertion of foreign ethnic groups into the Ecuadorian highlands. These mitimaes were native ethnic groups that were relocated in order to spread Inca culture, and included, in Quito plateau and its valleys, the Cañaris, Chachapoyas, Guayacuntos, and Cajamarcas [32,34].

During the Inca period, the following sites were especially important on the Quito plateau and Pichincha: Quito (which is the current historic center and urban center, where, mainly, excavations have been found in the current convent and plaza of San Francisco and the Ichimba sector), Rumiwucha, Guayllabamba, Toctiuc, and close to the Quito plateau: Quitoloma, Pambamarca and El Quinche [19,43]. The end of the Integration period and the stabilization of the colonial process are taken into account when establishing the chronological range of this period. In general, the decline of the Inca empire began between 1528 and 1532 AD with the weakening of the Tawantinsuyo. Between 1534 and 1548 AD, the Spanish empire entered the Ecuadorian Andes, and the formation of the colonial process took place in 1540 [24]. It has been determined that the approximate final year of the Inca period in the current province of Pichincha and the Quito plateau was 1534 AD, as from that year, the Spanish empire no longer allowed the ongoing development of the Incas in the Ecuadorian Andes [12].

Figure 1 shows the main human settlement sites on the Quito plateau and its valleys, according to the different archaeological periods.

Figure 1. Main sites of human settlements in the Quito plateau and its valleys during the pre-Hispanic chronological periods (11000 BC–1534 AD). The study area is the plateau of Quito and its valleys, which is delimited as follows: to the north is the Guayllabamba river, to the south is the political boundary between the current Quito canton and the Mejía canton, to the east is the Cordillera Real (Eastern Cordillera of the Ecuadorian Andes), and to the west is the Pichincha massif (Western Cordillera in the Andes of Ecuador). The settlements belong to the following periods: Preceramic, Formative, Regional Development, Integration, and Inca occupation. Map by Carlos Montalvo.
3. Food of the Pre-Hispanic Inhabitants from the Quito Plateau

This section presents data on the possible foods that were consumed on the Quito plateau. The archaeobotanical data were obtained mainly by identifying starches and phytoliths, while the zooarchaeological remains were obtained from middens that had faunal remains. Examples of these analyzes in Ecuador, and specifically in the Quito plateau, were carried out by archaeologists such as Pagán-Jiménez (2015), Ugalde and Dyrdahl (2021), and Zarrillo (2012) [7,21,35]. In summary, this section has been elaborated with references from zooarchaeology and paleobotanical research or studies referring to this type of research.

In the Preceramic period, it has been shown that the inhabitants of the El Inga site had a hunter–gatherer diet. Wild plants and local fauna were consumed. In the middle and late Preceramic periods, it is possible to find corn (Zea mays), chili (Capsicum annuum), amaranth (Amaranthus spp.), quinoa (Chenopodium quinoa), and pumpkins (Cucurbita ficifolia) [47]. In Rancho Bajo, the presence of corn (Zea mays), oca (Oxalis tuberosa), melloco (Ullucus tuberosus), mashua (Tropaeolum tuberosum), and species of bean (Phaseolus sp.) has been found [9]. According to Athens et al., (2016) and Van der Hammen, Noldus, and Salazar (2003), around 5000 BC the human groups of the Preceramic period begin their processes of the domestication of plants. These data have been obtained from sites in Mullumica-Pifo (which is a parish that is located at in the northeast of the Metropolitan District of Quito) and El Lago San Pablo (a lake in the province of Imbabura-Ecuador) and would be consistent with the Inga sites since they are from periods contemporary [22,48].

In the Formative period, with the appearance of polished stone and ceramic artifacts, hand grinders (lithic tools for grinding food), mills, and utensils for storing, conserving, and transporting liquid and solid food, as well as carved stones, were in use, while the practice of hunting animals for meat continued [24]. Data from Idrovo (2002) suggest the possible diet in the Ecuadorian Sierra during the Formative period. This included corn (Zea mays), potato (Solanum tuberosum), chocho (Lupinus mutabilis), chili (Capsicum annuum), beans (Phaseolus vulgaris), oca (Oxalis tuberosa), and quinoa (Chenopodium quinoa) in the temperate highlands, and sweet potato (Ipomoea batatas), cherimoya (Annona cherimola), guaba (Inga edulis), avocado (Persea americana), and cotton (Gossypium) in the valleys [49]. In Cotocollao, there is evidence of llama (Lama glama), guinea pig (Cavia porcellus), deer (Odocoileus virginianus), guanta (Cuniculus paca), puma (Felis concolor), rabbit (Sylvilagus brasiliensis), weasels (Mustela spp.), turtles (Kinosternon spp.), and various bird and reptile species. These would all have been part of the diet of the settlers. It should be noted that the consumption of animals may have been sporadic and dependent on their availability at the time of hunting. Cultivation was very important for this culture, allowing for the efficient production of cereals, legumes, and tubers, including maize (Zea mays), beans (Phaseolus vulgaris), achira (Canna indica), quinoa (Chenopodium quinoa), potato (Solanum tuberosum), and oca (Oxalis tuberosa), while eggs and giant snails (churos) were gathered and ichthyofauna were fished from the surrounding lagoons. The strategic location of the sites also allowed for the exchange of products with other regions, mainly obsidian and cotton, and food products such as chili (Capsicum annuum) and salt [7,24,34]. Other animals that have been identified in Cotocollao include opossum (Didelphis marsupialis), moor wolf (Dusicyon spp.), mouse (Sigmodon spp.), and turtledove (Columbina spp.). It seems that the settlements of Tababela and Toctiuco enjoyed the same diet as those of Cotocollao, but with a large number of llama (Lama glama) and guinea pigs (Cavia porcellus) remains [34].

For the Regional Development period, similar archeological artifacts have been found at the Jardín del Este site, as well as other settlements on the plateau. Evidence of food has also been found by some inhabitants who remained in Cumbaya and different sectors of the Quito plateau after the gradual recovery of the ecosystem, indicating that these sites were occupied by inhabitants of the same ethnic group, who used similar food utensils. Compoteras, hemispherical plates, pitchers, and vases have been found, together with elongated, globular, tripod, and zapatiformes (asymmetrical shoe-shaped) pots [10,36,50]. There is little food analysis research for the Regional Development period. According
to Iturralde (2015), coca leaf (Erythroxylum coca) also has been found. Based on their research, the main crops of the inhabitants of that period were maize (Zea mays), beans (Vicia faba), and potatoes (Solanum tuberosum). In Jardín del Este (Cumbayá), the remains of guinea pig (Cavia porcellus), rabbit (Sylvilagus brasiliensis), deer (Odocoileus virginianus), dog (Canis familiaris), several birds, guanta (Cuniculus paca), skunk (Conopatus spp.), and camelids of different species (mainly llama) have been found [36].

During the Intergration period, gradually improving climatic conditions and agricultural techniques increased the number of inhabitants [51]. Molestina (2006) has stated that, in Quito, the lake areas formed small swamps, mainly in the current area of La Y, the old airport, and the Jipijapa neighborhood. These clay, silt, sand, and pumice swamps formed the ancient lagoon of Iñaquito, allowing for populations of fish, birds, and totora to grow [39]. The area was also a source of hematite and saw the beginning of agriculture in the form of camellones, which is an agricultural technique called waru waru in Quechua where earth platforms are built in parallel rows that are separated by water channels. This farming technique is considered to be the oldest in South America [41,52]. Ducks (Cairina moschata), herons (Ciconiiformes), and other birds (which were possibly hunted) have also been reported in the Iñaquito lagoon, and their eggs were used as food. Rabbits have also been found. In Rumicucho and El Quinche, the remains of llamas (Lama glama), guinea pigs (Cavia porcellus), deer (Odocoileus virginianus), and Muscovy (or creole) ducks (Cairina moschata) have been found [34]. In Rumipamba, there is evidence for the presence of corn (Zea mays), beans (Leguminosae fabaceae), pumpkins (Cucurbita ficifolia), capulí (Prunus spp.), myrtle (Eugenia spp.), potato (Solanum tuberosum), melooco (Ullucus tuberosus), oca (Oxalis tuberosa), mashua (Tropaeolum tuberosum), coca leaf (Erythroxylum coca), cassava (Manihot esculenta cranz), which were acquired from another region and apparently consumed as a beverage, and chili (Capsicum spp.) [32]. Based on their analysis of the settlement of La Florida, Ubelaker, Katzenberg, and Doyon (1995) suggest that both low- and high-status inhabitants had access to corn, although those with a high status had greater access. According to these authors, the greatest amount of chicha production was reserved for those of a high status [53].

There is not much food information from the Inca period in the Quito plateau and its valleys. Research from Rumicucho has found llama (Lama glama), guinea pig (Cavia porcellus), and dog (Canis familiaris) remains, and archeologists have determined that these remains belonged to hunted animals, that is to say, the animals were probably consumed as food. It is also presumed that the Incas introduced the alpaca (Lama pacos), since the wool from this animal has been found in cumbi textiles, which were reserved for the nobility [34]. The main food from vegetables in the Inca empire was corn, in different varieties and preparations. This represented a large part of the daily diet, as both a staple food and a sacred drink (chicha). There is no evidence that the Inca increased or intensified the agriculture during their occupation in the Ecuadorian Andes, and they consumed food that was produced by the local population regularly [11].

Several paleoethnobotanical studies of the different food plant crops based on phytoliths have been conducted in the Andes. This allows us to know some of the edible plants that were probably consumed in the region [14,15]. There is also evidence of the domestication of some of the native animals among Andean cultures, including alpacas (L. pacos) and llamas (Lama glama). Cuy (Cavia porcellus or C. aperea porcellus) and Muscovy ducks (Cairina moschata) were introduced to Ecuador through overland trade routes in the second and first millennia BC and were available only to the elites [16].

Table 1 presents a summary of this chronology, with the sites and the main foods that were possibly consumed by the ancient inhabitants of the Quito plateau and its valleys. This chronology was developed through research and studies that have indicated radiocarbon dating and zooarchaeological and paleobotanical analyses.
Table 1. Proposed chronology for the Quito plateau and its valleys, and the foods that were possibly consumed.

<table>
<thead>
<tr>
<th>Period</th>
<th>Years</th>
<th>Main Sites</th>
<th>Possible Main Foods in the Diet</th>
<th>Reference</th>
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<tbody>
<tr>
<td>Preceramic:</td>
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<tr>
<td>Early</td>
<td>11,000–1500 BC</td>
<td>El Inga, Rancho Bajo</td>
<td>Hunter-gatherers (wildlife and wild flora)</td>
<td>[6,8,9,11,20–22,47,48]</td>
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<tr>
<td>Medium</td>
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<td></td>
<td>Corn, melloco, mashua, beans, chili, amaranth, quinoa, and pumpkins.</td>
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<td>Late</td>
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<td>Formative:</td>
<td>1500–500 BC</td>
<td>Rancho Bajo, Cotocollao, Tajamar, Rumipampa, Tababela, Toctiuco</td>
<td>Corn, beans, áchira, quinoa, potato, and oca. Eggs and snails. Chili and salt (obtained from exchange). Llama, guinea pig, deer, guanta, puma, rabbit, weasels, turtles, several types of birds and reptiles, opossum, moor wolf, mouse, and turtledove.</td>
<td>[7–9,24,30–34,49]</td>
</tr>
<tr>
<td>Early</td>
<td></td>
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</tr>
<tr>
<td>Late</td>
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</tr>
<tr>
<td>Regional Development</td>
<td>500 BC–500 AD</td>
<td>jardín del Este (Cumbayá)</td>
<td>Corn, broad bean, potato, and beans. Coca leaf. Llama, guinea pig, rabbit, deer, dog, various birds, guanta, skunk, and camelids of different species, mainly llamas.</td>
<td>[10,12,16,24,32,35,36,50]</td>
</tr>
<tr>
<td>Integration</td>
<td>500–1500 AD</td>
<td>Quito territory: Rumipampa, La Florida, Chillogallo, Chilbulo, Tajamar, Chauicruz, Rumicucho</td>
<td>Corn, broad bean, squash, pumpkins, capuli, myrtle, potato, melloco, oca, mashua, cassava (acquired from other regions and apparently in the form of a drink), and chili. Eggs Coca leaf. Guinea pig, llama, deer, creole duck, Muscovy duck, rabbit, fish, ducks, herons, and other birds.</td>
<td>[12,16,19,30–32,34,38–40,42,53]</td>
</tr>
<tr>
<td>Inca</td>
<td>1500–1534 AD</td>
<td>Quito (today’s historic center and urban area: San Francisco and Itchimbia), Rumicucho, Toctiuco, Guayllabamba</td>
<td>Corn (as the main food of the diet and as a sacred drink, the chicha). In the Andes, they were accustomed to consuming the crops of the local populations. Llama, guinea pig, dog, and alpaca.</td>
<td>[11,12,19,31,32,34,43]</td>
</tr>
</tbody>
</table>

This table was elaborated according to the chronology collected from archeological research that was carried out in sites in the Quito plateau and its valleys, the references are classified by each period. All of the sites included in the bibliography have radiocarbon dating, except for Chauicruz and Chillogallo, Porras (1980) references them with Chilbulo since similar styles of materials and ceramics were found [29]. The possible main foods in the diet are based on zooarchaeological and paleobotanical evidence that has been found in utensils, dumpsters, and tombs of archaeological sites and do not necessarily represent the exact diet of the inhabitants since not all of the residues were found in artifacts that were intended for food. Physical–chemical analysis of food utensils is required to verify what the inhabitants ate. Except for the Inca period, camelids (Camelidae spp.) were not an exclusive part of the diet in the central Ecuadorian highlands and were mainly used to transport cargo; deer and rabbits, along with other species, apparently met local dietary needs. The scientific names of the above plants and animals can be found in the text of the article.

4. The Presence and Health Implications of Potentially Toxic Substances in the Foods Consumed by the Ancient Inhabitants of Quito

In this work, we have decided to add a section about possible toxins in the food that was available to the inhabitants of the Quito plateau. It is important to understand the possible health problems that the populations could face in specific historical periods, since they may also be associated with foods of vegetable origin. Edible vegetable materials can endogenously contain different substances that can be toxic to humans. These substances can be potentiated in the soil, plants, and fruits through bad agricultural practices or with the environmental factors that dominated at that time. Therefore, a revision of the main toxicants that may have been associated with food that was consumed by the pre-Hispanic inhabitants of the Quito plateau has been made.

Medical archeology involves the analysis of archeological data in order to understand human health and to search for, as an example, the causes of pathologies and deaths in the past. Such analyses also explore whether these problems still exist in order to improve present-day health and medicine. Understanding these aspects of the past is fundamental to understanding the different behaviors in society, including overthrowing.
myths and beliefs that have no scientific grounding [54]. There is currently no research in Ecuador that explores the possible natural contaminants in the food to which pre-Hispanic inhabitants may have been exposed. In general, thanks to the advances in paleopathology, paleoepidemiology, and biochemicaly, patterns of the diseases that were suffered by the pre-Hispanic Andean cultures have been established.

Contrary to popular belief, the “old” and “new” worlds shared some pathologies (one difference between the continents was that the Americas experienced no massive outbreaks or epidemics of diseases, such as measles, bubonic plague, and smallpox) [55]. The sedentarization and concentration of the populations favored the proliferation of infectious diseases, primarily gastrointestinal infections (for example, water contamination may have increased when the populations stopped being nomadic). In the Andes, one of the most important aspects in the development of nutritional and health pathologies was the food. Starting in the Formative Period, the diet mainly consisted of corn and potato, both of which are deficient in certain nutrients [55]. Osteological studies have found that malnutrition caused a decrease in the height of the population. A high rate of infant mortality and a low life expectancy (24 years during the Formative period in Ecuador) have also been demonstrated [56].

It has been reported that the most common diseases were severe gastrointestinal (for example, at the Rancho Bajo site, through paleoparasitology studies, the eggs and larvae of the parasite Ascaris lumbricoides were found [9]) and respiratory infections (e.g., pneumonia), and studies have shown that typhoid, influenza, and tuberculosis were prevalent [55,57]. When analyzing the different types of pathologies that are related to poor nutrition, there is a possibility that these diseases may have been worsened by the ingestion of foods containing naturally occurring toxic substances. There may even be clinical pictures or pathologies that were directly due to the consumption of foods containing toxic substances, such as mycotoxins, heavy metals, and toxins that are naturally produced by vegetables, etc. Given this scenario, we have focused on the two staple foods of the Andean diet—potato and maize [55].

Ingesting tubers, such as potatoes, may be associated with glycoalkaloids (mainly α-solanine and α-chaconine), while cereals, such as corn, may contain tropane alkaloids. In addition, depending on the food, heavy metals may be present in diets in general [58]. The potato has the natural ability to endogenously synthesize several types of glycoalkaloids, including α-solanine (the sugar of which is solatriose, which is formed by D-glucose, D-galactose, and L-rhamnose) and α-chaconine (the sugar of which is chacotriose, which is formed by D-glucose and two L-rhamnose) [59]. The problem with potato cultivation is that the potato produces these compounds in order to defend itself from environmental hazards, such as predators, pests, high temperatures, lack of water, etc. [60], and, after harvest, it continues the production of these compounds if the storage conditions are dominated by excessive heat, light, and stress [61]. Tropane alkaloids are associated with potatoes and maize. These alkaloids can comprise more than 200 compounds. However, the ones that have been analyzed are (-)-hyoscyamine and (-)-scopolamine [62]. Heavy metals may be present in foods that have grown in contaminated soil. One cause of contamination (of water sources, soil, etc.) is volcanic activity. Quito has experienced volcanic eruptions throughout its history. These have caused human displacement and probably contaminated the soil and vegetation with toxic elements (heavy metals), such as cadmium (Cd), lead (Pb), chromium (Cr), nickel (Ni), cobalt (Co), and arsenic (As) [63].

The ingestion of foods containing these toxic substances can cause serious health issues, including teratogenic effects, gastrointestinal diseases, hemorrhages in the digestive tract, headaches, neurological changes, and death [64,65]. According to Delabarde (2010), gastrointestinal diseases were common in pre-Hispanic Ecuador [55].

In this regard, and knowing the possible foods that were common to the diet and the possibly toxic substances to which the pre-Hispanic inhabitants of Quito were exposed, lithic materials, vessels, and other artifacts that have been found, and continue to be
discovered, in different settlements should be analyzed in order to obtain more information about the contaminant issues.

5. Degradation of Biomolecules in Archaeological Remains and the Feasibility of Their Preservation

Stoessel, Martínez, and Constenla (2015) indicate the possible components that can be found in archaeological pots. When a pot is in use, it can absorb the different organic components of the food (such as lipids, carbohydrates, minerals, and proteins), which can be processed or stored. Most archaeological studies have focused on the analysis of fatty acids, since these molecules are relatively stable and are less affected by time degradation. The causes of degradation include high cooking temperature and oxygen and water influence, which, over the years, may alter the composition of the biomolecules in the buried pots [66].

Lipids can better withstand high cooking temperatures, but may be exposed to further oxidation or hydrolysis. In addition, it should be noted that unsaturated fatty acids degrade faster than saturated fatty acids, and long-chain acids degrade faster than short-chain acids. According to Bonomo, Colobig, and Mazzi (2012), lipids have higher stability at high temperatures and, therefore, can be stored in pots and will endure minimum decomposition. Lipids can remain absorbed in a ceramic paste with no degradation and can remain fixed in micro-cavities that do not allow access to microorganisms. These small holes containing lipids can also be sealed with bacterial residues and, due to their hydrophobic properties, they are not washed out by contact with water [67].

Concerning proteins, Hendy (2021) explains that these biomolecules can survive within different types of archaeological and paleontological materials for more than one million years. The discovery and the analysis of proteins in dinosaur remains that were found in mineralized substrates is proof of this [68]. Several investigations have found ancient proteins in biological substrates that were formed by a mineral component, mainly in bones, shells, and in human dental calculi (archaeological dental calculi have become an interesting source for biomolecules, such as the milk protein beta-lactoglobulin) [69]. Among these are the detection of proteins in mouth swabs and clothing from 500-year-old Andean mummies, the detection of proteins in fossil remains [70], and the sex determination of Neolithic fossils by detecting the peptides that can be extracted from tooth enamel [71]. The possible survival of collagen proteins is associated with the mineral that constitutes bone structure, hydroxyapatite, and the possible presence of peptides or proteins from eggshells has been related to the presence of calcium [68]. Proteins can suffer enzymatic attack or hydrolysis damage over time, depending on how the sample containing them is stored.

A common way to investigate paleodiet foods is by extracting and analyzing starch in order to determine the specific variety of the raw materials that were consumed. According to Copeland and Hardy (2018), starch granules can survive for extended periods of time. In modern archaeology, starch is usually determined by morphological analysis of the granules that are extracted from dental calculi, tools, and pots [72]. Several parameters allow starchy samples to remain unaltered over the years. These include the presence of water, low humidity, pH as close to neutral as possible, and relatively low temperatures. It is important to keep in mind that contemporary varieties of food plants are very different from their wild ancestors, due to human crop manipulation over thousands of years [73].

6. Detection of Biomolecules in Archaeological Remains

This section reviews the main techniques that are currently recommended for the analysis of the biomolecules and toxic substances in archaeological samples. As mentioned previously, the chemical molecules that are derived from food can be maintained over time; their structure may change over the years, but they can be identified through the use of appropriate methods. In this case, a qualitative phase to establish whether the sample contains the material to be analyzed is required before a quantitative phase.
6.1. Qualitative Phase

The extraction of samples from archeological remains, such as utensils, lithic material, and pot fragments, first requires the identification of residue or soot, the latter of which is an indication of possible organic remains. An organic sample for analysis (a supernatant) is obtained using a spatula, distilled water, a stove, an ultrasound, and a centrifuge [74]. The presence of carbohydrates is established by applying sulfuric acid and Thymol (1% w/v in ethyl alcohol) to the sample; the appearance of a reddish coloration ring indicates the presence of carbohydrates. The presence of lipids can be established by applying Sudan III (0.01% w/v in distilled water) to the sample; the appearance of red or orange coloration indicates the presence of lipids [74]. The presence of peptides/proteins is established using Biuret reagent; the appearance of violet coloration indicates the presence of proteins or polypeptides, and the intensity of the coloration is proportional to the amount of proteins that are present. Ninhydrin (2% w/v in ethanol) is used in order to detect amino acids, with the presence of blue–green coloration indicating their positive presence [75]. To identify alkaloids, the Dragendorff test could be used. The reagent of the same name is applied with concentrated hydrochloric acid; if opalescence, turbidity, or copious precipitate are observed, the presence of alkaloids is confirmed [76]. There is no qualitative method to test for the presence of heavy metals (considering the low concentration that is expected), therefore, the sample must be analyzed using a quantitative method.

6.2. Quantitative Phase

For the extraction, several methods can be used for the quantitative phase. The following are some of the most important methods, which are already used in archeology. Morphological evaluation to identify starch in food residues that are extracted from archeological materials is performed using optical microscopy. The sample, which is placed on a coverslip, is viewed through an optical microscope (using both bright field and polarized light), and a photographic record is taken with a digital camera. In order to identify which type of food comes from starch, it is compared with a specific guide of wild species of starches [47]. The analysis of the fatty acids is performed using a gas chromatograph with a flame ionization detector (GC/FID), the chromatograms indicate which types of fatty acids are present, which could be correlated with the kind of food [74]. For the identification of proteins, liquid chromatography with tandem mass spectrometry (LC-MS-MS) is used. Following the protocol for this method, LC/MS/MS equipment is used in order to obtain a peptide fingerprint that can be compared against worldwide open-access databases [77]. Food residue from different pots and lithic materials can be analyzed by infrared (IR) and Raman microscopy/spectroscopy. Minimal sample quantities can be measured directly, without pretreatment, and the main normal modes of the resulting vibrational spectra (IR and Raman) are assigned and attributed to the different food components according to the information that is available in databases, in the existing literature, and from the calculations that are derived from quantum chemistry [78]. Currently, quantum chemistry methods could be used to obtain results in order to complement the analysis of the molecules from a structural point of view, or even spectroscopical detection.

Finally, the analysis of toxic substances takes into account the presence of glycoalkaloids (α-solanine and α-chaconine, mainly), for which an acid-, a base-, or an ultrasound-assisted extraction of alkaloids is performed, followed by liquid chromatography analysis coupled with mass spectrometry; the mass spectra are analyzed in comparison to specialized databases [79]. In order to detect tropane alkaloids, the final mixture is passed through an HPLC filter and is introduced into a vial for analysis with high-performance liquid chromatography-tandem mass spectrometry (HPLC-MS/MS). In order to perform this analysis, solutions of tropane alkaloid standards ((-)Hyoscyamine and (-)-scopolamine) are prepared [80]. The analysis of heavy metals is performed using inductively coupled plasma mass spectrometry (ICP-MS) in order to detect and to quantify the presence of toxic and essential elements according to the calibration curves that are made with standard
solutions of arsenic, cadmium, barium, lead, sodium, magnesium, aluminum, phosphorus, potassium, calcium, chromium, manganese, iron, cobalt, copper, and zinc [81,82].

Table 2 shows the qualitative and quantitative methods that are used to analyze the biomolecules and toxic substances in archaeological residues.

<table>
<thead>
<tr>
<th>Test</th>
<th>Molecule</th>
<th>Method</th>
<th>Analysis</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Qualitative</td>
<td>Carbohydrates</td>
<td>Detection using Thymol</td>
<td>Reddish color indicates the presence of the molecule.</td>
<td>[74]</td>
</tr>
<tr>
<td></td>
<td>Lipids</td>
<td>Detection using Sudan III</td>
<td>Red to orange color indicates the presence of the molecule</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Peptides/proteins</td>
<td>Detection using Biuret</td>
<td>Violet color indicates the presence of the molecule</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Amino acids</td>
<td>Detection using Ninhydrin</td>
<td>The blue–green color indicates the presence of the molecule</td>
<td>[75]</td>
</tr>
<tr>
<td></td>
<td>Alkaloids</td>
<td>Dragendorff test</td>
<td>Opalescence, turbidity, or copious precipitate indicates the presence of the molecule</td>
<td>[76]</td>
</tr>
<tr>
<td></td>
<td>Carbohydrates/starch</td>
<td>Optical microscopy (using bright field, as well as polarized light)</td>
<td>A photographic record is taken with a digital camera. The sample is compared with a specific guide of wild species starches.</td>
<td>[47]</td>
</tr>
<tr>
<td></td>
<td>Lipids/fatty acids</td>
<td>Gas chromatography with flame ionization detector (GC/FID)</td>
<td>Chromatograms indicate which type of fatty acid is present</td>
<td>[74]</td>
</tr>
<tr>
<td></td>
<td>Proteins</td>
<td>Liquid chromatography with tandem mass spectrometry (LC-MS-MS)</td>
<td>The sample is compared with global open-access databases</td>
<td>[77]</td>
</tr>
<tr>
<td>Quantitative</td>
<td>Carbohydrates/lipids/proteins</td>
<td>Infrared spectroscopy (IR) and Raman</td>
<td>Spectra are assigned to the different food components according to the information available in databases, the literature, and calculations derived from quantum chemistry</td>
<td>[78]</td>
</tr>
<tr>
<td></td>
<td>Glycoalkaloids (α-solanine and α-chaconine),</td>
<td>Liquid chromatography with tandem mass spectrometry (LC-MS-MS).</td>
<td>Mass spectra are analyzed by a comparison with specialized databases</td>
<td>[79]</td>
</tr>
<tr>
<td></td>
<td>Tropane alkaloids</td>
<td>High-performance liquid chromatography-tandem mass spectrometry (HPLC-MS/MS)</td>
<td>Mass spectra are analyzed by a comparison with specialized databases</td>
<td>[80]</td>
</tr>
<tr>
<td></td>
<td>Toxic elements (heavy metals)</td>
<td>Inductively coupled plasma mass spectrometry (ICP-MS)</td>
<td>Detection and quantification of the presence of toxic and essential elements according to calibration curves made with standard solutions of heavy metals</td>
<td>[81,82]</td>
</tr>
</tbody>
</table>

7. Conclusions

The chronological periods in the Ecuadorian Andes vary according to the region, and different dates for the same periods were suggested. In this work, the periods have been classified according to the historical events that occurred in the Quito plateau and its valleys. This was performed via studies that were conducted with radiocarbon dating, which have proposed the dates and periods that have been considered here.

A variety of vegetables and animals that were possibly cultivated/produced and consumed in the Quito plateau and its valleys were systematized. It seems that vegetables constituted the basis of the diet, and they could contain toxic substances. Although meat was available, it was not always accessible because the animals were not domesticated, and their consumption depended on hunting.

It should be noted that no new analytical research (as procedures involving quantum chemistry) was conducted in order to analyze the biomolecules (mainly from amino acids and proteins) that were present in the diet of the inhabitants of the Quito plateau. These
biomolecules that may be present in samples of archeological utensils involved in food preparation and storage, which would allow correlating with the species of animal and vegetable consumed in the proposed periods.

In this regard, future research should deeply investigate (with all of the available analytical methods that are capable of determining biomolecules and possible toxic substances) archaeological samples from the Quito plateau. This kind of study must consider the different historical periods in order to objectively determine the characteristics of the diet of the ancient human communities and the toxic substances that they could have been exposed to.


All authors have read and agreed to the published version of the manuscript.

**Funding:** This research received no external funding.

**Institutional Review Board Statement:** Not applicable.

**Data Availability Statement:** Not applicable.

**Acknowledgments:** The authors acknowledge Escuela Politécnica Nacional (EPN), Universidad Iberoamericana del Ecuador (UNIB.E), Universidad de las Américas (UDLA), Universidad UTE in Quito, Ecuador, and AGROCALIDAD in Tumbaco, Ecuador, for the support of this research work.

**Conflicts of Interest:** The authors declare no conflict of interest.

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