Nutrition and Health
Series Editor: Adrianne Bendich

Ronald Ross Watson
Victor R. Preedy
Sherma Zibadi *Editors*

Chocolate in Health and Nutrition

Humana Press

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Adrianne Bendich, PhD, FACN, Series Editor

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Chocolate in Health and Nutrition

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ISBN 978-1-61779-802-3 ISBN 978-1-61779-803-0 (eBook)
DOI 10.1007/978-1-61779-803-0
Springer New York Heidelberg Dordrecht London

Library of Congress Control Number: 2012940874

Printed on acid-free paper

Humana Press is a brand of Springer
Humana Press is part of Springer Science+Business Media (www.springer.com)

Series Editor Page

The great success of the Nutrition and Health Series is the result of the consistent overriding mission of providing health professionals with texts that are essential, because each includes: (1) a synthesis of the state of the science; (2) timely, in-depth reviews by leading researchers in their respective fields; (3) extensive, up-to-date, fully annotated reference lists; (4) a detailed index; (5) relevant tables and figures; (6) identification of paradigm shifts and the consequences; (7) virtually no overlap of information between chapters, but targeted, inter-chapter referrals; (8) suggestions of areas for future research; and (9) balanced, data-driven answers to patients' as well as health professionals' questions that are based upon the totality of evidence rather than the findings of any single study.

The series volumes are not the outcome of a symposium. Rather, each editor has the potential to examine a chosen area with a broad perspective, both in subject matter as well as in the choice of chapter authors. The editor(s), whose training(s) is (are) both research and practice oriented, have the opportunity to develop a primary objective for their book, define the scope and focus, and then invite the leading authorities to be part of their initiative. The authors are encouraged to provide an overview of the field, discuss their own research, and relate the research findings to potential human health consequences. Because each book is developed de novo, the chapters are coordinated so that the resulting volume imparts greater knowledge than the sum of the information contained in the individual chapters.

Chocolate in Health and Nutrition, edited by Ronald Ross Watson, Ph.D., Victor R. Preedy, Ph.D., D.Sc., FRIPH, FRSH, FIBiol, FRCPath, and Sherma Zibadi, M.D., Ph.D., clearly exemplifies the goals of the Nutrition and Health Series. The major objective of this comprehensive volume is to review the growing evidence that chocolate contains a number of bioactive molecules that can be of value to many aspects of health. However, it would be highly remiss to not first review the complexities of sourcing of cocoa, chocolate manufacture, as well as the physical and biochemical aspects of chocolate components and its by-products so that the clinical studies can be placed in the proper perspective, especially with regard to the potential for comparisons between studies. For example, the volume includes discussions of milk chocolate, dark chocolate, white chocolate, cocoa powder, cocoa butter, and cocoa husks and hulls and comprehensively reviews the effects of temperature and fermentation conditions for the production of each of these "chocolates" on the potential for clinical efficacy. This first comprehensive review of the science behind the active molecules in chocolate and their effects on humans is of great importance to the nutrition community as well as for health professionals who have to answer client questions about this new area of clinical research.

Chocolate in Health and Nutrition represents the first comprehensive compilation of the newest data on the actions of the flavonoids and microorganisms associated with the beneficial effects of chocolate. It is to the credit of Drs. Watson, Preedy, and Zibadi that they have organized this volume so that it provides an in-depth overview of the natural occurrence and biochemistry of relevant molecules in chocolate as well as human exposure to chocolate in its many forms and includes the latest

research on the role of chocolate in normal health areas, including mood, pain and weight management, cardiovascular disease and related conditions, as well as their use as adjuncts to therapeutic agents used in the treatment of neurodegenerative diseases. Of importance, this volume includes an in-depth review of the safety of chocolate with emphasis on the mineral content as well as potential for adverse microbial effects. Fortunately, the safety reviews reinforce the confidence in the products sold by major manufacturers.

The volume is organized into five comprehensive sections. The first section comprises five chapters that include reviews of the history of use of cocoa products from the beginning of time up until present times; there are several unique chapters that describe the hundreds of compounds in chocolate and the thousands of microbes that are identified during the fermentation processes. The sensory component of chocolate that most people identify first is its fragrance, and an in-depth chapter examines the volatiles associated with chocolate.

The second section contains six chapters on the composition of chocolate sources and related plant components. There is an important review of the biochemistry of the cacao bean with detailed tables. In the next chapter, there is a comprehensive evaluation of the effects of processing on the bioavailability of the flavonoids in chocolates. The methodologies available for quantifying the bioactive molecules in chocolate products are outlined in the following chapter. Two critical chapters document the exposure to cocoa plants, including the bean and husk, by animals and manufactured products for humans. Cocoa butter's nutritive value is compared to other fat sources in the final, unique chapter of this section.

The third section, composed of four comprehensive reviews, examines the newest data on the metabolism of chocolate, its bioavailability and factors that affect this parameter, and the activities of the bioactives from chocolate in cell culture. The absorption, metabolism, and pharmacokinetics of the polyphenols are emphasized and provide relevant data with regard to the clinical chapters in the next two sections of the volume. Another unique, detailed chapter describes the significant effects of these bioactives on the human gut microbiota. The final chapter in Section C explores the in vitro biological activity of the cacao husk and mass lignin carbohydrate complexes found in by-products from chocolate manufacture.

Half of this volume is devoted to reviews of clinical significance, with the fourth section, containing 11 chapters, examining the evidence for a role of chocolate in prevention and/or treatment of certain chronic diseases. Most of the clinical studies have looked at potential cardiovascular and neurocognitive benefits. Four chapters review the studies of the cardiovascular system and include specific, in-depth examination of the data on endothelial function, arterial disease, coronary heart disease, and hypertension. Extensive tables and figures are included in these chapters. Two other chapters look at the association of chocolate and prevention and treatment of diabetes. There is a single chapter on the possible link between chocolate consumption and cancer risk, as data are emerging and not at the level of research as the cardiovascular area. With regard to cognitive function, three chapters examine the potential of the anti-inflammatory polyphenols in chocolate to reduce the risk of Alzheimer's disease and/or reduce loss of cognition from other causes, including diabetes.

The final section includes 11 chapters – those that examine many diverse aspects of the association of chocolate with human behaviors including the beneficial effects on mood and pain tolerance as well as those that can help the health professional provide data-based, objective responses to clients about the association of chocolate consumption and weight gain (or loss); effects on withdrawal, addiction, and acne; and potential for dental caries and altering food preferences in children. The final chapter provides an enlightened rationale for conducting well-controlled studies in healthy individuals to determine the full scope of actions of chocolate.

The logical sequence of the sections as well as the chapters within each section enhances the understanding of the latest information on the current standards of practice for clinicians and related health professionals including the dietician, nurse, pharmacist, physical therapist, behaviorist, psychologist, and others involved in the team effort required for the successful treatment of cardiovascular and

other relevant diseases as well as conditions that adversely affect normal metabolic processes. This comprehensive volume also has great value for academicians involved in the education of graduate students, postdoctoral fellows, medical students, and allied health professionals who plan to interact with patients with disorders that may be beneficially affected by the addition of chocolate products or their constituents to the diet.

Cutting-edge discussions of the roles of signaling molecules, growth factors, hormones, cellular and nuclear receptors, and all of the cells directly involved in chocolate flavonoid metabolism are included in well-organized chapters that put the molecular aspects into clinical perspective. Of great importance, the editors have provided chapters that balance the most technical information with discussions of its importance for clients and patients as well as graduate and medical students, health professionals, and academicians.

The volume contains over 100 detailed tables and figures that assist the reader in comprehending the complexities of the metabolism as well as the biological significance of chocolate for human health. The overriding goal of this volume is to provide the health professional with balanced documentation and awareness of the newest research and therapeutic approaches, including an appreciation of the complexity of this relatively new field of investigation. Hallmarks of the 40 chapters include keywords and bulleted key points at the beginning of each chapter, complete definitions of terms with the abbreviations fully defined for the reader, and consistent use of terms between chapters. There are over 2,500 up-to-date references; all chapters include a conclusion to highlight major findings. The volume also contains a highly annotated index.

This unique text provides practical, data-driven resources based upon the totality of the evidence to help the reader understand the basics, treatments, and preventive strategies that are involved in the understanding of the role chocolate may play in healthy individuals as well as in those with cardiovascular disease, diabetes, or neurocognitive declines. Of equal importance, critical issues that involve patient concerns, such as dental caries and food preferences in children, potential effects on weight gain, and addiction and withdrawal, are included in well-referenced, informative chapters. The overarching goal of the editors is to provide fully referenced information to health professionals so they may have a balanced perspective on the value of various preventive and treatment options that are available today as well as in the foreseeable future.

In conclusion, *Chocolate in Health and Nutrition*, edited by Ronald Ross Watson, Ph.D., Victor R. Preedy, Ph.D., D.Sc., FRIPH, FRSH, FIBiol, FRCPath, and Sherma Zibadi, M.D., Ph.D., provides health professionals in many areas of research and practice with the most up-to-date, well-referenced, and comprehensive volume on the current state of the science and medical uses of chocolate. This volume will serve the reader as the most authoritative resource in the field to date and is a very welcome addition to the Nutrition and Health Series.

Adrianne Bendich, Ph.D., FACN
Series Editor

Preface

Historically, the Mayans used the fruit and seedpods from the cacao tree as a food. This food was one of many brought from the New World by the Spanish. The Aztecs made a drink that was thick, unsweetened, and eaten with a spoon, although now chocolate products are widely used around the world, with many modifications. The first section of the book reviews chocolate's historical use in the Americas and production methods built upon that experience.

The second section then reviews constituents, their analysis, and bioavailability to provide a current understanding of chocolate. These include its role in meeting nutritional requirements, aroma, and the role of chocolate by-products, such as cocoa butter, in health. The third section logically leads to expert reviews of how the human body responds to chocolate and its polyphenol components, particularly their digestion by enzymes and gut microflora, absorption, and metabolic interactions that help define potential and defined health benefits.

The major goal of the third section is to evaluate the variety of clinical benefits of chocolate and especially its polyphenols. Thus, dark chocolate could reduce the risk of heart attack and provide other cardioprotective actions if consumed regularly. Reviews suggest that chocolate may have positive health roles in diabetes, cancer, hypertension, arterial disease, neurocognitive functioning, and modification of brain actions, a developing research and clinical arena.

The fourth section, with the most reviews, builds upon brain stimulation and mood alteration due to chocolate. Several sets of authors evaluate chocolate's biochemistry and chemistry and its effects on the brain, mood, and addiction. Withdrawal, cues that stimulate consumption, pain tolerance, mood, addiction, and flavor are reviewed. Cocoa and chocolate components modulate neurocognitive functioning. Some affect children's food and flavor preferences. There are behavioral, cognitive, and affective consequences of trying to avoid chocolate, including withdrawal, that are included in the book. Two major reported adverse effects of consumption of sweetened chocolate, acne and dental caries, are defined in detail.

Finally, contaminants of the cocoa bean in production and processing are reviewed. Knowledge of some of these is important for protection of the consuming public. Contaminants such as mycotoxin from fungi growing on the beans and pods as well as toxins from other fungal species are described and evaluated for well-known health risks. Chocolate can contain a variety of potential toxic materials with lead absorbed from the environment.

Clearly, chocolate and its many products are a complex and diverse set of foods with wide biological and health effects, both positive and negative. The book has 40 chapters, with world experts reviewing their own and others' research, which dramatically defines chocolate and its human effects. Overall, chocolate is a product with a long history of human use that has developed into a multitude of products, with research now showing that some have disease prevention actions.

Tucson, AZ, USA — Ronald Ross Watson
London, UK — Victor R. Preedy
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Acknowledgments

This book was made possible by the efforts of Dr. Watson's longtime editorial assistant, Bethany L. Stevens, and Diane Lamsback of Springer. These two editorial experts worked regularly with Dr. Watson and the authors to encourage and assist in the writing and review of 40 chapters for the book. Support for Bethany L. Stevens was generously provided by Southwest Scientific Editing and Consulting. The support of Dr. Adrianne Bendich, the series editor, in the planning as well as the final organization of the book was very useful, leading to an improved book.

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Part I
Historical Perspectives and Production

Chapter 1
Pre-hispanic Use of Cocoa

Patricia L. Crown

Key Points

- Native to South America, Theobroma cacao was cultivated in Mesoamerica by at least 1800 B.C.E.
- Cacao became a widespread trade item and form of tribute.
- Elites, priests, and warriors consumed a variety of chocolate drinks using distinctive drinking vessels, means of frothing, and additives.
- The healthful properties were recognized, and chocolate was used to treat a variety of ailments before European contact.

Keywords Olmec • Maya • Aztec • Chaco Canyon • Tribute • Currency • Chocolate drinks

Cultures of the New World incorporated cacao into their diet (the foods we eat) and cuisine (how we prepare and eat them) as early as 1800 B.C.E. (Fig. 1.1). The history of cacao use follows a trajectory of use by cultures at an increasing distance from the areas where cacao could be grown, along with increasingly elaborate and distinctive material objects associated with its preparation and consumption. Cacao consumption became an important component in ritual and everyday life, while control over access to cacao fueled economic interactions among New World populations up to (and even after) the arrival of Spanish explorers.

Archeologists rely on multiple lines of evidence in searching for use of plants in the past. Primary evidence may include macrobotanical remains, pollen, phytoliths, impressions of plant parts, and residues. Thus, archeologists traditionally collect soil samples systematically over sites, as well as sampling the interiors of vessels and tools, to search for macrobotanical remains (which often preserve well when they are charred), pollen, and phytoliths. Ancient feces, known as coprolites, can be particularly important in revealing short-term diet and parasite load. Impressions of plant parts in mud, adobe, or ceramics may show the presence of economic plants. Archeologists have employed residue analysis increasingly to determine food remains on vessels or tools, particularly in collaboration with chemists. Gas chromatography–mass spectrometry and high-performance liquid chromatography–mass spectrometry are the techniques most often employed. Some specific plants are more easily

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R.R. Watson et al. (eds.), *Chocolate in Health and Nutrition*, Nutrition and Health 7,
DOI 10.1007/978-1-61779-803-0_1,

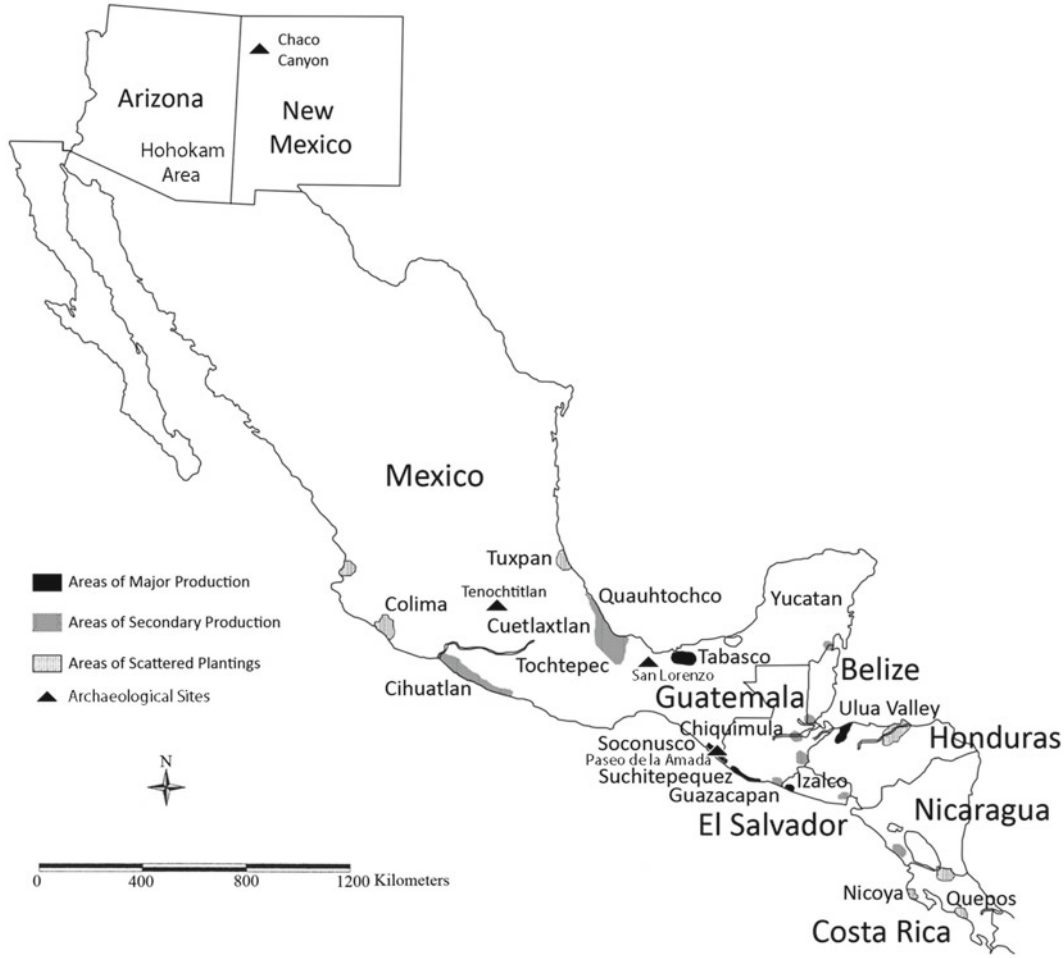

Fig. 1.1 The distribution of cacao cultivation in Central America and Mexico in A.D.1502 and sites/cultures mentioned in the text (Adapted from reference [13])

identified than others because of the presence of compounds, known as biomarkers, that are specific to one or a few plants. Other plants have a dizzying array of compounds, none of which are specific to that plant, so it is not possible to identify them definitively – corn is a good example of a plant known to have been grown and consumed widely in the New World that is difficult to identify as a residue by chemical techniques because there are no lipid biomarkers unique to Zea mays [1].

In addition to the primary means of identifying plants, archeologists employ secondary means of identifying the use of plants. This includes imagery showing plants, documents, and presence of tools known to have been used to prepare or consume specific types of foods. Images painted on pottery or walls or carved into rock may depict plants or foods or even meal preparation and consumption. In more complex societies, written languages document plant and food use. Imagery showing plant use and documents recording plant use in textual form are generally reliable sources, but not always. It is sometimes difficult to determine whether to interpret images literally or whether they may be metaphorical or mythical in meaning. And documents cannot always be trusted as reliable sources of the truth, particularly when written by colonial observers of a culture outside their own. Imagery and texts are very useful, but often archeologists have to rely solely on the presence of tools associated with specific foods. Just as many modern foods and drinks are prepared with tools or served in containers that are specific to that type of food or drink, foods and drinks in the past were often prepared with

tools dedicated to that preparation or served in special containers. This is particularly true for foods that anthropologists call *luxury foods,* foods that are desirable but not essential to human nutrition [2]. Such foods are often difficult to obtain, reserved for special occasions, require complex preparation techniques and knowledge, and are often fatty, sweet, or succulent [3]. Use of special containers to serve such foods enhances their distinctive qualities and signals their consumption from a distance. In our own culture, alcoholic drinks are often served in special vessel forms so that it is possible to determine what someone is drinking without asking and from a considerable distance – martini glasses or brandy snifters are good examples. A savvy archeologist in 200 years might interpret the recovery of a martini glass as proof that martinis were consumed without finding martini residues or a charred olive pit! In this same way, archeologists attempt to determine the presence of special tools or containers dedicated to the preparation or consumption of specific foods and drinks. We can argue from such indirect evidence that a specific food or drink was consumed in the past.

Archeologists have employed all of these forms of evidence to search for use of cacao in the past. Working in various parts of the New World, archeologists have recovered macrobotanical remains of cacao, residues, imagery, texts, and tools/containers as evidence of cacao use. Current evidence indicates that from early pre-Hispanic times into the historic period, consumption of chocolate drinks involved special containers, a method for frothing, cacao, and additives. The drinks varied in temperature and additives but shared the four characteristics listed. Research on cacao use is changing rapidly, with yearly publications providing new information. Here I summarize what we know today, with the caveat that new information may alter or supplement this discussion.

The most recent publications indicate that Theobroma cacao is a native Amazonian plant domesticated in Mesoamerica, with possible incipient domestication in Amazonia [4]. At the time of European contact, cultivated cacao trees were noted only in Mesoamerica. Archeological evidence places the earliest cacao use at the Paso de la Amada Site of the Mokaya Culture located on the southern Pacific Coast of Mexico, dating from 1900 to 1500 B.C.E., based on residue analysis of a neckless globular jar form [5]. Cacao residues were also present during the Early Preclassic occupation of the earliest Olmec capital of San Lorenzo at 1800 to 1000 B.C.E. [6], located in southern Veracruz, Mexico. Vessel forms tested confirm that cacao drinks were consumed, but not what these drinks were. They might have been drinks made from cacao nibs or from the sweet pulp surrounding the nibs; a fermented beverage may have been made from the pulp, as has been documented historically for wild Theobroma in South America and cultivated Theobroma among the Highland Maya [6, 7]. The argument for a precedent for a fermented beverage made from the pulp is based on the shape of the vessels containing residues, with earlier bottle forms shifting to later forms more amenable to creating a froth. As the froth is more likely associated with drinks made from cacao nibs, the argument is made that earlier drinks might be of the fermented, nonfrothing variety [7, 8]. The evidence from the Olmec area indicates cacao residues in many distinct vessel forms and ceramic wares, including cups, open bowls, and bottles as well as decorated fine wares and coarse ware [6]. Recovery of residues in such an array of vessel forms and wares suggests that cacao drinks were fairly widely available and consumed, particularly given that 17% of all ceramics tested had cacao residues. Of particular interest, four positive samples from San Lorenzo came from a mass of several hundred broken vessels capping a burial pit containing sacrificial victims; this association is interpreted as indicating the consumption of cacao drinks in "a well-attended, postinternment celebration" [6]. The consumption of cacao drinks in association with ritual thus has a history spanning nearly four millennia. Interestingly, the word "cacao" originated among speakers of an early Mije-Sokean language residing along the Gulf Coast of southern Mexico [9], the Olmec heartland.

Chocolate drinks subsequently became a widespread part of Mesoamerican cultures up to the present day. Consumption of cacao-based drinks moved far outside the area of possible Theobroma tree cultivation, indicating widespread exchange of cacao. These drinks most often were consumed using cacao nibs, a variety of additives, specialized vessel forms, and a method for frothing. Ultimately, cacao became an important part of the economy of Mesoamerica, an economy that was taken over by the Spanish, despite their initial distaste for chocolate drinks. Chocolate drink consumption was too widespread to describe every nuance here, so I provide a brief overview of the best known areas.

Chocolate drinks were probably prepared as they are today through a multistage process. First, growers harvested the cacao pods and removed the nibs from the pods. Then they fermented the cacao beans in the surrounding pulp for one to several days, often on the forest floor. The fermented beans were then removed from the pulp and allowed to dry in the sun for 1–2 weeks. Roasting was the next stage, although sometimes this stage was omitted. Winnowing then involved removing the papery shell to extract the nib. The nibs were then ground into cacao liquor, which might be mixed with a variety of additives and consumed immediately, or formed into tablets for later use. Tablets had a relatively long shelf life, lasting as long as 2 years. Exchange and trade in the past most often involved either the roasted cacao beans or tablets rather than the fruit or liquor.

The Maya occupied areas of the lowlands and highlands of Mexico, Guatemala, and Belize. Maya farmers grew Theobroma cacao trees in the lowlands, and at least some Maya drank chocolate, as attested by residues on vessels, inscriptions, and texts. During the Preclassic, the Maya drank chocolate from spouted vessels, the spout serving not only as a vehicle to pour the drink, but also perhaps as a means to blow air into the chocolate, creating a bubbly froth on the surface [10]. From about A.D. 250 to 900, the Classic Maya built cities with temple-pyramids occupied by kings and elites and supported by a rural population of farmers. The elite consumed chocolate both in drinks and thicker gruels, with a variety of additives; there was no single chocolate drink or recipe. Each concoction had a separate name. There were probably both hot and cold varieties of chocolate drinks, although the historic Maya tended to favor the hot varieties. Chocolate was also used as an additive in drinks and foods with more substantial ingredients, such as corn meal. Depictions of chocolate drink preparation show the Classic Maya using tall cylindrical jars to hold their drinks, a fact supported by inscriptions on the jars that state that they were used to hold chocolate drinks. The drinks were frothed by pouring from one vessel to another from a height, creating a cascading waterfall-like effect with froth bubbling up on the surface of the lower jar. Images confirm preparation of chocolate drinks in formal settings that suggest a theatrical performance surrounding the preparation. Elites and royalty are clearly the primary consumers, but it is unclear if lower classes, including farmers, drank chocolate as well [11].

Cacao was a sign of wealth and power among the Maya, often served at lavish feasts to gain loyalty and obligation. The Theobroma cacao tree was considered sacred and cacao figures prominently in Mayan myths. Cacao was often associated with graves and was considered an important food for the journey to the afterworld. There was a symbolic association among chocolate and blood, rulership, ancestors, and the Underworld [12]. Chocolate drinks were sometimes flavored with achiote/annatto, a red spice that dyed the drinks the color of blood. Cacao was exchanged in wedding ceremonies and was an important component of other rites of passage. Cacao beans were given as gifts and perhaps tribute payments among the Classic Maya [12]. Cacao beans were even counterfeited in clay [11].

By the end of the Classic, some Maya populations had developed widespread trading networks along the Gulf Coast, with large trading canoes. Cacao was both commodity and currency [11]. Cacao was grown wherever it could be, including exploitation of microenvironments in areas where cultivation would otherwise be impossible. Conflict over control of cacao-growing land or access to trade with cacao-growing populations was endemic up to the Conquest.

Cacao had spread to the American Southwest by about A.D. 1000 and perhaps earlier. Current evidence indicates cacao residues on ceramics from Ancestral Pueblo sites in Chaco Canyon, New Mexico, and the Hohokam area of southern Arizona [13, 14]. Ongoing research will likely enhance our understanding of the temporal and spatial extent of cacao use in the American Southwest. Within Chaco Canyon, cacao use is documented in association with cylindrical jars similar in form to those used in the Maya area (Fig. 1.2). However, the Chacoan vessels are locally made and later than the Classic Period Maya jars. Cacao could not be grown in the Chacoan area, so it must have been acquired through one of three mechanisms: by Chacoan people walking south to acquire cacao at the source (a distance of about 1,900 km to the nearest area known to have grown cacao during the historic period), by Mesoamerican traders bringing cacao northward to Chaco, or by a series of shorter exchanges across this distance. Parts of the distance might be traveled by canoe, but Chaco Canyon

Fig. 1.2 Cylinder jar from Chaco Canyon housed in the American Museum of Natural History (Patricia Crown, photographer)

is not located on a navigable watercourse. Other Mesoamerican items occur in some Chacoan sites, including the Scarlet Macaw (another species from the tropics), as well as copper artifacts, pseudo-cloisonné objects, and some species of shells. It is currently unknown whether the cacao came from western Mesoamerica, as did the copper objects and many shell species, or from eastern Mesoamerica.

The specific recipes for consuming chocolate drinks are not known; however, it seems most likely that chocolate was exchanged in prepared bricks rather than as raw beans, particularly because no cacao beans have been recovered in archeological sites in the Southwestern area. The cylinder jars often occur in sets of two to four identical jars, suggesting that preparation included the pouring method to create froth, as was common among both the Maya and later Aztec. Only about 200 of these vessels are known in museum collections and most came from a single large cache within the Chacoan site of Pueblo Bonito.

No records exist to provide information on the use of cacao within Chaco Canyon; however, it seems most likely that chocolate drinks were luxury foods. As defined by anthropologists, luxury foods are foods that are difficult to obtain and nonessential to human nutrition, but desirable. They are often sweet or succulent or fatty, and they often require specialized preparation knowledge [2]. Because the cylinder jars do not occur associated with individual burials, but rather primarily in large caches, it is likely that the jars and chocolate were served in communal feasts or rituals rather than in funeral rites. Serving chocolate drinks at a feast would have signaled wealth and ties to Mesoamerica. It likely created obligations for the guests to reciprocate with subsequent labor or gifts.

Less is known about cacao in the Hohokam area, except that the residues seem to be present on early, shallow oblong bowls that might have been used to grate cacao bricks by about A.D. 900

(ongoing research by Patricia Crown and W. Jeffrey Hurst) and on later beaker-shaped vessels dating to the fourteenth century [14]. The Hohokam area extended from the Arizona/Sonora border north almost to Flagstaff, and they had interaction with Mesoamerica, including macaws, copper bells, and pseudo-cloisonné, just as Chacoans did. The Hohokam particularly crafted items from shells, including many from species found in the Gulf of California, so it is most likely that they exchanged chocolate from West Mexico. Trading canoes from the south might have reached as far as the northern portion of the Gulf of California, with overland trade from there.

Returning to Mesoamerica, the Aztec occupied the Valley of Mexico from the early fourteenth century, conquering a large area by the late fifteenth century. This included the Soconusco area famed for growing high-quality cacao. The large Aztec capital of Tenochtitlan received massive amounts of tribute twice yearly, including cacao and many other luxury items. Aztec rulers occupied huge palaces that included cacao warehouses. In addition to acquiring cacao through tribute, Aztec merchants, called *pochteca*, bought and sold cacao. Cacao was sold in markets within the Aztec Empire. A single *pochteca* would normally carry 24,000 cacao beans in a single backpack [11]. Cacao beans were currency in the Aztec Empire with fixed values, and they were sometimes counterfeited.

The Aztec elite drank chocolate in a variety of elixirs, preferring cool rather than hot drinks. As with the Maya, they mixed chocolate with many different spices and additives. The conquering Spanish recorded various versions of how cacao was prepared, but maize, chili, annatto, honey, and vanilla were common additives, along with several types of powdered flowers. The Aztec consumed chocolate drinks from small, hemispherical bowls of ceramic, gourd, or gold [11]. Such vessels appear on tribute lists along with cacao itself. As with the Maya, the Aztec created a froth by pouring from one vessel to another. Cacao consumption was largely the purview of the elite, warriors, and merchants. Commoners did not have access to chocolate drinks [11].

For the Aztec, cacao was symbolically associated with the south, the Land of the Dead, the color red, and blood [11]. Denied cacao throughout their lives, slaves might taste cacao for the first time if chosen for sacrifice. A drink was even made of chocolate mixed with water containing human blood washed from sacrificial knives to give sacrificial victims courage [11].

Theobroma cacao, the fruit, and the drinks/foods made from it all figured prominently in Mesoamerican myths, songs, poems, and texts. Control over access to cacao created economic partnerships and conflicts throughout much of the millennium before the Spanish entered the New World. The first documented European contact with cacao occurred during Columbus' fourth voyage, when his men encountered a Maya trading canoe filled with trade goods, including cacao [11]. The massive tribute system controlled by the Aztecs, which included cacao, was a critical prize of the Spanish conquest, and although the Spanish did not initially consider chocolate drinks favorably, their success in the New World was at least in part due to their co-opting the cacao trade and tribute.

There is no question then that cacao had symbolic and economic value to many peoples of the New World, but what about medicinal uses for cacao in the past? It is not easy to determine medical practices in the past without texts. Wherever we find residues of cacao, it is possible that the chocolate drinks were viewed as having nutritional and healthful properties, but we cannot prove this. All human societies have healers, and these specialists often use plants to treat disease or to reach altered states of consciousness. Most of what we can glean about the use of cacao in medical practices comes from texts written in the 1500s, and most are specifically about the Aztec practices. The Aztec Emperor maintained a botanical garden to grow and test plants for medicinal purposes [11]. Three manuscripts are particularly useful in understanding Aztec use of plants in medicine: the Badianus manuscript, Florentine Codex, and Princeton Codex [15]. These manuscripts detail several medicinal uses for cacao. Chocolate drinks treated stomach and intestinal problems. When mixed with liquid from silk cotton tree bark, it cured infections [15]. When mixed with rubber, it (not surprisingly) stopped diarrhea [16]. Chocolate ended fever and faintness when combined with ground corn and blended with *Calliandra anomala* [15]. Chocolate drinks mixed with several herbs could also help end coughing. Chocolate was also blended with various medicinal preparations to improve their flavor [15].