The Botanical Science and Cultural Value of Coca Leaf in South America

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Abstract

This chapter on coca leaf integrates a comprehensive summary of the botany, ethnobotany and ethnography of coca and its traditional consumers in order to set the stage for subsequent chapters on cocaine, drug policy and reform efforts. First, we present the botanical diversity of coca including current cultivation patterns as well as geographic, ecological, and ethnobotanical properties for each of the four coca varieties. Second, we discuss the most popular traditional uses of coca leaf by Andean indigenous cultures across the ages. Third, we lay out the current scientific understanding of the chemistry and pharmacology of the coca leaf. Here we focus on the identification and quantification of its nutritive and medicinal compounds in addition to the alkaloids, especially cocaine. Finally, we use ethnographic data from Bolivia, Peru and Colombia to consider the ancient and modern cultures of coca cultivation and use, agrarian community politics, economic factors of licit vs. illicit coca markets, and how the public image of the leaf has shifted over the centuries, leading to some of the current controversy surrounding this ancient plant.

Keywords: *Erythroxylum*, coca leaf, *ayllu*, reciprocity, *Pachamama*, cocaine alkaloid, Aymara, Quechua, Kogi, Nasa, Spanish colonial era, Yungas.

Introduction

Any new analysis of current cocaine policy and reform should start with a comprehensive overview of the drug's botanical source: the coca leaf, from the plants *Erythroxylum coca* and *Erythroxylum novogranatense*. Derived from the Aymara and Quechua word *quqa* (or *kuka*), meaning 'tree', this hardy plant is said to be a gift from *Pachamama* (Mother Earth) because of its many beneficial properties and its ability to grow in depleted soil with little tending. Its importance to upland Andean communities in much of the region is exemplified by a common refrain heard in Bolivia's Yungas: "Coca is a part of everything, it is integral to life."[1]

Coca was among the first domesticated plants in the Andean region and over the past 8,000 years has acquired a wide range of medicinal, nutritional and ceremonial uses (Dillehay et al. 2010, Plowman 1984). Although it may be difficult to comprehend in Western culture, coca is a sacred plant whose cultivation and use is interwoven with the daily lives of millions of South Americans. The historical and contemporary significance of coca is a complex subject, and the reader will realise that a complete understanding of the dichotomous social aspects of this plant requires elaboration via the many publications we reference.

In assessing coca leaf consumption, it should be remembered that cocaine is but one chemical among many of a vegetal complex with varied

[1] Translation of quotes in the original Spanish, collected by Conzelman in the Yungas of Bolivia (a traditional coca growing area) since 2001.

pharmacological actions. The reputation of cocaine as a dangerous and disruptive drug among modern consumers sharply contrasts with the traditional and religious use of the coca leaf among South American indigenous and *mestizo* peoples. In the harsh and extreme environments of the Andes, mastication of the leaves for their mild stimulating and medicinal properties has shaped the plant's physical and spiritual roles as a bridge between the indigenous peoples and environments within the divine geography of the Andes (Davis 2009, 1996; Allen 2002). In more recent millennia, coca was adapted to the Amazon basin where it also became incorporated into creation stories of numerous tribes (Plowman 1986, Reichel-Dolmatoff 1971).

There are a number of scientific studies of the pharmacological and psychological effects of cocaine paste, cocaine hydrochloride, or cocaine base as compared with the chewing of coca leaf (see Weil 1981, Hurtado 2008). Modern research suggests that the potent psychoactive effects and personality disintegration of cocaine use has little relation to the complex and milder stimulant properties of coca chewing. Nutritional analysis of the coca leaf has documented numerous essential vitamins and minerals that add to this distinction. Today, even individuals who do not chew the leaves will commonly utilise them in folk medicine or religious ceremonies. Indeed, the overarching effects of coca consumption contradict the global anti-coca legislation embodied in the 1961 United Nations Single Convention on Narcotic Drugs. This legislation dates back to the 1950 UN Commission of Enquiry on the Coca Leaf, written at the high point of historical anti-coca fervour and founded upon biased and racist observational reports.

Today coca leaf is still revered for its medicinal, nutritional and ceremonial uses by over five million South Americans, but it is also a political symbol of indigenous resistance to Western hegemony and a factor in the formal and informal economies of Bolivia, Peru, Colombia and beyond. While some culture groups maintain the ancient traditions that honour the sacred leaf and connections with their ancestors, others, under the spell of cocaine capitalism, unceremoniously dump the leaves into pits of toxic chemicals to extract its particularly lucrative alkaloid. Meanwhile the majority of coca leaf users are engrossed in their daily livelihoods and cultural practices as the global complexities and contradictions surrounding this tenacious plant continue to unfold.

In the spirit of previous important efforts to represent the state of current knowledge on coca leaf and cocaine (Leons and Sanabria 1997, Pacini and Franquemont 1986), the primary goal of this chapter is to elucidate the fundamental botanical science of coca leaf and its long-established cultural uses among indigenous peoples, primarily in highland Bolivia and Peru. It begins with key information about the botany of coca plants and modern cultivation and ecological patterns. This is followed by an overview of the social and ritual uses of coca leaf with a focus on coca chewing, and a discussion of the plant's chemical constituents and their pharmacological, nutritional and medicinal effects.

The botany of coca

At the time of European contact, coca was probably being propagated and consumed by indigenous groups ranging from Nicaragua to Chile and Argentina (Bray and Dollery 1983). Although ecological and morphological (form) differences in coca were recognised by the 16th century, it was only recently that ethnobotanist Timothy Plowman formally identified the botanical diversity of coca (Plowman 1979, 1986). His studies showed that all varieties of coca are derived from two closely related species: *Erythroxylum coca* and *E. novogranatense.* Each of these species is further delineated into two distinct varieties, all with unique ecological and

ethnobotanical attributes. Thus the four cultivated cocas are scientifically described as follows: *Erythroxylum coca* variety *coca, E. coca* var. *Ipadu, E. novogranatense* var. *novogranatense,* and *E. novogranatense* var*. truxillense.*

All four of the cultivated coca varieties are slender bushes that reach one to four metres tall and bear bright green leaves. Their small white flowers grow along the branches and give rise to red, orange or yellow fruits that are readily eaten by tropical birds. In fact, the graceful form of these shrubs has led to their frequent use as ornamentals or garden plants in many South American countries. The shrubs are mostly grown from seed and can be harvested after one or two years, at which time the leaves are picked off the entire plant. Huánuco coca, the most common variety, can yield four to six harvests per annum for up to 40 years (Plowman 1986). As Johnson (1996) observes, there is no other woody plant whose leaf yield and quality remains so consistent while being harvested so frequently and for such duration.

Bolivian or Huánuco Coca, *Erythroxylum coca* var. *coca*

The nomenclature of this variety reflects the immense geographic area where it is grown, spanning from Ecuador to Bolivia. Huánuco is cultivated on all scales from family plots to large terraced plantations along the eastern slopes of the Andes in the *montaña* ecological zone, commonly called the *yungas* in Bolivia. Ranging from about 500 to 1,500 m in elevation, the *montaña* is characterised by high rainfall, mineral-rich soils and moist tropical forest vegetation. With its wide range of cultivation, Huánuco coca is the source of most commercial coca leaves and cocaine (UNODC 2014c). It has an average cocaine content of 0.63% by dry weight but this can be highly variable, suggesting an influence of environment (potentially altitude) on this trait as well as existence of different landraces that are still unidentified by botanists (Plowman and Rivier 1983, Plowman 1986). Its name derived from the 18th-century bishop of the southeastern town of Huánuco, Peru, who supplied the key sample coca plant known to European botanists, and generalised during the legal coca export boom of the late 19th century as a commercial trade name along with 'Bolivian' and 'Trujillo' brands (not to be confused with the genuine botanic varieties).

This variety stands out among cocas because it is the only variety that does not depend entirely on humans to survive and reproduce, and is found growing nearly wild in the *montaña* of eastern Peru. For this reason, Plowman believed the Huallaga Valley region of Peru (below the colonial and modern town of Huánuco) to be the actual native range of this coca. Moreover, this variety likely represents the ancestral lineage from which the other three cocas were derived via human selection and distribution (Plowman 1986). However, this hypothesis has yet to be supported by modern scientific methods (Emche et al. 2011).

Amazonian Coca, *Erythroxylum coca* var. *Ipadu*

Amazonian coca differs from its Andean forebear in its method of cultivation and preparation as well as a number of morphological and chemical features. It is primarily grown by numerous tribes in the upper Amazon basin (Colombia: Amazonas, Vaupes; Ecuador: Napo) but can be found infrequently along the length of the Amazon River and its major tributaries. Instead of growing from seed like all other cocas, Amazonian coca is grown clonally from stem cuttings in cleared forest patches along with other staples like maize, manioc and plantains. After one or two years, the plants are sectioned and ready to move to the next site of habitation with their itinerant human partners (Plowman 1986).

This variety shows the lowest concentrations of cocaine at 0.25% of dry weight (Plowman and Rivier

1983). This low content may have been the stimulus for the unique preparation of Amazonian coca leaves that is practised identically by all lowland tribes (traditional highland coca leaf chewing methods are presented later in the chapter). Leaves are toasted on a griddle, then pulverised and combined with alkaline ash from burned *Cecropia* leaves. The pulverisation process is repeated several times until the precise mixture is attained, resulting in a very fine greyish green to bright green powder that is placed in the mouth and masticated for work during the day and during celebrations at night (Plowman 1981).

In the mid-1970s, cocaine traffickers discovered Amazonian coca and began to exploit the lowland rainforest regions and the tribal groups living there (Plowman 1986). Many new hybrid coca varieties have since been established in Amazonia as cultivation has increased in this region (see below; Galindo and Fernández-Alonso 2010).

Trujillo Coca, *Erythroxylum novogranatense* var. *truxillense*

Trujillo coca is a drought-resistant and flavourful coca primarily grown in the dry uplands of river valleys of northern Peru, such as the Otuzco basin in La Libertad province. Today it is grown commercially on a small scale for coca chewing and for the 'secret' flavouring compound of Coca-Cola. The aromatic oil used in the cola, methyl salicylate (wintergreen oil), is unique to Trujillo and Colombian coca. Its leaves contain high cocaine content (0.72%), chemically removed from the Coca-Cola formula starting in 1903. It also contains significant concentrations of cinnamoylcocaine, which is almost absent in both other varieties of *E.* coca (Plowman and Rivier 1983).

These chemical factors, combined with the palatability of its smaller leaves, may explain why this variety was apparently preferred by the imperial Inca ruling class of Cusco. Indeed, all archaeological findings of coca leaves from Tawantinsuyu (the Inca empire) have been of the Trujillo variety, revealing that it was once grown and traded extensively on the west coast of what is now Chile and Peru (Plowman 1986). The most ancient and remarkable site in the Nanchoc valley near Cajamarca in northern Peru is about 8,000 years old (Dillehay et al. 2010), which confirms that coca is one of the oldest cultivated plants in the Americas.

Plowman thought Trujillo coca to be an intermediate, transitional species between Huánuco coca and Colombian coca. However, modern genetic evidence suggests *E. novogranatense* might have been domesticated independently from *E. coca* in northwestern South America (Johnson et al. 2005, Emche et al. 2011).

Colombian Coca, *Erythroxylum novogranatense* var. *novogranatense*

The fourth variety of the plant, Colombian coca, is thought to be the most derived and specialised of the cocas because of its ecological tolerance and its unique trait of being self-compatible, a trait quite favoured among cultivars because isolated or desirable individual plants can reproduce with themselves. Colombian coca is grown in household plots as ornamentals as well as for personal consumption and medicine.

This variety yields the most cocaine, averaging 0.77% of dry leaf weight (Plowman and Rivier 1983). Over the past three decades, because of the structure of the global cocaine trades, much Andean coca cultivation shifted to Colombia for illicit cocaine production. This production climaxed in more than 140,000 hectares at the start of the 21st century but is now reduced to under 40,000 hectares (UNODC 2014a). Plowman (1986) himself observed its small-scale cultivation largely in the Río Magdalena and Río Cauca valleys, used primarily by Nasa peoples, but now we find that coca cultivation

in Colombia has been pushed out of populated regions and into broad swathes of lowland tropical forests, such as in the Putumayo and Caquetá departments, as a result of post-2000 aerial fumigation under Plan Colombia. It is possible that the only original Colombian coca variety now in existence is being cultivated by indigenous groups like the Kogi and Arhuacos of the remote northern Sierra Nevada de Santa Marta.

Modern cocas

When crop plants are thrust from traditional cultivation into modern industrial agriculture, the characteristics and identity of plants change rapidly under sophisticated growth, breeding and selection regimes. The four traditional coca varieties are becoming more and more scarce as they are replaced by new variants and hybrids that resist disease and glyphosate, grow faster, tolerate new and challenging environmental conditions, and, of course, produce more cocaine. Today there are more than fifteen new varieties of coca produced in Colombia and we have only a preliminary understanding of their identity based on affinities to the four traditional varieties (Johnson et al. 2005, Galindo and Fernández-Alonso 2010, UNODC 2010).

Yet more important than identification and classification of these new plants is the study of their relationship to humans and Andean societies, and what desired characteristics are being selected for. This information would have many benefits for the control of illicit coca production and deforestation. Such data would reveal the geographic origins of novel varieties and whether there is international trade of new cultivars, as well as the ability of modern varieties to be grown in new habitats. An updated analysis of the botanical science of coca – building on Timothy Plowman's legacy, which was cut short by his untimely death in 1989 – is needed to catch up with almost three decades of modern breeding and evolution that have outpaced academic research on the *Erythroxylum* genus.

Coca cultivation patterns in South America

Coca cultivation patterns have shifted considerably in history and particularly in contemporary decades due to the pull of illicit coca for processed cocaine, where the preponderance of coca grown today ends up. After the Spanish conquest of the Incas in 1532, Spanish churchmen at first piously outlawed coca leaf as a pagan vice and a deterrent to assimilation. But the concurrent demographic collapse, the disappearance of Incan controls on commoner coca use, the violent reorganisation of 'Indian' caste lifestyles, the dependence on coca by indigenous people forced to work the *mita* labour drafts in the silver mines of Potosí (and other mining zones), and the Spanish commercialisation of the leaf for profit, all produced by the late 16th century a boom in Andean coca cultivation. Most of the coca brought to Potosí in the 1500s was grown in new plantations in the subtropical valleys below Cusco, where coca had been grown during Inca times. But by 1800, 90% of Potosí's coca production had shifted to the Yungas of Bolivia, near La Paz and Bolivia's heavily indigenous *altiplano* village consumer routes. The Yungas was dominated by the semi-feudal *hacienda* system involving the major European families, represented by the powerful landowners' union SPY (*Sociedad de Propietarios de Yungas*). A few entrepreneurial Indian *ayllu* groups participated as well (Spedding 2004, Klein 1986, Soux 1993).

Huánuco coca from the Yungas is still renowned for its superior nutritional quality and sweet flavour, ideal for its most common uses, chewing and tea (Sauvain et al. 1997). Yungas coca is still the standard for quotidian consumption around Bolivia and it is preferred by labourers and *curanderos* in the cross-border coca-user zones of northern Argentina (Rivera 2003). In Peru, coca is grown in numerous, scattered and geographically remote valleys, and

while its use is not as pervasive as in Bolivia, for highland indigenous consumers the leaf is revered as a central part of their cultural patrimony and food security (Durand Ochoa 2012). In Quito (today's Ecuador), where coca was not used for colonial forced labour, it is believed that suppression of coca chewing by Spanish viceroyal and ecclesiastical officials was successful in eradicating coca, and traditional uses of the leaf in Ecuador never fully revived (León 1952). As previously noted, New Granada (today's Colombia) had only sparse indigenous use of coca, and indigenous populations became a small minority over the colonial period.

Spurred on by the demand for illicit cocaine after 1970, the late 20th century and early 21st century has witnessed a number of dramatic shifts and expansion in coca cultivation – patterns covered rigorously in other areas of this report. The historic highpoint of Andean coca cultivation was likely the early 1990s, when Peru's Huallaga Valley alone sustained more than 120,000 hectares in coca – cultivated by some 60,000 peasant households – mostly for export by international drug traffickers in Colombia. In fact, coca had been expanding even prior to the drugs trades, as both Bolivia and Peru first built roads after World War I into lowland tropical valleys. In Peru, the state unsuccessfully tried to manage and regulate emerging growing areas, such as the Valley of Convención in Cusco, through ENACO, a post-1950 government sales monopoly. In Bolivia, production zones shifted and expanded dramatically with the Bolivian Revolution of 1952, which both broke up the long-standing elite Yungas coca *haciendas* and the SPY, and opened large-scale and unrestrained peasant cultivation in the more tropical valleys of Cochabamba, known as the Chapare region (Weil and Weil 1993). In another twist, by the late 1990s, aggressive US-backed eradication programmes in Peru and Bolivia had pushed illicit coca production into Colombia, a country with little prior local coca heritage but flourishing cocaine cartels who needed to maintain their supply of the leaf. In 2000, Colombia became the epicentre of the US-led war on coca with the implementation of Plan Colombia. Since about 2005, as the US-bound cocaine trafficking route shifted to Mexican control, illicit coca has begun to expand again in the central and southern Andes and new cocaine markets are opening up in Brazil and beyond.

In the years 2010 and 2011, coca production – primarily still of Huánuco coca – hit 31,000 hectares in Bolivia and more than 60,000 hectares in Peru, largely in the isolated VRAEM region (the southern Apurímac Valley system), which is now the world's leading site for producing illicit cocaine. In Peru, the vast majority of coca is grown for black markets, while in Bolivia, where coca use has now expanded well beyond indigenous people and uses, most coca flows though legal channels. Moreover, in 2013 and 2014 Bolivia actually witnessed a 20-25% reduction in its total coca area. This decrease is credited to President Evo Morales's 'social control' programme, a method of nonviolent manual eradication of coca crops in excess of one *cato* – a traditional 40x40 metre plot – per family (Ledebur and Youngers 2013, Kohl and Farthing 2012, Grisaffi 2010). This unconventional method to protect legal coca cultivation and curb illicit production is carried out by community-based *sindicato* councils and promoted by the Morales government in accordance with the Comprehensive Study of the Demand for Coca Leaf in Bolivia (CONALTID 2013; UNODC 2014b), backed by the European Union. Meanwhile, more conventional militarised eradication efforts are being renewed in Peru by the US and Peruvian governments (UNODC 2014c), so far to no avail. Coca cultivation in Colombia has been declining since 2001, with now dramatic cutbacks: the 2013 census reports only 48,000 hectares of coca in production, a third of the 1999 total. But rather than being concentrated in a limited highland area,

because of repressive eradication efforts most coca grown in Colombia is now scattered across tropical lowland rainforests (and increasingly in the Pacific region and borderlands with Venezuela).

Cultivation today is less than the scale of illicit production during the cartel-led cocaine boom of the 1980s and 1990s, but one repercussion of the aggressive militarised eradication campaigns by the US government is the so-called 'balloon effect'.[2] One facet of this effect is the ongoing cross-border cultivation shift, for complex geo-political reasons, just described. The other part is largely ecological: suppressing cultivation in traditional highland coca-growing regions caused a sharp increase in the deforestation of virgin tropical forest to introduce coca into the *montaña* and Amazon lowlands, such as the Chapare and Santa Cruz regions in Bolivia, Putumayo and Caquetá in Colombia, and VRAEM in Peru. Cocaine enjoys a fairly stable demand in some consumer nations and is traded on a black market; its price remains inflated (especially as the supply of coca falls) due to the risks involved in illegal processing and transport of the drug and its pricey precursor chemicals. As such, small-scale growers and trafficking cartels alike will move to uninhabited sections of forest to continue planting coca and producing the drug for export. Poor and marginalised *campesinos* provide a modest livelihood for their families, and cartels reap the substantial share of declining profits (Youngers and Rosin 2005, Gill 2004). This trend has been most pronounced in Colombia – one of five 'megadiverse' countries and a biodiversity 'hotspot', according to Conservation International – where 276,000 hectares of virgin Amazon rainforest have been cleared for coca crops since 2001 (Davalos et al. 2011, UNODC 2014a). As coca cultivation continues to spread to new and sensitive areas, the ecological balloon effect is evident in Bolivia (Conzelman 2007) and Peru, and on a small scale even in Argentina, Brazil, Ecuador and Venezuela.

[2] There are other alarming aspects of coca eradication policy in Colombia, notably the pervasive application of Monsanto's concentrated glyphosate as a fumigant; these topics will be taken up in subsequent chapters on drug policy.

Social and ritual uses of coca leaf

Traditionally, the agricultural cycle of coca depended upon the reciprocal labour of women and men, from clearing new or fallow land, building terraces and planting the coca seedlings, to harvesting the leaves and seeds. This ancient practice of Andean reciprocity – called *ayni* –builds relationships of trust and mutual aid within and between rural communities over the long term (Allen 2002). Before the Spanish arrived, textiles and coca leaf – not silver and gold – were the most valued commodities and as such were commonly used in trade or as compensation for labour, and as a ritualistic element of exchange (Murra 2002 [1972]). Such use of coca was only one component of a comprehensive system of barter exchange called *trueque*, by which products and labour, not money, were traded within and between communities and vertical ecological zones. The fundamental Andean cultural values of *ayni* and *trueque* were the foundation of the ancient kinship networks of the *ayllu* communities (Albó 1995).

Among all of the indigenous groups that use coca in the Andes and Amazon of South America, the primary applications of the leaf are for work, medicine and ritual – though these uses are not always distinct and often overlapping (Sikkink 2010). There are well over five million people using coca leaves in South America. Bolivia accounts for 3.1 million users (CONALTID 2013), including many *mestizos* and lowlanders, and the Peruvian government estimates over two million chew and use the leaves (Lewis III 1997). We know there to be consumption of the leaves in Colombia, Argentina, Ecuador and Brazil as well; there are at least a

hundred thousand more people using coca in these countries. Coca leaf is most commonly chewed by men and women workers in the fields, mines, markets, study rooms and meeting halls for its many workday benefits. As one Bolivian *campesino* put it: "Coca gives us strength, enthusiasm and the willingness to work. It reduces fatigue, it calms our hunger, and it takes away any pains we may have." Coca is also highly prized for making long distance journeys by foot over the Andes mountains (Burchard 1975) and by drivers of commercial trucks and buses. The 19th-century American coca enthusiast and medical man W.G. Mortimer epitomised the appeal of coca in one word: endurance. It is not speculative to say that among cultures living in the extreme topography of the Andes and Amazon, this function is not only valued but vital (Mortimer 2000 [1901]). But enhancing labour productivity is not the only reason to chew coca during one's daily work; it also shows respect to the goddess of crop fertility: "You have to chew coca in honour of *Pachamama*... if not, your work will be for naught."

The act of chewing coca – called *acullico*, *pijcheo* (Peru, Bolivia), *mambeo* (Colombia), *mastico,* or *coqueo* (general) – has remained relatively unchanged for millennia. Sun-dried leaves are placed in the mouth one or two at a time, and then not so much 'chewed' as gently moistened and massaged until a soft quid is formed and stored in the cheek. As the saliva permeates and extracts the chemical compounds of the leaf, it turns a rich green colour. This juice is absorbed by the mucous membranes and drips into the stomach for digestion. A single quid, the size of which is variable and may be augmented as the leaves are exhausted, will be chewed for 30 to 90 minutes, and regular chewers consume about 25-75 grams of leaves per day (Plowman 1986).

The juice of the coca leaf has a distinctive grassy flavour, like green tea leaves, that most describe as pleasant. Bitterness also characterises the early stages of chewing, this being the taste of the many alkaloids in the leaf. It is customary to add a pinch of powdered lime or an alkaline paste known as *llipta*, *lejía*, *tocra* or *mambe* to enhance the experience of chewing coca. This gritty black paste is prepared from the burnt stalks, roots, bark or leaves of certain plants, such as banana, quinoa, and now stevia (*mestizos* typically just use baking soda). In addition to the 'sweetness' that these additives impart to the quid, their alkalinity also strengthens the numbing and stimulating effect of the alkaloids in the leaves. In Colombia the powdered lime is traditionally carried in a separate vessel, usually a gourd called a *poporo*, apart from the woven bag for coca leaves. These vessels, which require the use of a dipstick to avoid chemical burns while adding the lime to the quid, are also the main evidence of ancient coca use from many archaeological sites in Ecuador and Colombia (Taussig 2004, Plowman 1986).

Chewing coca is ritualised in these cultures, in acts denoted by a unique vocabulary and etiquette (Antonil 1978, Davis 1996). For example, in Quechua communities around Cusco, before chewing coca it is customary to select three perfect leaves from your bag, array them between your thumb and forefinger, and blow gently across them as an offering of the breath of life to *Pachamama* in gratitude for her generosity. This *k'intu* is then passed to the person you are inviting to chew with you. It is common courtesy to offer guests some leaves to chew and it is proper to receive them with both hands open together. Such regular devotional acts help weave the web of reciprocity that connects humans with the sacred places of their divine geography and with the legacy of their ancestors (Allen 2002).

Coca is commonly used during community meetings and celebrations in rural villages and urban *barrios*, and at mass gatherings such as festivals or forums. When chewed collectively, coca inspires communication and the alliance of the group

(Laserna 1996: 14), creating "a sacred atmosphere that not only generates cohesion but also seals the pact of collaboration" (Mayer 2002: 179). It is a subtle yet potent reminder that Andean people depend on each other for their survival. "Coca signifies friendship, sharing," explained one participant at a union meeting in Bolivia. "Coca adds an element of seriousness, it makes the meeting more formal," said another. Coca leaf plays a practical role in these meetings as well, for its stimulant and nutritional properties allow people to stay alert and focused through many long hours. As anthropologist Enrique Mayer observed in Quechua community meetings in highland Peru, "Coca serves the additional purpose of sharpening the senses, permitting concentration, and, when consumed with care, creating a sense of internal peace and tranquillity that is indispensable for intellectual work" (Ibid.).

Because of so many quotidian uses linked to deep cultural traditions, coca not only represents the bonds of trust and reciprocity that exist within and between rural and urban indigenous communities, but it is also the central symbolic link to people's ancestors and the spiritual dimension of their everyday reality. "Our grandparents used [coca in gatherings and ceremonies] before, and what our ancestors left us we must not forget," said one community leader. "Chewing coca is the only way to cherish what is ours." It is also the medium of divination, in which a shaman scatters a set of leaves on a woven textile and reads the resulting patterns for signs and portent (sometimes appealing to a Catholic cross at the same time). When a person is laid to rest, leaves chewed by those in attendance are placed in the coffin to assist in the journey to the next world and as a greeting to their ancestors. For these reasons and many more, it is easy to understand why coca is considered 'the sacred leaf'.

Despite the strength and pervasiveness of coca culture in South America, ever since Spanish conquistadors arrived in the Andes in the 1500s coca has been used as a tool of exploitation. In effect, the profits and benefits of the coca economy have largely accrued to a handful of elite private interests – the Spanish Crown, *hacienda* owners, silver and tin barons, European pharmaceutical companies, the Coca-Cola Company, drug cartels, offshore banks, etc – while hardship and abuse from colonialism and the US 'war on drugs' have been collectively borne by indigenous people and poor farmers in Bolivia, Peru and Colombia. Andean and Amazonian indigenous groups have always resisted such political and economic manipulations, and they often used coca as symbol and sustenance of their resistance. For example, during the 'Age of Andean Insurrection' (Larson 2004) in the late 1700s, coca was a central feature of the Tupac Amaru Rebellion in Peru and the Tupac Katari Rebellion in Bolivia: "Coca became the principal element (...) to combat the cold, rain and inclement weather, as well as hunger and certain illnesses – all by chewing coca, which also raised their spirits" (Carranza 2001: 23). Tupac Katari is said to have worried more about their supplies of coca than food (Carter and Mamani 1986: 74). These movements did not succeed in ending Spanish rule, but they are still heralded by Quechua and Aymara leaders as an inspiration for indigenous resistance to oppression and the struggle for self-determination.

Today some movements are using the power of participatory democracy to defend the spiritual, social, medicinal, economic and political value of the coca plant. In Bolivia, the past 40 years of indigenous mobilisation (starting with the neo-Katarista movement of the 1970s) have gone hand in hand with a rising indigenous identity politics around coca use and a positive national identification with the leaf – a sea change also reaching Peru and Colombia. The leaf may have changed in imagination and ideology from a devilish but necessary evil in the colonial period, to a bad 'Indian' habit and symbol of

backwardness (the stance of early 20th-century *indigenista* crusaders) and, by the 1950s, to a disgraceful national mass drug addiction, an idea that built upon an elite-biased version of the modern Western science of 'toxicology' (Gagliano 1994, Weil 1995). Since the late 19th century, the fortunes of coca politics have too often mirrored those of its coveted alkaloid, cocaine. The post-1970s revindication of coca, particularly in Bolivia, has left these ideas behind with the new ideal of coca's eternal and essential place in indigenous cultural and social life, in contrast to cocaine's individualistic and savagely capitalist social meanings. Coca even serves as a symbol of heated resistance to 'imperialism', from memorialised rebellions against colonial Spain to the neoliberal domination of the United States (Rivera 2008).

Phytochemistry and pharmacology of coca

Coca is utilised for two physiological purposes: as a mild stimulant and as a medicine. The list of compounds produced by these plants is long; however, our understanding of the pharmacological effects of coca chewing is short, almost entirely derived from scientific studies on the effects of cocaine. We have few in-depth investigations that have controlled for chewing whole leaves in typical cultural settings. Anecdotal as well as peer-reviewed evidence suggests that coca leaves have a more complex yet subtle stimulatory effect compared to cocaine. While more research is needed to explain this relationship at the molecular level, it is clear that chewing leaves does not reduce to obtaining a cocaine high. Indeed, observers have long noted that Aymara and Quechua people prefer sweeter leaves with lower cocaine content (Sauvain 1997, Mortimer 1901).

Cocaine is present in all cultivated varieties of coca. Typical of alkaloids, cocaine is an effective natural insecticide even in the low concentrations (<1% by dry weight) found in the tissues of most coca plants (Nathanson et al. 1993). In tropical and neo-tropical environments where insects devour leaves year round, its psychoactive effect on humans is an accidental by-product of plant evolution, just like morphine in poppies and nicotine in tobacco. Over thirty wild species of *Erythroxylum* have been found to produce cocaine but only rarely in concentrations approaching the cultivated varieties. In addition to at least 18 other alkaloids, coca plants produce a variety of calystegines, terpenoids, and phenolic compounds (flavonoids, tannins and aromatic acids) (El-Imam et al. 1985). Nicotine was identified once in the leaf, but this is likely erroneous.

The pharmacological action, as described by chewers, manifests as mild euphoria, increased energy, and suppression of fatigue, hunger and thirst (Holmstedt et al. 1979). Relatively little pharmacological screening has been applied to the suite of other alkaloids and non-alkaloid compounds found in the plants, even though we know there to be other biologically active compounds. Cinnamoylcocaine has been found to have anticholinergic and sympathetic cardiovascular effects. Some of the metabolites are potent stimulants (benzoylecgonine) and do inhibit reuptake of dopamine and norepinephrine (benzoyltropine, methylecgonine, tropacocaine), but do not induce such a potent euphoric effect as pure cocaine does. Cocaine-like anaesthetic effects are also present in other alkaloids, especially tropacocaine, which is currently utilised as an ophthalmic and spinal anaesthetic due to its potency and low toxicity (Novák 1984).

These specific alkaloids were fundamental to the development of modern anaesthesia after Carl Koller's revelation about cocaine's effects on the eye in 1884. But it was not until the 1970s that researchers started to pose questions about the effects of coca leaf on the human body under physical exertion at high altitude (Burchard 1975), even though Peruvian scientists of the 'Andean Man' school of social medicine such as Dr Carlos Monge

had speculated since the 1940s that such an adaptive or co-evolutional relation existed. When individuals using cocaine during exercise are tested, a pronounced reduction in glycogen and increase in lactic acid is observed, coincidental with fluctuation in neurotransmitters. This glycolytic burst, characteristic of normal metabolic processes during short-term exercise, results in a peak of physical activity followed by a crash (Conlee et al. 2000). But when glucose levels are measured in people exercising while chewing leaves, the results are surprising. Researchers found that during exercise, compounds in coca leaves (specifics unknown) appear to block the glucose oxidation pathway, evidenced by an accumulation of glucose, glycerol and pyruvate in the blood. Coca might contain compounds (possibly flavonoids) that are *adaptogens*, or chemicals that specify the most efficient metabolic pathway given the level of energy expenditure. When coca is chewed, exercise energy budgets appear to be met via oxidation of fatty acids, as metabolism is switched to fats instead of carbohydrates; glucose levels remain high until the coca wears off. This is a much more efficient metabolic pathway for prolonged, moderate labour, explaining why coca is so valued for strenuous work (Rerat et al. 1997, Casikar et al. 2010). Not only is the scant quantity of cocaine that is absorbed during chewing insufficient for any physiological benefit, but these studies have shown that coca leaves have a much more elaborate effect on exercise physiology than previously understood.

The alkaline substances taken with the leaves also have a functional chemical effect on coca leaf chewing. Though many hypotheses were developed to explain the purpose of the alkali, including observations from Peru by famed South American explorer Alexander von Humboldt, the current scientific consensus is that it functions to liberate alkaloids as free bases from the other acidic plant compounds in the mouth. Cocaine and other alkaloids in this basic solution can be readily absorbed into the bloodstream via the mucous membranes. The alkaloid bases are also swallowed, and in the low pH of the stomach they will transform to soluble salts that can be digested in the gastrointestinal tract. However, it is thought that absorption of the alkaloids via the oral mucous membranes is a much more effective delivery method than in the gut from swallowing coca juice saliva. If no alkali substance is used during chewing, alkaloids are broken down by saliva and can lose their biological activity (Rivier 1981).

As public awareness improves and enlightened dialogue on the efficacy of cocaine and coca policy evolves, hopefully the door will open to more thorough investigations of the physiological effects of coca leaf. As in the case of cannabis, scientific study of its therapeutic and medical value has been stymied for decades by international legal prohibition, trade restrictions and governmental bias. But this terrain is shifting. A method for distinguishing coca from cocaine use has just been developed in the form of a drug test that analyses hair samples for their ratios of cocaine to other alkaloids (Rubio et al. 2014). If no other alkaloids are present then it is clear the person was not chewing coca. Application of this technology may help clarify the common confusion between traditional coca leaf chewing and illicit cocaine use, and it may also encourage more controlled physiological experiments to demonstrate the effects of coca leaf chewing on humans in the short and long term.

Nutrition and medicine

It is essential to evaluate the medicinal and nutritional benefits of the coca plant in order to vindicate its cultivation and consumption in light of the pervasive social and governmental paradigm of drug prohibition. It was once widely believed by elites in the Andean nations (and their supporters in the US and the UN, evidenced by the biased 1950 UN

Commission of Enquiry on the Coca Leaf) that coca contributed to malnutrition in highland Andean peoples because of its appetite suppression effects, or that it was widely used as a salve against poverty-related hunger. While nutritional status and growth standards require careful evaluation as they are easily extrapolated and subject to statistical bias, certainly malnutrition does exist throughout the Andes and Amazon. Two primary studies on coca nutrition have been conducted and, unfortunately, their results are incongruous. A universal conclusion is that coca should not be thought of as food, even though its nutritional value has been celebrated.[3]

In contrast to the original assay of coca leaf (Duke et al. 1975), scrupulous data collection by Penny and colleagues (2009) showed that many of the desired nutrients found in coca leaves are minimal to daily needs. Yet, some nutrients and minerals are significant, with an undeniable influence on moderate chewers. Coca is in fact a complete protein with about 20% protein concentration by dry weight, yet the digestibility and quality of this protein needs appraisal. For vitamins and minerals, they found that the average amount of coca leaves chewed by an adult per day (50g) would supply the following percent daily requirements: calcium 51%, iron 81%, magnesium 26%, vitamin A 32%, vitamin D 20%, vitamin E 100%, zinc 9%.

There is a vital connection between the typical Andean diet and the nutrient content of this plant. Andean populations, particularly those in the high-altitude *altiplano* (3,000-4,000 metres) – where the diet centres around potatoes, local vegetables and dried llama meat – are frequently deficient in calcium, iron, vitamin A and zinc. It would be quite useful to have a nutritional analysis that specifically evaluates the benefits or complementarity of coca chewing in such communities because while some of these concentrations are remarkable, their values must be interpreted with caution. Most importantly, the mastication of coca leaves is not equivalent to consumption because the chewed leaves are almost always discarded and not swallowed, hindering total absorption. Penny et al. also reiterate that the presence of a nutrient does not mean it can be readily assimilated. They show that there are also significant inhibitors of some nutrients in the leaves. What this means is that we still do not have a proper scientific understanding of whether the vitamins and minerals that are present in coca are effectively used by our bodies or not.

The application of coca is extensive in Andean folk medicine (Sikkink 2010). The primary medicinal use of coca among South American indigenous people is for its gastrointestinal benefits and as a mild topical anaesthetic. The leaves are chewed whole or eaten as a toasted powder to normalise digestion and alleviate stomach distress, including indigestion, ulcers, nausea, pain and spasms. Other popular beliefs are that coca improves dental health by acting as an antiseptic against periodontal bacteria (Seki and Nishi 2012), and that it facilitates nutrient assimilation during digestion. The parasympathetic action on the smooth musculature of the gastrointestinal tract could be attributed to the anaesthetic properties of cocaine, other alkaloids (ie, atropine, ecgonine) or non-alkaloidal components such as volatile oils. Other benefits of anaesthesia are utilised for oral sores, toothache and laryngeal strain. Indigenous people also will apply a poultice of leaves to bruises and minor wounds, and directly to the forehead to alleviate headaches. Travellers to the Andes will probably encounter coca as a common way to combat the effects of temporary high altitude

[3] In Bolivia, a popular trend is to use coca 'flour' (finely ground leaves) to replace up to one-fourth of regular flour in bread, cakes, pasta and cookies (nutritionist María Eugenia Tenorio [see Montaño 2004] is well-known for her recipes; see also Escobar Moscoso 2006). The idea is that the vitamins and minerals in coca can augment the nutritional value of baked goods, but there is no scientific consensus about this practice.

sickness, or *soroche*. Here, coca tea (made with fresh leaves, called *mate de coca*) or chewing leaves is a reliable remedy for dizziness, nausea and headache. It is still unknown whether coca works physiologically to combat high altitude sickness or simply minimises its symptoms.

Andrew Weil (1981) provided an early comprehensive assessment of the medicinal value of coca based on his research in Peru. After studying the dynamics of coca use in indigenous groups, he applied his findings to treat a number of *mestizo* and North American patients. In many ways, Weil was following the forgotten tradition of 19th century fascination with herbal medicine and early research on coca, particularly in the United States and France, well summarised by Mortimer in his 1901 study and physician survey. Dr Weil, who studied ethnobotany as well as medicine at Harvard, indicated coca tea or leaves for a variety of ailments including gastro-intestinal conditions, depression, motion sickness, weight reduction via exercise stimulation, toothache and oral sores, and as a reductive for dependency on amphetamines, coffee, and even cocaine itself (as Bolivian sociologist Jorge Hurtado [2008] also proposes as part of a holistic reformed drug policy). Weil has long advocated that coca leaf advance to clinical testing to be assessed as a modern treatment. Another vital discovery is that coca regulates blood glucose levels through carbohydrate metabolism, a factor that possibly facilitates the Andean diet that is rich in starch from potatoes (Burchard 1975). These characteristics, Weil suggests, should be investigated for wider treatment of hypoglycaemia and diabetes. Another key finding, in contrast to the carcinogenic effects of other chewed leaves such as tobacco, khat and betel nut, is that coca leaf use among heavy chewers has actually been correlated with decreased genetic instability in cells of the mouth (Nersesyan et al. 2013).

The discrepancy of clinical research on coca is mostly due to the schizophrenic history of public opinion on cocaine, where captivation with the pure alkaloid as a topical anaesthetic and medical panacea in the late 19th century was followed by its vehement rejection due to its toxicity and high risk of dependence (though it is still sparingly used in ophthalmology). Its outlawing was also due to the prohibition hysteria that raged in the early 20th century United States, which stigmatised cocaine use as the vice of African American men hell-bent on destroying mainstream white society. Coca leaf was thus ostracised by association, even though the supposed physical deterioration and psychological dependence arising from traditional coca leaf use has never been documented (Martin 1970, Weil 1981). Modern laboratory research on coca effects, such as that sponsored in the late 1940s by the US Navy (seeking to improve high altitude performance in early jet pilots) was stopped in its tracks by zealous anti-drug authorities, reluctant to establish any strategic or medicinal uses of the leaf (Gootenberg 2008).

Thus, the primary source of scientific legitimacy for the medicinal application of coca continues to be the traditional healers and spiritual leaders of indigenous Andean communities, such as the Kallawaya *yatiris* of Bolivia and the Kogi *mamas* in Colombia, who have practised their craft for millennia. Women report using coca leaf during childbirth, thus reinforcing the leaf's traditional link with *Pachamama* and fertility. Rather than pay for expensive (and often imported) medicines at a drugstore, Andeans chew coca or drink *mate de coca* to cure what ails them – most commonly headaches, toothaches, nausea, hangovers, altitude sickness, diabetes and gastrointestinal irritation. Other medicinal uses of coca include the treatment of colds, asthma, depression, obesity, diarrhoea, ulcers, motion sickness, impotence, and even malaria (Carter and Mamani 1986). In other words,

the quotidian and devoted use of coca leaf in the Andes is here to stay, partly as a practical health strategy and partly as a way to preserve ancient rites and rituals.

Conclusion

Although its public image on the international stage is sometimes crudely distorted, in the eyes of millions of Andean people coca is still considered the 'sacred leaf' – as the Incas anointed it – for it contributes irreplaceable nutritional, medicinal and spiritual value to everyday Andean lifestyles. Modern scientific study of coca use must be encouraged after decades of neglect, even though the defamatory view of the leaf lost its scientific legitimacy by the 1980s. Coca continues to flourish in some areas of the licit regional economy, especially in highland Bolivia, and many NGOs and governments have suggested that it may find substantive new commercial uses and even export value in teas, herbal medicines and other products (dependent upon future United Nations policy reforms). Coca as a cultural good is increasingly deployed as a symbol of solidarity and resistance in indigenous struggles against outside forces of oppression and exploitation. The history of cocaine production, trafficking, use and policy warrants a comprehensive analysis to illuminate avenues for reform, but it is important to recognise that the modern history of coca leaf's criminal entanglements with cocaine occupies but an instant in the more than 8000-year adaptive trajectory of coca in this region. The fate of the leaf and the people who use it are woven together as tightly as a wool textile; as Peruvian sociologist Enrique Mayer (2002: 180) puts it: "Andean culture has endured because of the fierce will of its native people to maintain it – an accomplishment made possible by internal solidarity, group integration, and feelings of belonging. In this effort, coca has been judiciously used." Coca culture is far more holistic, communal, beneficial and tenacious than any modern drug culture, and for this reason South American people and civil society – and increasingly governments, like Bolivia's – will defend it.

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