Chemistry and Ethnobotany of Commercial Incense Copals, Copal Blanco, Copal Oro, and Copal Negro, of North America

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Química y Etnobotánica de los Copales Comerciales del Incienso, Copal Blanco, Copal Oro, y Copal Negro, de Norte América. *Los copales comerciales norteamericanas del incienso se derivan de las especies de* Bursera, Protium *(Burseraceae), y* Hymenaea *(Caesalpiniaceae) pero también son distinguidos por la técnica de cosechar así como por las especies. Sesenta y ocho compuestos fueron identificados en tres copales comerciales del incienso. El aceite esencial del copal blanco (probablemente de* B. bipinnata*) es dominado por el α-copaene(14.52 ± 1.28%) y el germacrene D (13.75 ± 1.06%). El aceite esencial del copal oro (probablemente de* H. courbaril*) es dominado por el α-pinene (21.35 ± 5.96%) y el limonene (26.51 ± 1.22%). El aceite esencial del copal negro (probablemente de* P. copal*) es dominado por el α-pinene (17.95 ± 1.35%), el sabinene (12.51 ± 0.08%), y el limonene (16.88 ± 2.02%).*

Key Words: Copal; *Bursera*; *Protium*; *Hymenaea*; Burseraceae; Caesalpiniaceae.

The word "copal" first appeared in the English language in 1577. John Frampton wrote in his "Englished" edition of Nicolas Monardes' *Dos libros, el veno que trata de todas las cosas que traen de nuestras Indias Occidentales,"* originally published in 1596 (Monardes 1577): "They doe bring from the Newe Spaine [Mexico] twoo kindes of Rosine . . . the one is called Copall." Over three centuries later, Walter Hough (1912) wrote: "There is a great confusion as to the identity of copal, the name, according to some writers, being used to cover a number of gums. It is possible that the confusion has arisen from post conquest times when errors multiplied rapidly as Mexican culture slipped swiftly into the background, for the earliest reliable chroniclers are clear as to the commonest use of the gum which we know as copal, and whose characteristic odor would place it distinctly in the first rank of incense materials."

Among the gums and resins in the European and American markets today, "copal," as a generic term, refers to a large group of resins characterized by hardness and relatively high melting point. These natural resins have been employed in varnishes, paints, and as binders in pressed and stamped articles. Most commercial copals on the international market are collected from trees of the genus *Agathis* (Araucariaceae) or the family Leguminosae (Coppen 1995;

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Howes 1949; Parry ca. 1900). Copal becomes amber with the loss of essential oils and hardening by polymerization and oxidation. Amber typically dates from the Triassic to Tertiary Periods. Fresh copal, usually intended for incense, should not be confused with sub-fossil copal ("copalite" from the Quaternary Period) that is incorrectly sold as Colombian, Dominican, Mexican, or Baltic "amber" (Dahlström and Brost 1996; Grimaldi 1996; Langenheim 1969, 1990, 1995; Poinar and Poinar 1999; Ross 1998).

From North American origins, "copal" may refer to resins from *Bursera* or *Protium* of the Burseraceae; *Hymenaea* of the Caesalpiniaceae; *Jatropha* of the Euphorbiaceae; *Pinus* of the Pinaceae; or *Rhus* of the Anacardiaceae (Edmonson 1965; Langenheim 1995; Langman 1964; Standley 1926; Stross 1997; Uphof 1968). The importance and diversity of copals for incense in North America are well illustrated in the *Popul Vuj* (*Popol Vuh*), the sacred book of the ancient K'iche' Maya (Goetz and Morley 1950; Tedlock 1985), which was written in Latin script in 1554–1558 but dates much earlier from oral tradition. The *Popol Vuj* records the coming of the sun, moon, and stars (Tedlock 1985): "After that they unwrapped their copal incense, which came from the east, and there was triumph in their hearts when they unwrapped it. They gave their heartfelt thanks with three kinds at once: Mixtam Copal [Mixtán-Pom] is the name of the copal brought by Jaguar Quitze [Balam-Quitzé]. Cauiztan Copal [Cavixtán-Pom], next, is the name of the copal brought by Jaguar Night [Balam-Acab]. Godly Copal [Cabauil-Pom], as the next one is called, was brought by Mahucatah. The three of them had their copal, and this is what they burned as they incensed the direction of the rising sun. They were crying sweetly as they shook their burning copal, the precious copal." Goetz and Morley (1950) remark: "These names have a marked Mexican flavor and seem to come from the Aztec tongue, *Mixtán-Pom* might be the copal, or incense, which they burned to Mictán Ahau, and *Caviztán-Pom* that which they offered to Cavestán Ahau .... The Aztec word *Mictlán* serves to designate the inferno. *Cabauil-Pom* is clearly the incense of the Quiché divinity in general, which is expressed with the word *Cabauil,* probably derived from the Maya *Kauil,* "god." The variety of incense of the offerings seems to be explained by the fact that the Quiché liked to offer 'incense of a certain fragrance' to their gods."

Also, in sacrifices in the presence of Tohil and Avilix, the *Popol Vuj* records (Goetz and Morley 1950): "They did not bring great gifts, only resin, the remains of the gum, called *noh,* and *pericón,* they burned before the gods." Goetz and Morley (1950) remark: "*Xa col xa r'achac noh ruq yiá.*" Instead of the incense of the East, the Quiché burned a kind of aromatic substance on the altars of their gods: turpentine, or the resin from the pine, which they called *col*; *pom,* which is the *copalli* of Mexico; the gum called *noh,* which is another resin, according to Ximénez, and the large fan-grass, or *hypericum, Tagetes lucida,* of the composite family made up of them. According to Sahagún, the Aztecs used the grass called *yiauhtli,* dried and ground, which burned like incense and which seems to be the same grass which the Quiché called *yiá.* The gum *noh* which the text mentions may be the same as the Maya of Yucatán call *xnoh,* "resin which drips from the pine" or turpentine, according to Roys."

Today, people of Maya descent in Guatemala and El Savador still burn *pom.* "Dew, human sweat, rust, blood, a mother's milk, tears, and resin are all substances called *itz* through which the Maya gods become manifest. *Itz* is the life-giving force and a gift from the gods" (Schlesinger 2001). Lilly de Jongh Osborne (1975) writes: "*Pom* (Maya; *copal,* Aztec), a resinous tree gum, is the Indian incense burned at all ceremonies, whether Christian or pagan. The darker kind, wrapped in two pieces of pumpkin shell (*tol*), is now used only in Momostenango for the most sacred rites. The second variety, wrapped in cornhusks, serves for other ceremonies. The kind sold currently in small gray pebbles in all the markets is used extensively in Indian huts as a disinfectant or insecticide and as an incense before the household altars. Poor people burn it in church." The appearance of this resin on the local markets of the Q'eqchi' Maya is repeated in Edmonson (1965): "**pom**: (*n.*) incense wafers of discs 1 ½" in diameter, sold in banana-fiber packages 15" long containing two dozen pieces and made from various trees (*Icaca* sp. [*sic, Icica = Protium*], *Elaphrium* sp., *Protium copal*) ... *ah pom*: incense burner ... *pon*: anoint with resin ...."

Wisdom (1940) remarks about copal among the Ch'orti Indians of Guatemala: "Copal is

made from the gum of copal trees. The men find the trees in the hills, notch the trunks in about a dozen places, all on the same side, place a gourd underneath, and allow the gum to drip into it for eight days. The gum, together with a great deal of the tree bark, is then dried in the sun for a day, after which it is put to boil with water in a large olla. Fresh water is added as the old boils away. The copal gum rises to the surface slowly and is skimmed off with a gourd dipper. After eight or ten hours of boiling, all the gum is extracted, and it is placed in cold water to harden. It is then shaped in the hands into round, elongated pellets, each of about the size and shape of a cigar, and extremely hard and brittle. Each pellet is wrapped in maize shucks and tied at the ends with shuck string. For ceremonial use, the gum is shaped into small disks." "Each disk is of the shape and size of a small coin and is called a 'peso.' In this form it is a ceremonial money and is sacrificed to the deities by being burned in the incensarios. It is offered as a 'payment' to them." Wisdom (1950) further elaborates on the use of copal in his unpublished notes on the Ch'orti language: "Uht's-up' te' ('incense tree). *Copal, Copal de santo, Paolo de Santo. Bursera* sp. A wild lowland tree. The gum is boiled, shaped into hard pellets, burned with live coals in incense burners, and the fumes allowed to pass over the body to cure various illnesses, to protect oneself against sorcery, sickness, and misfortune, and to cleanse the body after contact with the ritually unclean, especially sick persons and corpses. A tea of the bark is taken to relieve dysentery. A type of sandal is carved from the wood, to be worn on muddy trails. The wax is burned in the houses to drive away insects, and when freshly made serves as an all-purpose solder or glue. This is used to mend leaks in all non-cooking containers, to plug the mouth end of flutes, to tip drum sticks, to glue wood, especially in the manufacture of TUN drum, fiddles, and guitars, and for gluing the leather straps to tool handles. It is burned in incense burners at nearly all the religious ceremonies, and the Catholic churches of the area are said to use it exclusively."

Sources of Incense Copals in North America: *Bursera* and *Protium* spp.

The three commercial incense copals on the North American market today are *copal blanco, copal oro,* and *copal negro.* These three copals may be distinguished by the technique of harvesting as well as by species. *Copal blanco* is obtained by excision of the branches, *copal oro* is from resin exuded after removal of the bark (i.e., xylem-derived), and *copal negro* is beaten from bark (i.e., phloem-derived). In the U.S., Mexico, and Guatemala, these copals are primarily derived from the genera *Bursera* and *Protium.* Garcia Ruiz (1981) writes extensively of these three commercial copals: "*Le copal, 'arbe culturel' par excellence dans le contexte ethno-botanique de Motozintla fournit, d'une part, la sève avec laquelle on élabore le saq ti po.m, copal blanc et, d'autre part, l'écorce pur elaboration, du q'eq ti po.m, copal noir.*" Furthermore, "*A la différence de la sève qui sort par incision et qui est de couleur blanche, celle-ci est de couleur jaune—q'am, et elle est recueillie en même temps que l'écorce.*" And, "*Le copal noir est gènéralement élaboré quelques jours après la cueillette de l'écorce, car celle-si conserve plus difficilement que la sève.*"

One way to distinguish copals is from the origin: species of *Bursera* can be found in the highland country as well as the rainforest; whereas *Protium* is limited to the rainforest (R. E. Schultes quoted in Strucker 1963). While the genus *Protium* is mostly neotropical with ca. 90 species, the primary source of copal in Veracruz, Oaxaca, Yucatán, and Guatemala is *P. copal* Engl. This is also known as *pom,* as quoted above, doubtfully from *P. heptaphyllum* (Aubl.) March, as reported in Soustelle (1937). Kockelman (1999) observed a unique method of the harvesting of copal by the Q'eqchi Maya in Guatemala today: "A copal tree (*Protium copal*) stands out as lighter bark against the forest's dark brown and green background, because it has no branches until almost 3m above the ground. At each tree, the collectors kneel with their machetes on the ground at their sides, using the palette [a piece of wood shaped as a ping pong paddle] (held horizontally) to scrape the now dried resin flow from the bark. One can see the white stains of past secretions and the new patches of yellow from recent cuts that slowly turn orange around the hardening resin. Scraping is done with several upward motions interspersed with generous tongue-licks (as if eating ice cream), which both move the resin towards the center of the palette and form it into a more compact shape—the approximation of a half-

ball .... Their hands do not touch the copal the whole time, so as to not get them sticky and so as to keep the copal clean from dirt. Throughout this process, there is constant spitting ...." Tripplett (1999) confirms the use of a paddle made from *madre de cacau* [*Gliricidia sepium* (Jacq.) Steud., Leguminosae] and the use of saliva to "keep the *pom* moist." Tripplett (1999) calculates that ca. 1200 kg of *pom* can be harvested from 100 *P. copal* trees over a period of about eight months.

The 35–100 species of *Bursera* are native to mostly Mexico, and all or most contain an aromatic resin known as copal (Alcorn 1984; Becerra and Venable 1999; Bullock 1936; Gentry 1993; Rzedowski and Guevara-Féfer 1992; Rzedowski and Kruse 1979; Standley 1926). Some systematists have proposed that *Commiphora* and *Bursera* should be combined into a single genus (Gillett 1980), while others consider *Bursera* closer to *Boswellia* (Lam 1932).

In North America, copal may be most often derived from one of three possible species of *Bursera*: *B. copallifera* (Sessé & Moc. ex DC.) Bullock [*Elaphrium copalliferum* Sessé & Moc. ex DC., *E. jorullense* H.B.K., *B. jorullensis* (H.B.K.) Engl., *B. palmeri* S. Wats. var. *glabrescens* S. Wats.], *B. microphylla* A. Gray, or *B. bipinnata* (Sessé & Moc. ex DC.) Engl. (*Amyris bipinnata* Sessé & Moc. ex DC.) (Bullock 1936; Hernández 1943; Martínez 1959, 1969; McVaugh and Rzedowski 1965; Oliva 1866; Standley 1926; Uphof 1968). *Bursera copallifera,* the most common of these resinous trees, is common throughout most of Mexico; it is documented from the states of Durango to Puebla, and also in eastern Michoacan, where it is variously known *as copal, copal blanco, copal de penca, copal santo, copalli, copalquahuitl, elemí de México, goma de limón, ngedni,* or *ngidi. Bursera microphylla* occurs in dry hillsides from southern Arizona and Baja California to Zacatecas, Morelos, and Puebla, where it is known as *copal, cuajiote colorado, torote,* or *torote blanco*; it is know as elephant tree in the U.S. *Bursera bipinnata* is found from southern Chihuahua to Sinaloa, Morelos, Guerrero, and Chiapas, where it is known as *ach'el pom, tzo' ka' pom* ("mud pom"), *copal amargo, copal amargoso, copal chino, copal del santo, copal de la Virgen, copal címarrón, cuajiote colorado, incienso del país, jaboncillo, palo copal, tetlate, tetlatía, tetlatián,* or *tetlatín* (Breedlove and Laughlin 1993; Bullock 1936; Coggins and Ladd 1992; García Ruiz 1981; Hernandez 1943; Herrera 1895; Hickman 1993; Martínez 1959; McVaugh and Rzedowski 1965; Moore 1990; Oliva 1866; Standley 1926; Stross 1997; Vogt 1969).

Five additional species have been utilized as copal, but their limited distribution in North America lends doubt to their widespread commercial utilization: *B.* × *diversifolia* Rose (*B. bipinnata* hybrid), *B. fagaroides* (H.B.K.) Engl. var. *elongata* McVaugh & Rzed. (*B. odorata* T. S. Bandeg.), *B. lancifolia* (Schlechtend.) Engl. (*B. fragilis* S. Wats.), *B. penicillata* (Sessé & Moc. ex DC.) Engl. (*B. delpechiana* Poisson ex Engl. in DC.), *B. tomentosa* Jacq. (Berlin, Breedlove, and Raven 1974; Bullock 1936; García Ruiz 1981; Laughlin 1975; McVaugh and Rzedowski 1965; Yetman and Van Devender 2002). *Bursera excelsa* (H.B.K.) Engl. in DC. has also been suggested to be a source of copal (*bats'i pomj,* genuine pom, *mi' pom, muk'ta pom, pom ryox*), but this may be taxonomically confused with *B. tomentosa* (Breedlove and Laughlin 1993; Bullock 1936; García Ruiz 1981; Laughlin 1975; Martínez 1959; McVaugh and Rzedowski 1965; Vogt 1969, 1976). The distribution and use of *B. simaruba* (L.) Sarg. are in question because of the misidentification of other species as this species, because this species is probably not native to Mexico, and because this species is still in need of taxonomic revision (Bullock 1936; Martínez 1959; McVaugh and Rzedowski 1965; Roys 1965; Standley 1926, 1930). Another possible source may be the Guatemalan *B. steyermarkii* Standl. (*pom ka', sotz' te',* horse pom) (Breedlove and Laughlin 1993; McVaugh and Rzedowski 1965).

Use of Copals from *Bursera* and *Protium*

Copal has been commonly burnt as incense in Maya- and Nahua (Aztec)-influenced societies, in particular in prayer or to ward off witchcraft, evil spirits and the evil eye, along with blood sacrifices (usually a melanotic chicken, see Johannessen 1981, 1982). Communication or guidance from the gods is desired on a daily basis; for this purpose, the people turn to copal, the "blood" of trees, as the preferred food of the gods. It is believed that, as it burns, the smoke of copal carries the message of the people into the heavens. If the smoke rises straight into the

clouds, then you have the favor and the protection of the deities. Wilson (1995), in discussing the recent Maya resurgence in Guatemala, states "*Pom,* carries the prayers upward into the mouth of the tzuultaq'a, who consumes the *pom* and the messages with it. *Pom* is *xwa Qaawa'*, the 'tortilla of our Father.' According to informants, '*pom* calls the spirit [*xmuhel*] of the mountain.' *Pom* is the ritual purifier par excellence, sanctifying any space and expunging evil spirits. A proper sacrifice will include a large piece (one to five pounds) of regular white *pom* and small red pieces called *torak'*. *Torak'* is referred to as "pennies" and is given in a specified number, either thirteen, sixteen, or eighteen. One sacrificer spoke about the use of different types of *pom*: 'You have to feed the God. When we eat stew we include salt, onions, meat, *xayau* [achiote, *Bixa orellana* L.], squash, and herbs. It's the same when we give food in a cave, there have to be different types of *pom.*" It was for this reason that copal also became known as the "brains of the heavens," "placenta of heaven," or "super odor of the center of heaven" (Alcorn 1984; Arvigo and Balick 1993; Coe 1988; Coggins and Ladd 1992; Edmonson 1986; García Ruiz 1981; Holland 1963; Knab 1995; Messer 1975; Parsons 1936; Roys 1931; Sahagun 1953; Sandstrom 1991; Savinelli 1997; Stross 1997; Wisdom 1940). This agrees with the etymology of the word "copal" from the Nahuatl *copalli,* literally "with the help of this path" or "thanks to this path" (Corzo 1978). *Pom* is derived from the Mayan *po-*, a root word meaning "in harmony with the action of fire," and *-om,* a suffix which denotes "activity," literally "that which is to be burnt" (Barrera Marín, Barrera Vázquez, and López Franco 1976).

The royalty of the Nahua and related societies also sanctified themselves with incense from copal. This was illustrated in 1519 by the scenting of Xicotencatl of the Tlascalans on his surrender to Cortes, as well as the scenting of Cortes himself by the priests at Quiahuitzlan (Díaz 1963; Berler 1988). However, by 1629, Ruiz de Alarcón, a *criollo* and ecclesiastical judge of the Holy Inquisition in Mexico, was equating the use of copal with Nahua sorcery in his *Tratado de las Idolatrías, Supersticiones, Dioses, Ritos, Hechizerías y otras Costumbres Gentilicas de las Razas Aborígenes* (Ortiz de Montellano 1990).

Copal was, in addition, part of the funerary rites of the Mayan tomb. Coe (1988) has remarked: "Most of these censers are believed to have been found in deep caverns, traditionally the entrances to the Underworld in Maya belief, and the overwhelming majority have as their main iconographic theme the Jaguar God of the Underworld, the Night Sun on its nocturnal journey through the nether regions. The theme thus suggests that, although the wisps of sacred smoke may have been wafted toward the heavenly gods, they may also have been directed toward the land of the dead."

Copal is still used today in funeral rituals in Mexico. Copal has also been used to guarantee good hunts, to divine the future, to bless the farming land, to control weather, and to bless marriages and births (Freidel, Schele, and Parker 1993; Hough 1912; Kockelman 1999; Parsons 1936; Sandstrom 1991; Strucker 1963; Tripplett 1999; Wilson 1995; Wisdom 1940).

As recovered from the Cenote of Sacrifice in Chichén Itzá, Yucatan, and further substantiated in the glyphs, copal (probably from *P. copal*) was molded or poured into vessels. Hard copal was worked until malleable, incorporating bark and leaves, and sometimes wrapped in a corn husk (to mold into the shape of a corn cob, to keep it from touching the hands and ground, and to enhance flammability). Copal soot (as sacred as the smoke) and blue-green paint from anil indigo ("Maya Blue," a sacred color from *Indigofera suffruticosa* Mill. of the Leguminosae) were applied to the surface of the molded copal. Sometimes, chicle [from *Manilkara zapota* (L.) P. Royen of the Sapotaceae] or rubber (from *Castilla elastica* Sessé of the Moraceae) were included with the molded copal, along with jade or shell beads. Rubber or sticks of "fat wood" acted as a wicks to light the copal. The pattern of the copal varied with round, rolled pellets, pinches in parallel rows or a cruciform pattern; arrays of pellets or pinches range from 2 large ones to 100 small ones, and, in addition, jade, a greenstone, or beads were sometimes added to the molded copal arrays (Coggins and Ladd 1992; Coggins and Shane 1984; Lounsbury 1973). Today, the Lacandón, following ancient customs, fashion truncated cones of copal reminiscent of corn ears with nine smaller bits of resin into a "male" cone and three disks of copal resin atop a "female" cone (Hough 1912; Stross 1997; Tozzer 1907).

Contrary to the almost universal identification

of *pom* from *P. copal,* McGee (1990) asserts that *pom* among the Lacandón Maya is from *Pinus pseudostrobus* Lindl.: "The most common offering is copal incense (*pom*), which is made from the resin of the pitch pine (*Pinus psuedostrobos* [sic]). Young boys are given the task of gathering the sap from the pine trees, which is collected by making shallow diagonal cuts in the trunk. The sap flows along the path of the cut and drips into a leaf cup placed at the base of the tree. The resin is then pounded into a thick paste and stored in large gourd bowls in the god house. Pom is important because it is the principal foodstuff given to the gods. Although obviously not edible by humans, the Lacandón believe that when pom is burnt, the incense transforms into tortillas, which the gods consume." The use of exudates from *Pinus* spp. is also noted in Tripplett's (1999) survey of Mayan indigenous markets, in which she found exudates from *Pinus* spp. in addition to *Bursera* spp. and *Protium copal.*

Copal served as the "flesh" of idols with a wooden skeleton that were further covered with a rubber skin. Copal itself was also worked into anthropomorphic figures, whereupon the *pom* became *sil,* meaning an gift or offering (Coggins and Ladd 1992; Lounsbury 1973). The use of anthropomorphic figures molded of *pom* continues today in Guatemala, as illustrated in Wilson (1995): "... spirits usually become separated from their owners near a river or spring. At the edge of the water, the caller burns *pom* incense and candles while calling the name of the afflicted. The caller prays to God and the closest tzuultaq'a for the spirit of the patient. She shouts to the spirit, 'Arise! Get up! Come! Come to your house and rest! Come and sit on a chair, on the bench!' A substitute (*reqaj*) for the person is left at the edge of the water as an offering to the tzuultaq'as. This is called a *muñeek,* or doll, and it is fashioned from *pom* and beeswax into a human form. The patient's hair and fingernail and toenail clippings are stuck into the doll. After the calling and prayers, the doll is burned."

Yellow copal, because it resembles corn, was sometimes mixed with ground corn and thrown into ceremonial fires (Coggins and Ladd 1992; Lounsbury 1973). Copal (probably from *B. bipinnata*) was also used as a binder for cinnabar painted on jade and for color pigments on encaustic murals ("frescoes") (Stross 1992, 1997).

Contrary to the interpretation of the shape of copal as "pesos" as remarked by Wisdom (1940) above, Stross (1997) interprets a different meaning from the color and shape of manufactured copal: "Painting copal the color of jade recalls the fact that jade placed in the corpse's mouth in Maya burials has been interpreted as symbolizing maize as food for the soul of the newly departed (Coe 1988:225), while copal itself is said to be food of the gods." And, "Frequently copal in Guatemala is sold in disc form as wafers wrapped in banana leaf or maize husk packages. The tortilla shaped wafers are approximately the size and shape of some of the Classic Maya jade discs, and there is likely to be a symbolic relationship between these two different forms of metaphorical 'food.' "

Copal also serves as a medicine among indigenous peoples. Pulverized and dissolved in water, copal was used as one of the many treatments for diarrhea among the Nahua (Vogel 1977). The Nahua and Maya peoples also used copals to plug tooth cavities (Laughlin 1975; Savinelli 1997). In Oaxaca, a poultice of copal has been used for boils or tumors; mixed with milk and egg yolks, copal has been used to treat pneumonia (Parsons 1936). In Zinacatán, a Tzotzil-speaking municipality in the Highlands of Chiapas in southern Mexico, 3–6 splinters of the trunk of *batz'i pom* tree (*B. excelsa*) are brewed as a basic ingredient for "flower water" for "rituals of affliction." For swelling, 13 wooden splinters are brewed with gunpowder for a tea before breakfast. Likewise, for loose teeth, 13 splinters of *ach'el pom* (*B. bipinnata*) are brewed with 13 splinters of *tzajal tulan* (red tulan, *Quercus rugosa* Nee) for a tea, also drunk before breakfast (Breedlove and Laughlin 1993; Laughlin 1975; Vogt 1976).

The gum of *B. copallifera* was used as a remedy for uterine diseases and in making ointments, while the smoke was inhaled as a remedy for headaches (Standley 1926). In Sinaloa, the resin of *B. bipinnata* has been used to treat wounds (Standley 1926). In the southwest U.S., the resin of *B. microphylla* is steeped in tequila or grain alcohol to make a tincture for gum sores, cold sores, and abscessed teeth. The dried stems and leaves are used in a tea to relieve painful urination and as a stimulating expectorant for bronchitis and chest colds (Moore 1989, 1990), while the gum has been used to treat venereal diseases in Sonora (Kearney and Peebles 1942). A species identified as *Bursera simaruba*

(which may not be correctly identified, see previous discussion on identification) has been used by Nahua in Sierra de Zongolica in the state of Veracruz, Mexico to treat fever and chicken pox (Bork et al. 1996). *Palo jiote* (also identified as *B. simaruba*) is used in Guatemala as a diuretic and as a treatment for diarrhea, dysentery, and intestinal infections (Cáceres 1996); the boiled leaves are used as a bath water or enema for fever (Comerford 1996). In Salvador, the seeds of a species also identified as *B. simaruba* are used for rheumatism, while the powdered fruits are used for stomachache (Altschul 1973). Roys (1965) translates in the "Ritual of the Bacabs," a manuscript from Yucatán dating from the eighteenth century, on the use of *chacah* (again, identified as *B. simaruba*) for eruptions, fevers, seizures, running sores, and worms in teeth. In the early nineteenth century, natives of the Antilles used the resin of *B. simaruba* for ulcers, asthma, and digestive and circulatory problems (Descourtilz 1833). Anti-tumor agents have been isolated from *B. fagaroides* and *B. microphylla* (Bianchi, Caldwell, and Cole 1968; Bianchi, Sheth, and Cole 1969; Cole, Bianchi, and Trumbull 1969; Jolad, Wiedhopf, and Cole 1977; Puebla-Pérez et al. 1998). Agglutination of human spermatozoa (and thus an indication of the potential as an contraceptive) was observed with ethanolic extracts of the cortex of *B. fagaroides* (Huacuja et al. 1990).

Copal may also have been used to induce trances. Emboden (1979) has equated the Nahua *teuvetli* with fresh copal: "*Teuvetli* is a tree know to the Aztecs but remaining something of a mystery to contemporary botanists. We know that a tree by this name was incised to release its resins so that they might be used in ritual sacrifice. Slaves and captives had to climb to very high altars on these occasions and force was not appropriate to sacrificial ritual. It was necessary to induce a trance state that would not impair motor coordination and cause them to fall. We know little of this narcosis except that given this control of muscle combined with passive behavior it was most likely a hypnotic. *Bursera bipinnata* (*Elaphrium bipinnatum*) seems the most likely candidate for the mysterious tree .... *Bursera* species were used in diverse medical practices among the Aztecs. All of these have resin canals running through the bark and when slashed, a gummy resin is exuded. Leaves frequently spray a mist of volatile oils when broken. These gums and oils were applied directly to induced wounds before the ceremony so that a direct connection with the circulatory system of the blood might be established. This practice parallels that among the African bushmen who express the juice of a bulb of *Pancratium* (species unknown, but locally called *Kwashi*) [Amaryllidaceae] into a wound on the forehead in order to provoke visual hallucinations. In contemporary Mexico some species of *Bursera* (especially *B. penicillata*) are used to allay pain in instances of toothache."

Mayan uses of the decoction of resin of *P. copal* include treatments for coughs and asthma, diarrhea, biliousness, abdominal pains, sore rectum, diarrhea with pus or mucus, and swelling of the body (Roys 1931). In Guatemala, the resin of *P. copal* is used for rheumatism and for toothache (Comerford 1996). In Belize, the resin of *P. copal* is used to treat painful tooth cavities, while the bark is scraped, powdered, and applied to wounds, sores, and infections; an infusion of the bark is used for stomach complaints and intestinal parasites (Arvigo and Balick 1993). The resin of *P. copal* is used in Yucatan to treat respiratory infections (Flores and Ricalde 1996).

Further medicinal uses of other plant resins in southern Mexico and Central America are recorded in Tripplett (1999).

Another Source of Incense Copal in North America: *Hymenaea courbaril*

While the primary source of copal for incense in North America is from species of *Bursera* and *Protium, Hymenaea courbaril* L. is also a source of incense in Mexico. This species occupies a vast geographical area of tropical America and the Antilles with six varieties; var. *courbaril* occurs in Mexico (Lee and Langenheim 1975). The pale yellow or reddish gum exudes from the trunk and is called *resina de cuapinole, goma animé de México, ámbar del país, ámbar de cuapinole, succino del paísm succino criollo, goma de la terram incienso de la tierra,* or *incienso de petapa.* The gum of *H. courbaril* was also used in varnishes and in the preparation of ointments and plasters and was sometimes smoked to relieve asthma or employed locally for rheumatism, catarrh, ulcers, and venereal disease. (Altamirano 1903; Flores 1919; Martínez 1969; Standley 1926; Vanden-Burghe 1894). Wisdom (1950) reports on the use of *H. cour-*

TABLE 1. THE ESSENTIAL OILS OF *COPAL BLANCO*, *COPAL ORO*, AND *COPAL NEGRO* (MEAN ± SD%, N.D. = NOT DETECTED).

Oil/Yield/Compound	*Copal blanco* (N = 3)	*Copal oro* (N = 3)	*Copal negro* (N = 3)
Oil yield	0.01 ± 0.01	0.04 ± 0.02	1.96 ± 0.68
α-pinene	n.d.	21.35 ± 5.96	17.95 ± 1.35
camphene	n.d.	1.90 ± 0.94	1.60 ± 0.10
β-pinene	n.d.	8.69 ± 0.60	0.23 ± 0.10
sabinene	n.d.	n.d.	12.51 ± 0.08
δ-3-carene	n.d.	0.18 ± 0.07	1.94 ± 0.22
limonene	0.03 ± 0.05	26.51 ± 1.22	16.88 ± 2.02
1,8-cineole	0.16 ± 0.13	0.51 ± 0.12	n.d.
β-phellandrene	n.d.	n.d.	1.91 ± 0.81
γ-terpinene	n.d.	0.88 ± 0.11	2.35 ± 0.76
p-cymene	n.d.	2.31 ± 0.19	3.09 ± 1.34
terpinolene	n.d.	0.43 ± 0.01	0.72 ± 0.19
6-methyl-5-hepten-2-one	0.37 ± 0.14	0.81 ± 0.12	n.d.
1-octen-3-yl acetate	n.d.	1.21 ± 0.07	n.d.
2-nonanone	n.d.	0.47 ± 0.62	n.d.
1,3,8-*p*-menthatriene	n.d.	0.17 ± 0.03	n.d.
α-campholenal	n.d.	0.20 ± 0.10	0.08 ± 0.01
α-*p*-dimethyl styrene	n.d.	0.61 ± 0.11	0.92 ± 0.87
trans-sabinene hydrate	n.d.	n.d.	0.60 ± 0.20
α-cubebene	1.39 ± 0.61	0.09 ± 0.02	n.d.
trans-limonene oxide	n.d.	n.d.	0.30 ± 0.02
cyclosativene	n.d.	0.25 ± 0.06	n.d.
α-copaene	14.52 ± 1.28	2.79 ± 0.16	0.05 ± 0.08
β-bourbonene	6.07 ± 0.75	n.d.	1.19 ± 0.32
camphor	n.d.	n.d.	0.15 ± 0.25
linalool	n.d.	0.99 ± 0.49	n.d.
cis-sabinene hydrate	n.d.	n.d.	0.60 ± 0.20
β-cubebene	1.56 ± 0.63	n.d.	n.d.
linalyl acetate	n.d.	0.35 ± 0.02	n.d.
pinocarvone	n.d.	n.d.	0.85 ± 0.19
bornyl acetate	n.d.	1.35 ± 0.03	0.27 ± 0.08
2-undecanone	n.d.	0.39 ± 0.07	n.d.
β-ylangene	2.29 ± 0.11	n.d.	n.d.
β-elemene	8.50 ± 0.35	n.d.	n.d.
terpinen-4-ol	n.d.	0.82 ± 0.14	6.20 ± 1.66
β-carophyllene	8.54 ± 0.54	n.d.	2.89 ± 0.65
aromadendrene	<0.01 ± <0.01	n.d.	n.d.
trans-dihydrocarvone	n.d.	0.38 ± 0.09	0.01 ± 0.02
myrtenal	n.d.	1.35 ± 0.09	0.82 ± 0.11
trans-pinocarveol	n.d.	1.22 ± 0.97	n.d.
α-humulene	2.18 ± 0.38	n.d.	n.d.
α-amorphene	1.67 ± 0.16	n.d.	n.d.
α-terpineol	n.d.	n.d.	5.88 ± 2.52
α-terpinyl acetate	n.d.	3.97 ± 0.30	n.d.
borneol	n.d.	n.d.	0.14 ± 0.02
germacrene D	13.75 ± 1.06	n.d.	0.29 ± 0.08
α-muurolene	0.95 ± 1.17	n.d.	n.d.
β-selinene	0.24 ± 0.42	n.d.	n.d.
α-selinene	0.12 ± 0.20	n.d.	n.d.
bicyclogermacrene	3.77 ± 0.37	n.d.	n.d.
piperitone	n.d.	0.20 ± 0.14	0.18 ± 0.01
carvone	n.d.	1.74 ± 0.21	0.99 ± 0.14

TABLE 1. CONTINUED.

Oil/Yield/Compound	*Copal blanco* (N = 3)	*Copal oro* (N = 3)	*Copal negro* (N = 3)
δ-cadinene	2.66 ± 0.26	0.14 ± 0.12	n.d.
γ-cadinene	n.d.	0.14 ± 0.12	n.d.
ar-curcumene	n.d.	0.01 ± 0.02	n.d.
cadina-1,4-diene	0.12 ± 0.11	n.d.	n.d.
myrtenol	n.d.	0.38 ± 0.02	0.96 ± 0.18
perillaldehyde	n.d.	0.33 ± 0.22	n.d.
cis-calamenene	0.07 ± 0.07	n.d.	n.d.
trans-carveol	n.d.	0.71 ± 0.13	0.88 ± 0.22
p-cymen-8-ol	n.d.	0.20 ± 0.08	0.25 ± 0.18
cis-carveol	n.d.	0.25 ± 0.05	0.20 ± 0.05
α-calacorene	0.02 ± 0.04	n.d.	n.d.
caryophyllene oxide	2.18 ± 0.16	n.d.	1.39 ± 0.74
cuminyl alcohol	n.d	n.d.	0.02 ± 0.02
spathulenol	5.14 ± 1.07	n.d.	n.d.
α-cadinol	0.10 ± 0.10	n.d.	n.d.
carvacrol	n.d.	n.d.	0.04 ± 0.03
opposita-4(15),7(11)-dien-1β-ol	0.30 ± 0.14	n.d.	n.d.

baril by the Ch'orti: "A tea of the bark is drunk for malaria and liver inflammations, and a potion of the bark and fruit shell is drunk for jaundice." Capuchin monkeys have also been observed rubbing their fur with the trunk exudate of *H. courbaril* (and the fruit of a *Protium* sp.), possibly to repel ectoparasites (Rodriguez and Wrangham 1993).

ESSENTIAL OILS OF NORTH AMERICAN COPALS AND RELATED SPECIES

Reports on the essential oils of North American copals are limited. Populations of *B. microphylla* in Baja, California are high in α-pinene, β-pinene, and/or "phellandrene" (probably α-phellandrene) (Mooney and Emboden 1968). The leaf pocket resin of *H. courbaril* from Mexico and Brazil [var. *stilbocarpa* (Hayne) Lee and Langenheim] was found to contain sesquiterpenes such as 0.4–1.4% α-cubebene, 2.8–6.8% α-copaene, 1.5–7.5% cyperene, 2.6–8.2% β-copaene, 15.8–68.1% caryophyllene, 4.0–12.0% β-humulene, 1.9–3.7% γ-muurolene, 8.4–17.2% α- and β-selinene, trace γ-cadinene, 2.1–3.4% δ-cadinene, and 0.1–30.7% caryophyllene oxide (Arrhenius and Langenheim 1983; Martin, Langenheim, and Zavarin 1972, 1974). The light intensity and predatory pressure may influence the content of sesquiterpenes in *Hymenaea* (Langenheim et al. 1978, 1981). The trunk resin from trees of *H. courbaril* from Brazil contains labd-13-en-8-ol-15-oic acid (Cunningham, Martin, and Langenheim 1974).

Other species of *Bursera* and *Protium,* however, have also been examined chemically. Mexican linaloe wood oil, chiefly distilled from *B. penicillata,* sometimes with admixture from *B. glabrifolia* (H.B.K.) Engl. [*B. aloexylon* (Schiede ex Schlecht.) Engl.], and/or *B. fagaroides,* consists of linalool and linalyl acetate modified by lesser amounts of methyl heptenone, methyl heptenol, α-terpineol, nerol, and geraniol (Guenther 1950; Husain et al. 1988; Theagarajan and Prabhu 1987). The resin from *P. heptaphyllum* of Brazil is rich in α-terpinene, p-cymene, γ-terpinene, terpinolene, p-cymen-8-ol, α-pinene, and dill apiole (Bandeira et al. 2001; Siani et al. 1999a,b), while the leaves and stems yield primarily terpinolene, β-elemene, β-caryophyllene (Zoghbi, Maia, and Luz 1995). The resin from *P. subserratum* (Engl.) Engl. of Brazil is rich in β-phellandrene and α-phellandrene (Zoghbi et al. 1998). The oils from trunk exudates from six other species of *Protium* from Brazil were found to be rich in α-pinene, *p*-menth-3-ene, α-phellandrene, α-terpinene, *p*-menth-1-ene, *p*-cymene, β-phellandrene, and/or terpinolene (Ramos et al. 2000).

MATERIALS AND METHODS

Copal blanco, copal oro, and *copal negro* were purchased from Native Scents, Taos, NM,

and Penn Herb Co., Philadelphia, PA. Oils were distilled with a neo-Clevenger of Moritz after Kaiser and Lang with the modification of Hefendehl (Kaiser and Lang 1951; von Rudloff 1969). Mass spectra were recorded with a 5970 Hewlett-Packard Mass Selective detector coupled to a HP 5890 GC using a HP 50 m × 0.2 mm fused silica column coated with 0.33 mm FFAP (crosslinked). The GC was operated under the following conditions: injector temp., 250°C; oven temp. programmed, 60°C held for one min., to 115°C at 2.5°C per min, then to 210°C at 1.0°C per min. and held for 30 min.; injection size, 1 μL (~50% solution in spectroscopy grade n-pentane) split 1:10. The MSD EI was operated under the following conditions: electron impact source 70 eV, 250°C. Identifications were made by Retention Indices and library searches of our volatile oil library supplemented with those of NBS/NIST, and Wiley. IR was performed according to Tripplett (1999): IR data were collected in the 4000–400 cm^{-1} region on disks pressed from an approximately 10:1 mixture of KBr and sample using a Nicolet 550 FTIR spectrometer.

Results and Conclusions

Sixty-eight compounds were identified in the three commercial incense copals (Table 1). The essential oil of *copal blanco,* a hard, whitish resin, is dominated by 14.52 ± 1.28% α-copaene and 13.75 ± 1.06% germacrene D. The essential oil of *copal oro,* a hard, golden resin, is dominated by 21.35 ± 5.96% α-pinene and 26.51 ± 1.22% limonene. The essential oil of *copal negro,* a hard, somewhat sticky, blackish resin is dominated by 17.95 ± 1.35% α-pinene, 12.51 ± 0.08% sabinene, and 16.88 ± 2.02% limonene. The IR spectral analyses were comparable to that of Tripplett (1999).

From 1) the published literature, 2) color and consistency of the copal, 3) quantity and quality of essential oil, and 4) IR spectra, the following identities were made: *copal blanco* is probably obtained from *B. bipinnata, copal oro* is probably obtained from *H. courbaril,* and *copal negro* is probably obtained from *P. copal.* However, accurate correlation of any of these commercial copals with a species should be made with GC of resins from authentic, vouchered species in the field, incorporating a study of geographic and harvesting technique variation.

Copals have been recorded to have a multiplicity of uses among indigenous peoples of North America and have been used for different functions in religion, medicine, art, and crafts, as summarized by Tripplett (1999): "both the ritual act of burning copal and the exudates substance itself, are sacred. Copal incense invokes, propitiates, and nourishes deities who possess a somewhat temperamental hold over the well-being of humans. Copal as medicine, as ointment or smoke, relives the body of harmful spirits, fever, and respiratory problems, and gladdens and strengthens the soul of human and spirit alike. The function and significance of copal, primarily as an incense, becomes clearer if one considers the web of social relationships that are generated and maintained by its collection and its ritual uses." We should not be surprised that the sources and uses vary from region to region or even from individual to individual, as the Nahua and Maya were never monolithic societies. Hence, the multiplicity of interpretations of sources and uses of copal as recorded in the archaeological and anthropological literature are quite plausible.

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