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CHEMICAL SENSES

Volume 2
Irritation

edited by

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Monell Chemical Senses Center
Philadelphia, Pennsylvania

1990

Marcel Dekker, Inc. New York and Basel

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Getting to Like the Burn of Chili Pepper
Biological, Psychological, and Cultural Perspectives

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I. INTRODUCTION

We can only presume that there was some astonishment in the mind of Christopher Columbus when he entered into his journal on Jan. 15, 1493, with respect to the ingestion of fiery hot chili peppers by American natives, that "toda la gente no come sin ella, que la halla muy sana" (they eat nothing without it, and deem it very wholesome) (Columbus, 1493/1986, p. 176). DeCuneo (1495; cited in Govindarajan, 1985a), accompanying Columbus says "those Caribes and Indians eat that fruit like we eat apples." Bernardo de las Casas (1909, p. 436) comments, with respect to the recently discovered Mexican indians, that "without chile, they do not think they are eating" (p. 436). Indeed, according to Diaz del Castillo (1963), the Aztecs practiced their cannibalistic practices by eating their victims with chimole sauce: chili, tomato, onion, and salt.

This unlikely enthusiastic and widespread preference was soon exported to the rest of the world. It wasn't just the Mexicans and Caribes who were to be so fond of the fiery stuff. In one of the most remarkable culinary progressions in history, hot chile peppers became a mainstay of cuisine in diverse parts of the world, such that today about one-quarter of the adults in the world eat them on a daily basis. Chile pepper is a basic, recurrent, almost ubiquitous flavoring ingredient in many world cuisines. It is part of what

Elisabeth Rozin (1982, 1983) calls a flavor principle in the cuisines of Korea, India, southwestern China, Indonesia, west and east Africa, Hungary, Spain, and, of course, Mexico. In all of these cuisines, chili pepper is used on a meal-to-meal basis; it is not an occasional condiment but rather a fundamental part of the daily diet. In Mexico, home of the most commonly consumed species of *Capsicum*, chili pepper is eaten at all meals. It is consumed in three forms: as a principal component of a set of sauces (salsas), along with tomatoes and a few minor ingredients, that is widely used on tortillas and other foods; cooked as a component of main course stews; and raw, often in slices, on foods. It is also used as a principal flavoring in snacks (reviewed in Rozin and Schiller, 1980). It tends not to be used in beverages and in sweets, but there are exceptions.

In spite of its New World origins, India and China are currently the biggest producers of chili peppers, and China is the biggest exporter (Govindarajan, 1985b). Korea has perhaps the hottest of all cuisines, with the highest intake of chile pepper (9 g/person/day) (Govindarajan, et al., 1987). Black pepper is the only spice with a bigger trade volume in the world, in terms of dollars, but there is much more chili pepper consumed; it is much less expensive, and a much larger proportion of the amount produced is consumed locally (Govindarajan, 1985b). Chili is a basic constituent in most of the tropical cuisines of the world and many temperate cuisines as well; it is not only the most consumed spice in the world, but, because of its association with low-meat diets and its low cost, the spice of the underprivileged (Rosengarten, 1969).

In a survey of a few hundred tropical and semitropical cultures designed to determine the best constituents for universal emergency rations, Moore (1970) concludes: "Let us imagine that you wished to invite the entire populations of East, South and Southeast Asia, the Middle East, Africa, Latin America and Oceania to dinner. What to serve that will be acceptable to all and reasonably balanced nutritionally? This is the menu: chicken, rice, squash and chili sauce with tea for a beverage and a banana for dessert."

This extraordinarily popular item is the same one whose smoke when burned, according to sixteenth century chroniclers, was used as a toxic gas in wars by South American Indians against the Spanish invaders. It is the same food that these chroniclers claimed the Spanish found too strong, at least for awhile (Heiser, 1969). Indeed, the genus name *Capsicum* and the name of the pungent chemical capsaicin may well derive from the Greek root *kapto* ("I bite") (Heiser, 1969). The handling of this preferred food is described in a popular cookbook featuring recipes with chili pepper as follows: "They require special handling. Their volatile oils may make your skin tingle and your eyes burn. Wear rubber gloves if you can and be careful not to touch your face or eyes while working with the chilies. . . . After handling hot chilies, wash your hands thoroughly with soap and warm water" (Time-Life, 1970).

Strange, indeed, that in the great Columbian exchange (Crosby, 1972) of foods between the New and Old Worlds, in which chile peppers, tomatoes, potatoes, chocolate, squash, peanuts, vanilla, turkey, and other foods made their first contacts with the Old World, chile pepper, surely the least palatable on first tasting, became one of the most widely accepted ingredients.

II. BACKGROUND

A. Botany

All current chili peppers trace their origin to the New World, and were unknown in the Old World until the time of Columbus. The genus *Capsicum* contains many species, five of which have been domesticated. One of these, *C. annuum*, originating in Mexico, accounts for the great majority of existing peppers (Andrews, 1984; Heiser, 1985; Govindarajan, 1985a,b). There is much dispute on the number of varieties of domesticated peppers, with estimates varying from 30 to 150 (Heiser, 1985). The wild form of the chili peppers is small and highly pungent; it is through domestication that mild forms, such as the bell pepper, have been created. The pungency is controlled by a single dominant allele (Heiser, 1969). The pungency results from a family of chemicals, called capsaicins, which are localized primarily in the placenta, the inner ribs of the peppers to which the seeds attach (Govindarajan, 1985a,b). Capsaicin levels for most peppers vary between 0.1 and 1%.

There is evidence for five different natural capsaicins, all decylenic acids of vanillylamide (Table 2) (Szolcsanyi and Jancso-Gabor, 1975; Todd, et al., 1977; Govindarajan, 1986). These have somewhat different sensory properties (Todd et al., 1977) (see below) and vary in concentration from variety to variety, and as a function of ripeness. In general, the amount of capsaicins in peppers increases with ripening (Govindarajan, 1985a).

Chili peppers are high in volatiles and have characteristic flavors and aromas which vary with maturity and variety. The appeal of the peppers results from both the volatiles and the capsaicins as well as their striking and saturated colors. The colors are produced to a large extent by carotenoids, which also account for one of the primary nutritional components of the peppers—high levels of vitamin A or its precursors. The other most significant nutritional component is vitamin C (Govindarajan, 1985b).

B. Cultural History

In Mexico, there is evidence for consumption of chili peppers dating back to about 7000 B.C., and there is evidence for cultivation at some time in the period between 5200 and 3400 B.C. (Heiser, 1969; Pickersgill, 1969). Domestication probably began in about 1500 B.C. Peppers were brought back to Europe by Columbus and subsequent explorers, and subsequently spread to many parts of Europe, Africa, the Middle East, and Asia (Halasz, 1963). Some of the spread in Europe may have been motivated by the attraction of peppers as ornamental plants (Halasz, 1963), and there were also medicinal (e.g., fever prevention, antimalarial) as well as food uses for the plant (Halasz, 1963). Present day Hungary became a center for chili pepper cultivation and was the location where sweet (non-pungent) paprikas were developed in the early twentieth century (Halasz, 1963). By 1650, peppers were cultivated in Europe, Africa, and Asia (Rosengarten, 1969); pepper use was widespread in India by the eighteenth century (Crosby, 1972). The widespread acceptance in the Old World may have been prompted by previous acceptance and the strong desire for black pepper (Andrews, 1984); chile peppers provided a similar "burn" and were much cheaper. The similarity in sensations is indicated by the similar names provided to black and chili pepper in Spanish (pimienta and pimiento, respectively).

C. Pharmacology of Capsaicin

Capsaicin is a pharmacologically active substance (see Jancsó, 1960; Jancsó-Gábor and Szolcsányi, 1969; Maga, 1975; Rozin, 1978; Buck and Burks, 1986) for reviews. For this reason, it has a history of medicinal use. The Mayans used it to treat cramps, diarrhea, aching gums, and sore muscles (Rosengarten, 1969; Schweid, 1980), and in the Old World it was used as a skin irritant, carminative (inducing gas expulsion), stimulant, and as a treatment for rheumatism, gastritis, and throat irritations (Heiser, 1969; Parry, 1969).

The effects of capsaicin depend very much on the route of delivery: skin contact, oral contact, ingestion, and systematic effects (via injection). The skin effects involve stimulation of circulation at the site of contact, and mobilization of an inflammation response (Jancsó, 1960, 1968; Jancsó-Gábor and Szolcsányi, 1969). So far as we know, the capsaicin acts as a mimic in the sense that it does not directly produce harm; the body responds to it as if it were a harmful agent.

Capsaicin acts as an irritant to the oral and gastrointestinal membranes, activating both the defensive and digestive systems. It produces copious salivation and gastric acid secretion (Solanke, 1973). Oral capsaicin also induces sweating on the face, neck and the front of the chest; this effect seems to be a reflexive response to oral stimulation, since it does not occur if the mouth is anesthetized (Lee, 1954).

So far as I know, very little capsaicin is absorbed. On the basis of its molecular structure, one might expect modest levels of absorption of intact capsaicin. Certainly, at least some capsaicin passes through the gut untouched, accounting for the Hungarian saying, "Paprika burns twice," or the

Indian saying, "You feel chili on the way out." There is a report from an animal study indicating that capsaicin lowers blood pressure (Porszasz, et al., 1955). Experimental work on the effects of capsaicin emanated originally from the Hungarian laboratories of Jancsó (1960, 1968), Jancsó-Gábor, and Szolcsányi (Jancsó-Gábor and Szolcsányi, 1969; Szolcsányi and Jancsó-Gábor, 1973); these laboratories remain centers for research on this subject. Large amounts of capsaicin in the blood stream of animals seem to have two prominent effects: there are massive effects on thermoregulation with damage to the hypothalamic centers for temperature control, and there is permanent, system-wide damage to chemical irritant receptors (Jancsó, 1960; Szolcsányi and Jancsó-Gabor, 1973; Szolcsányi, 1977). The cells (receptors) in the anterior hypothalamus that mediate the response to heat and chemical irritant noniceptors in and on the body are destroyed. These effects have become of central interest in neuropharmacology, both for their own sake and because they provide a powerful tool for the investigation of neurochemical phenomena (see chapter 8 in this volume). A review of the neuropharmacology of capsaicin in 1986 cites 283 references (Buck and Burks, 1986).

The site of action of capsaicin is primarily a subset of afferent endings (principally nociceptive C fibers) that subserve detection of chemical irritation in various parts of the body. The stimulatory effect and the inflammation or desensitization that may follow seem to be mediated by release and subsequent depletion of substance P (Buck and Burks, 1986).

Many of the effects of capsaicin resemble general cholinergic effects, particularly activation of the gut and lowering of blood pressure. There is some evidence from animals and humans that chili ingestion is associated with exacerbation of, and perhaps increased incidence of, ulcers of the stomach or intestine (Bergsma, 1931; Nopanitaya, 1974). Such an effect would be an expected consequence of the great amount of acid secretion that capsaicin produces. However, at low levels the inflammatory response that capsaicin stimulates may have a protective value against erosion by acid (Szolcsanyi and Bartho, 1980).

The data on ulcers aside, it is surprising how little evidence there is that chronic consumption of this active substance has any effect, positive or negative, on health (but see Lee, 1963). There is the potential for massive cross-cultural comparisons, since many cultures consume very high levels of capsaicin, but the appropriate controls for correlated factors are daunting enough to have discouraged systematic study. If capsaicin was even moderately toxic, we would certainly know this by now; and it would be surprising, given that there are many millions of elderly Mexicans, Koreans, Thais, and Asian Indians.

So far as is known, the noncapsaicin constituents of chili pepper are also not toxic; this is strikingly illustrated by a case from Germany (Tokay, 1932). A 20-year-old woman consumed an excessive amount of paprika (at one point, 2 kg over 2 weeks, probably non-pungent). The resulting syndrome, "Kapsizimus," was characterized by reddish color of the skin, especially hands and feet. There was some loss of appetite but no other untoward symptoms.

D. Why Is Chili Pepper Irritating? Why Is Anything Irritating?

Capsaicin is a natural substance. Since birds participate in the dissemination of pepper seeds, it should not come as a surprise that they are not deterred by (and presumably do not sense) the presence of capsaicin (see Mason, this volume). We do not know whether the strong aversion that mammals show to capsaicin is a result of evolution of a defensive response by plants that capitalized on a pre-existing irritation-sensing system in mammals or is an accident. Since capsaicin does not appear to be harmful, the strength of negative response to it is particularly noteworthy. In fact, the major sources of irritation in the world seem to be a few harmless plant products (chili pepper, black pepper, ginger, horseradish, and plant sources of menthol) and a variety of manmade aerial pollutants, including industrial byproducts, petroleum products, and tobacco smoke. It is indeed puzzling that this highly elaborated irritation detection system seems to be detecting primarily harmless plant components or chemicals that have entered our environment since the industrial revolution. Where does the irritation sense come from, and what were the selection pressures that promoted its evolution?

E. Preferences for Chili Pepper in Animals

In subsequent sections, we will address the question of *why humans consume* and like chili pepper. Since some of the proposed mechanisms are uniquely human, and others have more general applicability it is of special importance to determine whether acquired likes for chili pepper can occur in nonhuman mammals. The evidence on this point is mixed. Birds readily consume hot peppers; indeed, some types of chili peppers are called bird peppers (Heiser, 1985). I know of no reports of consumption, outside of conditions of great privation, by mammals in nature. Two studies directed at fostering a preference for spicy foods in laboratory rats by extended exposure to these foods failed to establish a preference (Hilker et al., 1967; Rozin et al., 1979). In different experiments, Rozin et al. (1979) continued exposure for a year, used gradually increasing levels of pepper, and associated the pepper with recovery from deficiency. None of these manuevers led to a preference. However, a recent study with rats (Dib, 1989) revealed strong preferences after minimal exposure. I cannot explain this disparity in results. In a yet more recent study, Galef (1989) reports substantial and enduring preferences for an otherwise mildly unpalatable pepper diet by rats exposed on a few occasions to a "demonstrator" rat that had just eaten this diet.

Humans are exposed to chili pepper as a flavoring in a set of dishes that are much more varied than the rat chow that has served as the vehicle in the laboratory studies. Perhaps this is a factor in the human preference. In Mexican villages, domesticated animals, including chickens, pigs, and dogs, are steadily exposed to chili since they eat meal leftovers that are almost invariably piquant. A survey of residents of a Mexican village in Oaxaca about the preferences of the local animals, and tests of a number of dogs and pigs, revealed not a single case of a clear preference for food (usually a tortilla seasoned with hot sauce, as opposed to the same food without much seasoning, offered in a simultaneous choice) (Rozin and Kennel, 1983). In contrast, I have now identified five cases of a clear preference for hot foods in mammals. One is a pet dog in the United States who developed a taste for hot foods from table scraps offered by her mistress. In direct preference tests, "Moose" showed a clear preference for seasoned foods (Rozin and Kennel, 1983). Dua-Sharma and Sharma (1980) fed two pet Indian macaque monkeys their daily Indian cuisine over a period of time. The monkeys showed a clear preference for the seasoned food. Finally, Rozin and Kennel (1983) carried out an experiment on two young captive chimpanzees. The chimps were offered pairs of identical crackers, except that the crackers differed in color and the crackers of one color contained capsaicin oleoresin (an oil extract of chili peppers which is the commercial vehicle for capsaicin). Both chimpanzees strongly preferred the nonpiquant chip on initial testing. The chimps were then offered mildly piquant chips (100 Scoville units, or SU) with a distinctive color, by their trainer over a period of weeks. Both chimps reversed preferences, one after 25 samplings of mildly piquant chips and the other after 125 samplings. This effect, with a small amount of additional exposure, extended to crackers of the same color with piquancy strengths of 200 and 400 SU. The effect was still present 2 months later. Furthermore, when a new pair of crackers of very different composition from the original pair was offered in two different colors, one of which was paired with piquancy, the chimps promptly preferred the hot cracker.

With the exception of the recent, anomalous finding of Dib (1989), all cases of animal piquant preferences arose in the context of social interaction, i.e., rats served as social facilitators in Galef's work (1989); in all other cases humans were the social facilitators. These findings support the idea that there is *something uniquely human about the acquired liking* for chili pepper in the sense that it may involve human mediation and a social/affective relation to humans.

III. EXPLAINING THE LIKING FOR CHILI PEPPER

What might an explanation for the liking of chili pepper look like? That depends on the type of explanation one is looking for. Confusion about the type of explanantion often causes unnecessary debate about alternative explanations that are not comparable. One type of explanation is adaptive.

It accounts for a behavior in terms of its survival value. For the case of chili pepper, an example of such an explanation would be that chili is eaten to supply vitamin A. Associated with adaptive explanations are evolutionary explanations, which give a historical account of the biological or cultural evolution of a practice. A second type of explanation deals with immediate causation, i.e., what factors operating at the current time cause the behavior? For the case of chili pepper, such an explanation might be that the burn produces pleasure or, at a physiological level, that it causes secretion of endorphins in the brain. A third type, developmental explanations, account for a current behavior in terms of the past history of the organism. For chili pepper, such an explanation might be that chili liking results from past association of chili with eating with the family.

These different types of explanation are all consistent with one another; the adaptive value or developmental origins of a behavior do not necessarily account for, or even constrain, the current motivation to perform it. For this reason, we will separately consider adaptive/evolutionary, current motivation, and development explanations for the liking for chili pepper. Most attention will be focused on developmental explanations, since this is where most of the fundamental issues and most of the research resides.

A. Adaptive/Evolutionary Explanations of Chili Preference

As we have indicated, there is no convincing evidence that the regular consumption of chili pepper causes any negative effects (Nutrition Reviews, 1986). However, especially since the taste is innately negative, there is a challenge to discover the adaptive value and evolutionary history of pepper consumption. The history and motives that might account for the origin of pepper ingestion in the New World are buried in the preliterate past. However, because chili pepper was introduced to the Old World in the sixteenth century, in literate times, there is the unfulfilled possibility that the causes of its successful adoption could be uncovered. The existing preferences for black pepper, which produces a corresponding burning sensation but a very different flavor, was certainly of importance in encouraging acceptance of chili pepper (Andrews, 1984). It was a much cheaper way of getting a for-some-reason desired sensation; indeed, from an Old World perspective, chili pepper was discovered by Columbus in a search for spices, black pepper being foremost among them.

Adaptive/evolutionary explanations for chili use are commonly offered, but uncommonly evidenced. A particularly popular view is that chili helps to preserve food, a valuable characteristic in prerefrigeration, premodern Europe. There is no historical or biological evidence for this claim, so far as I know (see Sass, 1981, for a discussion of motivations for using spices in premodern Europe). Although capsaicin seems like it should be able to kill anything, with respect to microbes as well as the oral mucosa, its bark is much worse than its bite. There is no evidence for an antibacterial effect (Dold and Knapp, 1948; Govindarajan et al., 1987) although there is some evidence for an antioxidant effect (Govindarajan et al., 1987).

A second, related claim is that the pepper helps to cover the sensory evidence of spoilage and was sought for that reason. Again, there is neither historical evidence for this (Sass, 1981), nor is there current evidence that it serves that function. In fact, both the original New World setting for chili and in the areas where it is currently most widely used, the diet is primarily of vegetable matter, and it is employed to a large extent on grain dishes that are rather resistant to spoilage.

A third claim is that the sweating/cooling effect elicited by capsaicin provided relief from the high temperatures of the tropics. There is no evidence that this is a significant function of chili pepper as it is used today. Chili pepper is popular in many moderate climates, including Korea and the Mexican plateau, the very place of its origin.

Although any of these three factors might have a minor role in both the cultural adoption and adaptive value of chili pepper, the answer to the adaptive evolutionary question cannot lie here. Indeed, this argument requires the establishment of two facts: (1) that there is a particular adaptive value (not yet demonstrated for spoilage retardation or masking) and (2) that this value had some role in cultural adoption. Four other hypotheses seem more promising.

Chili peppers are extraordinarily rich sources of both vitamins A and C. These vitamins are often in short supply in the tropical and semitropical grain-dominated cuisines in which chili pepper is most commonly consumed. For example, chilies are estimated to provide 33% of the vitamin A in the rural Mexican diet (Anderson, et al., 1946). Furthermore, rats have been shown to grow better when fed a South Indian rice diet supplemented with chili and tamarind than with the same diet without the supplement (Krishnamurthy et al, 1948). This may well result from vitamin A supplementaion. The peppers therefore fill a nutritional niche. It is hard to imagine how people discovered this nutritional advantage, if they ever did, since both vitamin C and A deficiencies develop and recover slowly and insidiously; indeed, scurvy decimated European sailors on long voyages for centuries before the simple fresh fruit cure was appreciated. In any event, the vitamins provide a clear adaptive value for chili pepper.

Chili pepper activates the gut and produces extensive salivation, presumably facilitating the processing and digestion of food. Digestion of the bland, high complex carbohydrate diets characteristic of the cultures that use chili as a flavor principle may well be improved with the capsaicin stimulant. It is surely true that mastication of these often dry and mealy diets is facilitated by the copious flow of saliva induced by chili pepper. In this sense, the pepper may also improve the flavor of the diet.

Finally, to move to more "psychological" adaptive values, chili peppers add a meat quality, a mouth fullness to the otherwise bland diets with which they are associated (Rozin, 1978). They also add variety to the diet because of the wide variety of colors, aromas, flavors, and burn intensities and patterns that are produced by different combinations of peppers (see next section).

Finally, judging by the history of spice use in Europe (Sass, 1981), the initial adoption of chili pepper was medicinally (e.g., Holasz, 1963) and socially motivated. In medieval Europe, the use of spices, including black pepper, was mainly limited to the upper classes; consumption of spices was a sign of elevated social status, and was no doubt sought by those not privileged as an indicator of social advancement (Sass, 1981). However, the establishment of chili pepper as a common food in Hungary seems to have taken a course opposite to what normally occurs; chili was initially a food of the lower classes, and moved into the upper classes (Halasz, 1963). There is much to be said, in general, for the powerful role of social forces in the establishment of cultural traditions (see, for example, Simoons, 1961, for a detailed consideration of Old World meat taboos in this context).

I have presented a list of possible adaptive values. In at least some cases, such as induction of salivation and vitamin content, there is little question of the existence of an adaptive value. However, the argument that a particular value or set of values actually supported the adoption of peppers needs more than a demonstration of adaptive value (see Rozin, 1982, for a more extended discussion). In this regard, the effects that are most perceptible, such as salivation and flavor enhancement, seem most likely to have been discovered and exploited.

B. Explaining the Current Liking for Chili Pepper

Chili peppers are not simply vehicles for the conveyance of capsaicin. They have attractive colors, aromas, and flavors, and all of these factors contribute to their appeal. Commercially, in both Mexico and other countries, piquancy is conveyed to foods using either fresh or dried peppers, or capsaicin oleoresin, an oil extract of peppers that contains the capsaicin along with much of the coloring and aroma. Indeed, neither capsaicin (as an additive to produce an isolated burn) nor bell peppers (aroma/flavor/color without capsaicin) are particularly popular in Mexico. The color and aroma/flavor are not only attractive, but they provide richness and variability in the diet. Figure 1 shows one of many dried chili pepper stalls in a market in Oaxaca, Mexico (fresh peppers are sold at different stalls). This particular stall offers many different types of peppers, each with distinctive shapes, colors, aromas, flavors, and burn intensity and pattern. Thus, while chilies add a familiar burn to almost all staple Mexican foods, they also provide a subtle variety, in the mixture of different peppers in different dishes, and the distinctive taste, smell and irritation

FIGURE 1 A typical stall selling dried chilies in the market in Oaxaco, Mexico. Note the wide variety of dried peppers on sale.

of each pepper type. We (Rozin and Rozin, 1981) have described this persistent use of a basic flavor principle, but varied in many subtle ways, as culinary themes and variations. The complexity of the aroma/flavor part of the stimulus is illustrated in Table 1, showing identified aromatics in three varieties of chili peppers.

Furthermore, it is a mistake to think of capsaicin as a monolithic stimulus. Five natural capsaicins have been isolated, and they have different sensory properties (Szolcsányi and Jancsó-Gábor, 1975, 1976; Todd et al., 1977; Govindarajan, 1986; Govindarajan et al., 1987). According to Todd et al. (1977), capsaicin, dihydrocapsaicin, and nordihydrocapsaicin have a more rapid bite and produce irritation more toward the back of the mouth than do homo- or homodihydrocapsaicin (Table 2). Since these capsaicins are present in different amounts in different peppers, there is considerable variety in the intensity and burn locus in different dishes (Govindarajan, Rajalakshmi, and Chand, 1987).

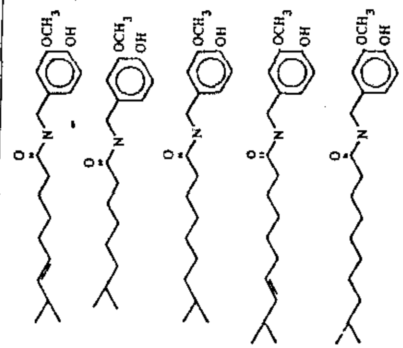
The burn produced by capsaicin is a major contributor to the liking for chili pepper. One hundred twenty adults (57 from a university community in the United States and 63 villagers in Oaxaco, Mexico) were asked why they

TABLE 1 Compounds Identified in Different *Capsicum* Volatiles by GC-MS

Alcohols	In volatiles of		
Cyclopentanol	O	—	—
2-Methylbutanol	—	E	—
3-Methylbutan-2-ol	—	E	—
1-Pentanol	O	—	—
2,3 Butandiol	—	E	—
trans-2-Hexen-1-ol	O	—	—
cis-3-Hexen-1-ol	O	—	F
2-Methylpentan-2-ol	—	E	—
3-Methylpentan-3-ol	—	E	—
4-Methylpentan-1-ol	O	—	F
1-Hexanol	O	E	—
2-Hexanol	O	E	—
3-Hexanol	—	E	—
Linalool	O	E	F
Terpinen-4-ol	O	E	—
alpha-Terpineol	—	E	F
Carbonyls			
2-Butanone	—	E	—
2-Methylbutanol	O	E	—
Cyclohexanone	—	E	—
4-Methyl-3-penten-2-one	O	E	—
n-Hexanol	O	E	—
2-Hexanone	O	E	—
Benzaldehyde	O	—	—
2-Acetylfuran-E	O	E	—
5-Methyl-2-furfural	O	E	—
2-Heptanone	O	—	—
2-Octanone	O	—	—
para-Methylacetophenone	O	—	—
Carvone	O	—	—
Camphor	O	—	—
Thujone	O	—	—
iso-Thujone	O	—	—
2-Undecanone	O	—	—
β-Ionone	—	—	F
Geranylacetone	O	—	—
Carboxylic acids			
Acetic	O	—	—
2-Methylpropionic	—	E	—
2-Methylbutyric	O	E	—
3-Methylbutyric	—	E	—
Pantanoic	O	—	—
4-Methylpentanoic	O	E	—
Hexanoic	O	E	—
Heptanoic	O	—	—
2-Octanoic	O	—	—
Octanoic	O	E	—
7-Methyloctanoic	O	—	—
Nonanoic	O	—	—
2-Decenoic	O	—	—
8-Methylnonanoic	O	—	—
Esters			
Methylpentanoate	O	—	—
Methylhexanoate	O	—	—
Esters (continued)			
Ethyl-3-methylbutyrate	—	E	—
Methylheptanoate	O	—	—
Methylphenylacetate	O	—	—
Methyloctanoate	O	—	—
β-Phenylethylacetate	O	—	—
Methyl-β-phenylpropionate	O	—	—
Ethyloctanoate	O	—	—
Methylnonanoate	O	—	—
Methyl-8-methyl-6-nonenoate	O	—	—
4-Methyl-1-pentyl-2-methylbutyrate	O	—	F
4-Methylpentyl-2-methylbutyrate	O	—	F
Methyl-8-methylnonanoate	O	—	—
Methyldecanoate	O	—	—
Methyldodecanoate	O	—	—
Ethyldodecanoate	O	—	—
Methyltetradecanoate	O	E	—
Methyltetradecanoate	O	—	—
Methylhexadecanoate	O	—	—
Methyloctadecanoate	O	—	—
Pyrazines			
2,3-Dimethylpyrazine	—	E	—
2,3,5-Trimethylpyrazine	—	E	—
2-Methyl-5-ethylpyrazine	—	E	—
2,3-Dimethyl-5-ethylpyrazine	—	E	—
Tetramethylpyrazine	—	E	—
2-Methoxy-3-isobutylpyrazine	O	E	—
Terpene Hydrocarbons			
para-Cymene	—	E	—
Camphene	—	E	—
δ-3-Carene	—	E	—
Limonene	O	E	—
Myrcene	O	E	—
α-Pheilandrene	O	E	—
α-Pinene	—	E	—
β-Pinene	O	E	—
Sabinene	—	E	—
γ-Terpinene	—	E	—
Terpinolene	—	E	—
α-Thujene	—	E	—
Caryophyllene	O	E	—
α-Copacne	—	E	—
Miscellaneous			
Toluene	—	E	—
para-Xylene	O	E	—
Octane	—	E	—
2-Pentylfuran	O	E	—
2-Pentylpyridine	—	E	—
1,8-Cineole	O	—	—
Eugenol	—	E	—
Pentadecane	O	—	—
Hexadecane	O	—	—
Heptadecane	O	E	—

Note: O — Oleoresin African chilies, *C. frutescens;* E — Miscella, mild chili, *C. annuum;* F — Fresh jalapeno, *C. annuum.*

TABLE 2 Sensory Properties Of Capsaicins



Capsaicinoid	Pungency	Time-Course	Location	Structure
Capsaicin	High	Rapid	Back	Capsaicin (C)
Nordihydrocapsaicin	Mod.	Rapid	Back	Nordihydrocapsaicin (NDC)
Dihydrocapsaicin	High	Rapid	Back	Dihydrocapsaicin (DC)
Homocapsaicin	Low	Slow, long	Mid	Homocapsaicin (HC)
Homodihydrocapsaicin	Low	Slow, long	Mid	Homodihydrocapsaicin (HDC)

Source: Adapted from Todd, P. H. Jr., Bensinger, M. S., and Biftu, T., *Journal of Food Science*, 42, 660-665.

ate chili pepper (Rozin and Schiller, 1980). These adults generated 125 reasons for ingestion; 106 of these referred explicitly to the flavor, i.e., the enhancement of flavor or piquancy. The term flavor is used to include piquancy: 28 of the Mexicans who responded with the word flavor were asked if that included the burn; 26 answered affirmatively. The modal Mexican response was: "da sabor a la comida" (adds flavor to food). Only 15% of the responses dealt with the consequences of eating chili, such as improving health, giving strength, or cooling the body. Mexicans and Americans were also given a checklist of 19 possible reasons for consuming chili, including all reasons that the investigators could think of. The only two reasons that were subscribed to by at least 50% of both Mexicans and Americans were "It tastes good" and "I like the burning or tingling feeling." It appears that for the great majority of chili eaters, the burn produced by capsaicin is pleasant. That is, a sensation that is initially negative becomes positive. There is a hedonic reversal. The source of pleasure in consuming chili is well captured by the Indian writer, Kamala Markandaya (1954, p. 57), who, in Nectar in a Sieve, a novel about life in rural India, says ". .when the tongue rebels against plain boiled rice, desiring ghee and salt and spices which one cannot afford, the sharp bite of a chillie renders even plain rice palatable."

C. Liking the Burn: What Is Liked?

If there is a liking for the burn of capsaicin, then those who like chili pepper should also like other foods that produce a burn. Two common examples are ginger, which contains the irritant zinzerone, and black pepper, with the irritant piperine (see Szolcsányi & Jancsó-Gábor, 1975; Stevens & Lawless, 1987, for comparisons of the sensory properties of the different irritant substances). Other common irritant-containing foods or substances are raw onion, tobacco, mustard, horseradish, alcohol, and menthol. Table 3 presents correlations for preferences among these substances, gathered from three studies on students that I have carried out over recent years. As indicated in the table, there are substantial positive correlations between liking for chili and liking for all irritants except menthol; in contrast, the correlation between chili preference and liking for a bitter taste (a totally different innately unpalatable taste) is essentially zero (quinine in Table 3).

D. Locus Specificity of Liking

Those who like chili pepper seem to like a burning irritation on their oral mucosa. Do they like this burn only on those surfaces that have actually contacted chili pepper? If they had, under experimental conditions, only experienced chili pepper on their left lip, would they only like it on their left lip? Normal mastication guarantees that the pepper will be distributed throughout

TABLE 3 Relation Between Liking for Chili Pepper and Liking for Other Innately Unpalatable Substances

Food/substance	Correlation with chili preference
Black pepper	0.44
Horse radish	0.40
Ginger	0.24
Raw onion	0.20
Cigarettes	0.18
Quinine water	0.02
Menthol	0.02

Note: Data from college students (N = 110-300, depending on item. Correlations are Pearson or Spearman coefficients.) These findings come from three different studies. When more than one study included the same correlation, the values were averaged. Some data appear in Rozin andShenker, 1989.

the oropharynx, so that we cannot address this question. However, we can compare liking for irritation on widely separated surfaces. Generally, chili likers do not seem to relish it in their noses, and they seem to dislike it in their eyes; indeed, exposure of the eyes to the smoke of burning peppers was a punishment practiced by the ancient Mexicans, as illustrated in the accompanying figure from the *Codex Mendoza*, a sixteenth century Aztec manuscript (*Codex Mendoza*, 1978) (Fig. 2).

Chili pepper is an occasional component in skin linaments, such as Icy-Hot (menthol is a more common ingredient). The burning sensations resulting from application of these linaments may become pleasant. Sandy Koufax (1966), the great Los Angeles Dodge pitcher, regularly used capolin hot ointment on his arm. He reports: "I also had discovered, very early in my career, that I enjoy the feeling of warmth on my arm. After all these years, a mixture that might parboil someone else's arm is no more warm to me" (p. 238). These linaments produce a burning sensation which seems related to the oral sensations. Because menthol dominates as the irritant in skin creams and linaments, we can examine the mouth-to-body generalization hypothesis with menthol. There is a weak relation between liking for the burn of menthol in the mouth and on the body (the spearman ρ is 0.24; Rozin and Shenker, 1989). Correlations are higher when menthol burns in closer areas are compared (mouth and face, $\rho = 0.50$). For chili pepper, the only comparisons we can make are between the burn of chili pepper in the mouth and horseradish in the nose ($\rho = 0.33$) or the hot burn sensation on first stepping into a hot bath ($\rho = 0.05$) (Rozin and Shenker, 1989). Again, it seems that there is generalization to neighboring but not to distant surfaces.

FIGURE 2 Drawing from the Codex Mendoza, a post-Columbian document created by Aztecs for the Spanish, depicting aspects of Aztec life. Shown is child being punished by being held over the smoke of burning chilies. (from Codex Mendoza, 1978, p. 80.)