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Coriander (cilantro): A most divisive herb

Charles Spence

Department of Experimental Psychology, New Radcliffe House, University of Oxford, Oxford, OX2 6BW, UK

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ABSTRACT

Coriander is one of the most interesting of herbs/spices given the polarizing (or bivalent) responses that the fresh leaf evokes in people. While many people appreciate the citrusy, herbal qualities of the fresh leaf when added to food, others find its presence to be offensive, describing it as having an unpleasant soapy taste instead. The olfactory receptor (OR) gene responsible for this genetically-determined perceptual difference has now been uncovered, with the incidence of the soapy response estimated at between 3 and 21%, depending on the ethno-cultural group tested. Intriguingly, the spice, coriander seed (actually the dried ripe fruit), does not appear to elicit the same response, hinting at the divergent chemical make-up of the various parts of this popular culinary plant.

1. Introduction

Coriander (*Coriandrum sativum* L.) is a particularly interesting herb/spice, given the unambiguously divisive (i.e., polarizing) chemosensory properties that are associated with the fresh leaf (e.g., when added to food). The fresh green leaves of the plant (*Coriandri herba*), commonly known as cilantro,[1] or Chinese parsley,[2] are nowadays widely used in the cuisines of Mexico, South America, China, India, and Southeast Asia. While the fresh leaves (and stalks, together often referred to as ferns) are used as an herb, the dried seeds (which are technically the dried ripe fruit, *Coriandri fructus*)[3] are used as a culinary spice best known for the pungent and aromatic powders and oils. Coriander seeds have a pleasantly citrus-filled, fruity aroma.[4] The ground, and often toasted, seeds are widely used in Indian cuisine; They also form a part of the *garam masala* (meaning hot spices) dried spice blend (along with cumin seeds, ground cardamom, black pepper, cinnamon, cloves, and nutmeg) that are often added to food once a dish is almost complete. Belgian brewers have been importing and brewing with coriander seeds since the Middle Ages. Currently, they are most frequently used in Belgian White (or wit) beers as well as in hoppy beers (Allagash Brewing Company, 2017).[5] Coriander root is also edible though does not appear so often in recipes (Al-Khayri et al., 2023).

Nowadays, especially when combined with tomatoes and chile, coriander is closely associated in many people's minds with the cuisine of Mexico (e.g., Albala, 2021; Rozin, 1983; see also Rozin and Rozin, 1981). However, this particular herbaceous plant, which is indigenous

E-mail address: charles.spence@psy.ox.ac.uk.

[1] Note that in the U.S., the leaves are called cilantro, while the seeds are called coriander, whereas elsewhere both the herb and spice are referred to as coriander (see Balslev, 2010). Harrington (1978, pp. 145–146) notes how certain gourmet cooks were using the term cilantro for a plant that "had acquired a certain amount of snob appeal" by the 1970s.

[2] According to Leach (2001, p. 14), the fact that coriander is referred to as parsley over the last 75 years or so, presumably due to the visually-similar appearance of the former to flat-leafed parsley. Leach suggests that the use of this descriptor may reflect the contemporary lack of familiarity of European consumers with fresh green coriander (see also Visser, 1992, p. 268).

[3] The coriander fruit is actually a globular dry schizocarp, that is referred to as a seed (Omidbaigi, 1997).

[4] According to a blogpost from the Allagash Brewing Company (2017), coriander seeds have a round, fruity flavour (cf. Spence, 2023a). This description strikingly different from the suggestion in Noah Webster's An American Dictionary of the English Language where, in the first edition of 1828, the seeds of *Coriandrum sativum* are described as having "a strong smell and a spicy taste." Meanwhile, Paterson (1990, p. 204) suggests that coriander herb has a "sweet, cloying smell". Given such different sensory descriptions, one might wonder that people were talking about the same plant.

[5] Though it should be noted that there are a few people who are allergic to coriander (Brussino et al., 2018, Unkle et al., 2012; see also Hind, 2023).

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to the Near East and Mediterranean regions, was first introduced to the New World during the so-called Columbian Exchange (Crosby Jr., 1973),[6] in the 1600s. Coriander was also one of the first herbs to be taken by the English when establishing the Massachusetts Bay Colony in New England in 1630.[7] Coriander is a hardy annual member of the *Umbelliferae* family, which also includes parsley, dill, chervil, fennel, carrots, etc. The plant fern grows to a height of approximately 50 cm, with dense foliage and pink-white flowers. Given that coriander bolts quickly in warm temperatures, it is best grown in the spring or fall. As soon as it flowers, it makes seeds that can be harvested and thereafter replanted. Furthermore, with some planning and routine, it is possible to grow coriander throughout the year, depending on the climate (though see Hornok, 1976).

1.1. On the history of coriander's culinary use

Featured in the cuisines of the Middle East, North Africa, Europe and Asia, cilantro has a culinary history that dates back millennia. Coriander seeds were found in 8000-year-old caves in Israel (Zohary and Hopf, 2013). Coriander also appears in both ancient Sanskrit and biblical references (see Fig. 1 for the historical spread of *Coriandrum sativum*). Coriander seeds were scattered in King Tutenkhamun's tomb (Hepper, 1990, pp. 57–58). Cilantro appears frequently in the recipes of the ancient Roman gourmand Apicius (Apicius, 1936; though see Lindsay, 1997). However, as Albala (2021) notes, it is subsequently replaced by basil and other herbs in Italian cuisine, and rarely appears in contemporary Italian recipes. Similarly, Elizabeth David (1979) finds that while sixteenth century Spanish recipes call for both green and dried coriander, virtually no contemporary recipes incorporate the fresh herb either. Coriander is thought to have reached Britain in the Late Bronze Age (Conolly, 1941) though, once again, by the end of the sixteenth century, the dissolution of medieval European cuisines was almost complete and coriander had largely disappeared from British cooking (Leach, 2001, p. 12). Indeed, coriander has been described as an underutilized spice by Diederichsen (1996). It was thought to have been introduced into China from the west in the Han period (Yü, 1977). India is currently the world's largest producer of coriander (Coşkuner and Karababa, 2007), with significant supplies also coming from Morocco, Argentina, Romania, Spain, as well as several other countries (e.g., Bhuiyan et al., 2009; Peter, 2000).

As has been noted elsewhere, it is difficult to know how much to infer from the contents of historical recipe books (e.g., see Albala, 2012), given that the early examples bear little relation to the foods that would actually have been eaten by the majority of the populace. Nevertheless, it is still an interesting question to consider when people first started referring to the 'soapy' taste of coriander in print? If some proportion on the population had always found coriander leaf to taste unpleasant (and/or soapy), surely it would have left some historical trace. However, there is no mention in Apicius, or texts concerning taste and the ancients (see Rudolh, 2018); Nor for that matter does one find a bad word said about coriander leaf in Evelyn's (1699) *Acetaria: A discourse of sallets*,[8] nor in the first edition of Mrs. Beeton's *Book of household management* (Beeton, 1861).[9]

However, the leaves in particular have long inspired passionate hatred. Famously, John Gerard, a Renaissance English botanist, called coriander a "very stinking herbe" with leaves of "venemous quality" (see Gerard, 1597; Leach, 2001; Ortiz, 1979). A couple of centuries later, one finds a similar sentiment being expressed in Vilmorin-Andrieux's book on vegetables, first published in English in 1885: "Some writers say the leaves are used for seasoning, but this statement seems odd, as all the green parts of the plant exhale a very strong odour of the wood-bug, whence the Greek name of the plant." (Vilmorin-Andrieux, 1976, p. 202). One of the first mentions of the soapy taste of coriander leaf comes from the famous and highly respected North American cook and author, Julia Child (Petruzzello, n.d.). If, however, as such an anecdotal observation might suggest, it should turn out that the soapy unpleasant descriptor only starts to appear in print in recent times, one has to ask why, or more specifically, the bug-like descriptor changed to a soapy one.

Here, one might contrast coriander with other spices such as chile where, once again, people's perception (or better said their appreciation) differs markedly, but where everyone would appear to perceive the same quality (namely, the trigeminal burn of capsaicin). Individuals differ in how much they have grown accustomed to (and appreciate) that particular sensory attribute (e.g., see Spence, 2018, for a review). The polarizing response of people to fresh coriander leaf would also appear to be qualitatively different from the selective anosmia to 1, 8-cineol, that affects roughly a third of the population (Pelosi and Pisanelli, 1981). This volatile compound provides the dominant olfactory note in bay leaves (Spence, 2023c), perhaps helping to explain why it is that many chefs argue that the addition of bay leaves to a dish is pointless (e.g., Desai, 2023). The bivalent response exhibited by people to coriander leaf would, in fact, seem to have more in common with the context-dependent hedonic response to a mixture of isovaleric and butyric acids, which people find to smell pleasant if primed with the word cheese, but generally rate the smell unpleasant if primed with sweaty socks instead (e.g., De Araujo, Rolls, Velazco, Margot and Cayeux, 2005; Herz and von Clef, 2001).

2. Individual differences in the perception/appreciation of coriander leaf

Cilantro is, then, one of the most polarizing and divisive of culinary ingredients. As Balslev (2010) puts it: "Why is this ancient, worldly herb so polarizing? There are theories that nature plays a role: Some people may be genetically predisposed to cilantro intolerance… For the rest of us, nurture or environment may be a factor." The majority who like the herb provide very different descriptions of its flavour from those who dislike it (Herz, 2006; McGee, 2010; Rubenstein, 2009). Those in the former category describe coriander leaf as fresh, fragrant or pleasantly citrusy, whereas those in the latter category say that it tastes like soap, mold, dirt or bugs, among other descriptors (e.g., Leach, 2001; McGee, 2010; Rubenstein, 2009). What is more, there is little evidence to suggest that people learn to like the soapy taste, or that the taste itself changes, as a result of mere exposure (see Davidson, 1999, pp.

[6] As such, the ubiquitous presence of coriander leaf in the *aji* of countries such as Colombia must also have been introduced subsequent to the arrival of the Spaniards.

[7] Intriguingly, cilantro is also one of the herbs that EDEN ISS researchers are exploring how to grow in Antarctica in preparation for a possible mission to Mars (Wilhelm, 2018).

[8] The only mention of coriander, comes on p. 49 when (Evelyn, 1996) writes that: "*Coriander* and *Rue*, which *Galen* was accuſtom'd to eat raw, and by it ſelf, with *Oyl* and *Salt*, as exceedingly grateful, as well as wholſome, and of great vertue againſt Infection. *Pliny*, I remember, reports it to be of ſuch effect for the Preſervation of *Sight*; that the *Painters* of his Time, us'd to devour a great quantity of it. And it is ſtill by the *Italians* frequently mingled among their *Sallets*."

[9] While Beeton, refers at several points to coriander seeds, the only mention of the leaf comes when she writes that: "CORIANDER.–This plant, which largely enters into the composition of curry powder with turmeric, originally comes from the East; but it has long been cultivated in England, especially in Essex, where it is reared for the use of confectioners and druggists. In private gardens, it is cultivated for the sake of its tender leaves, which are highly aromatic, and are employed in soups and salads. Its seeds are used in large quantities for the purposes of distillation." However, the mention of coriander disappears from the 1889 edition of her book. Mrs. *Beeton's Family Cookery* only refers to the seeds, noting that: "when fresh, [they] have a disagreeable smell." (Beeton, 1907, p. 687).

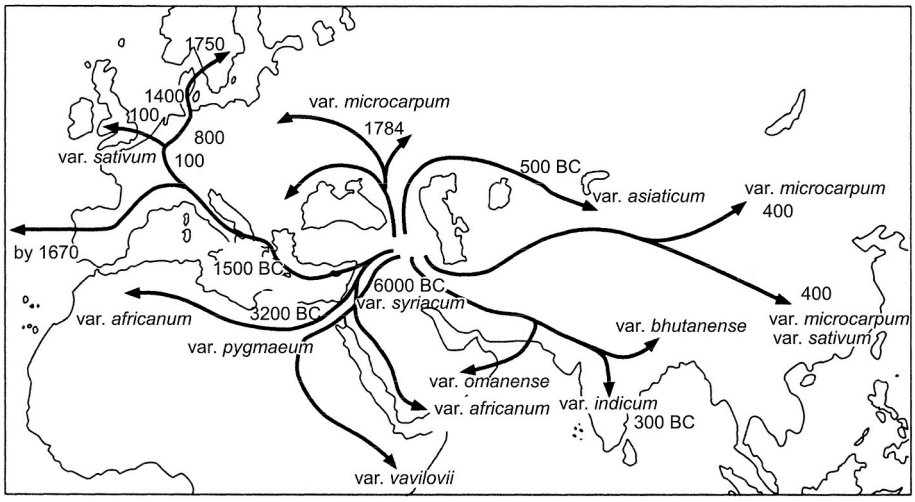

Fig. 1. Distribution and dissemination of the botanical varieties of *Coriandrum sativum* and the oldest historical documentation (years AD or BC) of coriander along these pathways according to a figure presented in Diederichsen and Hammer (2003).

216–217). The prevalence of cilantro (*Coriandrum sativum*) disliking differs markedly amongst different ethnocultural groups. According to the results of a survey of more than 1600 young adults (aged 20-29 years) living in Canada (Mauer and El-Sohemy, 2012), the prevalence of people disliking cilantro was 21% for East Asians, 17% for Caucasians, 14% for those of African descent, 7% for South Asians, 4% for Hispanics, and 3% for those from the Middle East.[10] Indeed, one intriguing suggestion is that those cultures where coriander leaf is especially popular, such as Central America and India, may have fewer people with these genes, perhaps explaining how the herb was able to become such a mainstay there. However, convincing evidence in support of this claim is yet to emerge. Here it might also be interesting to consider Japan, since this country never incorporated coriander into its cuisine. On the other hand, though, what also really needs explaining is why European countries that once often used coriander in recipes came to stop using it in their cuisine.

The relevant genetic difference determining people's response to coriander leaf has been tracked down to a mutation on an olfactory receptor gene (Eriksson et al., 2012; see also McGee, 2010).[11] In particular, Eriksson et al. conducted a genome-wide association study in 14,604 participants of European ancestry who reported whether cilantro tasted soapy, with a replication in a distinct set of 11,851 individuals who reported whether they liked the fresh herb or not. A single nucleotide polymorphism (SNP) that was significantly associated with soapy-taste detection was identified lying within a cluster of olfactory receptor genes on chromosome 11. The relevant olfactory receptor gene (*OR6A2)* turns out to have a high binding specificity for several of the aldehydes that give coriander leaf its characteristic odour. By tagging common SNPs, the heritability of coriander soapy-taste detection was estimated to be low. Eriksson et al.'s results confirm the genetic component to the perception of coriander leaf and, what is more, confirm that cilantro dislike results from genetic variants in olfactory receptors.

Given that those individuals who perceive the soapy-flavoured aldehydes in cilantro leaves have a variation in a group of olfactory-receptor genes, it would seem more appropriate to say that they find fresh coriander leaf to smell soapy, and that the food to which it is added has a soapy flavour, rather than necessarily that it has a soapy taste.[12] That said, Rohde (1940, p. 23) also claims that coriander leaf "has an intensely disagreeable taste and smell". Similarly in Rombauer and Becker's (1975, p. 581) *Joy of Cooking,* one finds the suggestion that coriander has a fetid odour and taste. Note that a similar confusion between smell, taste, and flavour has also been documented when it comes to the sensory modality/modalities responsible for the so-called metallic off-taste (see Reith and Spence, 2020; Spence et al., 2021).

3. What is coriander leaf doing in our food?

Given the above, it would seem legitimate to question why coriander leaf, an herb that a not-insignificant section of the population find to impart an unpleasant taste/aroma/flavour is so often added to food. Indeed, given how many people find coriander to have a soapy taste (see Mauer and El-Sohemy, 2012), it might seem surprising that it should be so ubiquitous, and has become more popular in the west in recent decades (Parker, 2004). In part, of course, this is presumably linked to the increasing popularity of those ethnic cuisines (such as Mexican and Thai) that currently make extensive use of the herb (Leach, 2001).

At the end of the last century, Sherman and colleagues promoted the antimicrobial hypothesis as an explanation for the use of herbs and spices in cuisine (e.g., Sherman and Billing, 1999; Sherman and Flaxman, 2001; Sherman and Hash, 2001). Their suggestion was that herbs and spices may originally have been added to food due to their anti-microbial function (especially important in the era before refrigeration). Support for this suggestion was adduced from the fact that as a country's mean annual temperature increases so does the number of herbs/spices that are found in its recipes; and also from the fact that meat-based dishes tend to have more herbs/spices than vegetable-based dishes (note that the former are more likely to spoil pre-refrigeration). Indeed, coriander (both the seed and the leafy fresh herb) have

[10] Note that such percentages are not so different from a number of the other selective anosmias to specific compounds that have been demonstrated to affect the general population (Reed and Knaapila, 2010), and/or the polarizing response of people to androstenone (otherwise known as boar taint; see Wysocki and Beauchamp, 1984).

[11] I would therefore argue that Balslev (2010) in her piece of for National Public Radio (NPR) in The States is wrong to suggest that cilantro tastes soapy to everyone, but that some people simply like the soapy taste.

[12] At the same time, however, it should be noted that some biologists have recently questioned whether it really makes sense to maintain a distinction between olfaction and gustation (smell and taste), suggesting instead that there is only a chemesthetic sense (Mollo et al., 2022), perhaps offering a radically different resolution to the issue of which senses are involved.

antimicrobial/antibacterial properties (e.g., Cantore et al., 2004; Kačániová et al., 2020; Kačániová and Ivanišová, 2019; Silva and Domingues, 2017),[13] as well as purported anti-cancer properties (Wong and Kitts, 2006). As Kačániová et al. (2020, p. 2) put it: "The extracts and essential oils of coriander have exhibited antibacterial, antioxidant, free radical, antidiabetic, anticancer and antimutagenic activities." (cf. Al-Khayri et al., 2023; Darughe et al., 2012; Duarte et al., 2016; Freires et al., 2014; Mandal and Mandal, 2015; Marangoni and Moura, 2011; Wangensteen et al., 2004).

However, the latest statistical analyses suggest that the antimicrobial hypothesis does not actually explain the range and number of herbs in our diet, once various artefacts (such as phylogenetic non-independence) have been eliminated from the statistical analysis (see Bromham et al., 2021; Zhu et al., 2013, for evidence against the anti-microbial hypothesis).[14] As such, one needs to look beyond the anti-microbial hypothesis when searching for a convincing answer to the question of what herbs/spices, such as coriander, are doing in our food. Coriander leaf provide little in the way of nutrition though, like parsley, it does contain vitamins K and C (see Bhat et al. 2014; Nadeem et al., 2013).

Given that coriander's use in cuisine cannot easily be explained either in terms of its anti-microbial properties, nor in terms of its nutritional content, it would seem natural to search for a flavour-based explanation instead.[15] Perhaps coriander leaf simply tastes 'delicious' (see Dunn and Sanchez, 2021), or it serves to complement the flavour of the foods to which it is added. However, this, in turn, raises its own problems, given that flavour perception, and more importantly flavour appreciation, cannot simply be adduced from the chemical composition of herbs and spices (e.g., Spence, 2021; Spence et al., 2017). Furthermore, any attempt to reconstruct how the herb/spice may have tasted in ancient times is itself complicated. In Ancient Rome, for example, the question becomes all the more challenging given the globalized nature of the contemporary palate (Leach, 2001), since at the time the populace would have had none of the associations with Mexican cuisine that many of us have nowadays (see Albala, 2021).[16]

4. Coriander flavour chemistry

The volatile components of the fruit oil (i.e., coriander seed) include d-linalool as the principal constituent, as well as α- and β-pinene, diterpene, p-cymene, and decyl aldehyde (decanal) which is described as having a sweet, aldehydic, waxy, orange peel, citrus, floral perfume (e.g., Burdock, 2002; Farrel, 1985; Peter, 2000; Pino and Borges, 1999; Rogers and Fischetti, 1980) (see Table 1).[17] In Kačániová et al.'s (2020) study, the major volatile compound of the coriander dried fruit essential oil tested was β-linalool (66%). Anwar et al. (2011) also found linalool to be the principal constituent (70%) of the essential oil of hydrodistilled coriander seeds, along with geranyl acetate (5%), γ-terpinene (4%), α-pinene (2%), anethol (1%), and *p*-cymene (1%).

Using Gas Chromatography/Mass-Spectrometry (GC/MS), Potter and Fagerson (1990) analyzed the composition of coriander leaf volatiles, identifying 37 compounds. Their analysis revealed 4 mg/g (wet weight of leaves) with aldehydes accounting for 83% and alcohols 17% of the compounds detected (see also Cadwallader et al., 1999; Shahwar et al., 2012) (see Table 1 for a summary of key volatile chemicals in the coriander leaf essential oil established by several groups of researchers). Constituents identified included alkenals in the C_9-C_{16} range, C_7-C_{17} alkanals, C_{10}-C_{12} primary alkenols and alkanols, and nonane. According to Peter (2000), d-linalool, C10-C14-2-alkenals are the key essential in coriander leaf oil. However, it turns out that over the last century there has been quite some disagreement concerning precisely which volatiles are present in coriander leaf (e.g., see Carlblom, 1936; MacLeod and Islam, 1976; Mookherjee et al., 1989; Potter, 1996). Note that the soapy or pungent aroma of coriander leaf is thought to be triggered by the presence of several of the aldehydes that are present in coriander leaf.

One relevant question to ask here is whether this difference might

Table 1
Several of the key coriander leaf and coriander seed (dried ripe fruit) essential oils. % range essential oil composition amalgamated from figures presented in Raal et al. (2004), Nejad Ebrahimi et al. (2010), Anwar et al. (2011), and Shahwar et al. (2012).

Chemical name (Synonym)	Chemical group	% range essential oil	Odour descriptor
Coriander seed			
Linalool	Alcohol	41-80%	Fresh, clean, mild light floral odour
α-pinene	Hydrocarbon	0-11%	Coniferous scent, herbaceous, verdent
Neryl acetate	Ester	2–14%	Sweet floral roses w. orange blossom
γ-terpinene (p-mentha-1,4-diene)	Hydrocarbon	0-14%	Refreshingly herbaceous & citrusy
Camphor	Ketone	0-6%	Smells like mothballs
p-cymene	Hydrocarbon	0-8%	Harsh chemical, woody and terpy-like with an oxidized citrus lemon note
Geraniol (trans-geraniol)	Alcohol	0-5%	Sugary &floral with citrus undertones
Geranyl acetate	Ester	0-4%	Pleasant floral or fruity rose aroma
Decanal		0-5%	Pungent, sweet, floral, orange peel
Limonene	Hydrocarbon	0-3%	Pleasant lemon-like odour
Camphene	Hydrocarbon	0-2%	Earthy scent, emitting a woodsy-like aroma that's reminiscent of fir needle
D-limonene	Hydrocarbon	0-1%	light, pleasantly dry, & refreshingly-sweet citrusy scent
Coriander leaf			
(E)-2-decenal	Aldehyde	32%	Sweet aldehydic, green odour that blends well with citrus and floral compositions
(E)-2-dodecenal	Aldehyde	8%	Citrus flavors (i.e., orange & tangerine)
(E)-2-tetradecenal	Aldehyde	7%	Waxy, slight green, soapy, & fatty
2-decen-1-ol	Alcohol	5%	Waxy fresh air citrus rose, rummy rue
(E)-2-undecenal	Aldehyde	4%	Citrus peel, esp. orange & grapefruit
Dodecanal	Aldehyde	4%	Sweet, aldehydic, orange, waxy, floral
(E)-2-tridecenal	Aldehyde	3%	Powerful odour reminiscent of cilantro
(E)-2-hexadecenal	Aldehyde	3%	na
Pentadecenal	Aldehyde	2%	Strong smell of wood/hay
α-pinene	Hydrocarbon	2%	Verdant, bracing, herbaceous, grassy

[13] What is more, the fresh leaf tends to lose its antimicrobial function when cooked, consistent with its typical addition as a garnish.

[14] While a number of more exotic spices were treated as a luxury in Europe in centuries gone by (Schivelbusch, 1993), coriander being already widespread throughout Europe in the Middle Ages was never treated in such terms, thus ruling out another potential explanation for this spice's appearance in our foods.

[15] Though note that coriander does have a number of medicinal properties (Rajeshwari and Andallu, 2011).

[16] Nor, of course, would the Ancient Romans have been familiar with the New World tomato either, come to think of it (see Rozin, 1983).

[17] Here, it is interesting to note how a number of the same volatile organic compounds (VOCs), e.g., such as α- and β-pinene, *p*-cymene, etc., are found in a range of different herbs and spices.

simply reflect the fact that different coriander cultivars (such as 'Jantar' and 'Alekseevski'), genotypes, varietals (Al-Khayri et al., 2023), or accessions might have distinct flavour profiles (Diederichsen and Hammer, 2003; Gil et al., 2002; Kiralan et al., 2009; see also Eyres et al., 2005, on the distinction between cultivated (*Coriandrum sativum*) and wild coriander, *Coriandrum tordylium*) and, if so, whether this might help to explain the differences in findings between studies.[18] Intriguingly, Nejad Ebrahimi, Hadian, and Ranjbar (2010) have reported differences in the essential oil composition of different accessions of *Coriandrum sativum* L. taken from Iran (cf. López et al., 2008). However, according to Potter and Fagerson (1990), it may also be the case that certain compounds (such as C12 aldehydes) were misidentified by, for example, MacLeod and Islam (1976) in their earlier study. At the same time, however, it is important to remember how different extraction methods may also have an influence on the composition of the essential oil (Anitescu et al., 1997).

Potter (1996) writes that: "Leaf oil was isolated from two commercial samples of cilantro (*Coriandrum sativum* L.) and from growth-chamber-grown plants at five different stages of growth. The oils were analyzed by GC/MS. They were found to be composed mainly of C10−C16 aldehydes. (E)-2-Alkenals predominated. Substantial quantitative differences were observed between the two cilantro samples and in the leaf oils isolated at different growth stages. The data indicate that cilantro oil may exhibit significant variation in composition due to ontogenic factors. The data also suggest a possible link among growth stage, oil composition, and consumer preference." (see also Nurzyńska-Wierdak, 2013; Scratz and Qadry, 1966 and Telci et al., 2006, for the influence of where the plant was grown). What is also worth noting is that the chemical profile of the fresh leaves start to change as soon as they have been picked (Mookherjee et al., 1989).

In conclusion, therefore, coriander is, then, rather unlike many other herbs and spices that are commonly used in cuisine, where many of the same compounds tend to appear in the different parts of the plant (e.g., as is the case of lovage leaf and root, Spence, 2023b, or bay leaf and the bark of the tree; Spence, 2023c). Ripe coriander seeds (actually the fruit), however, have a flavour profile that is entirely different to the fresh leaves.[19] However, one striking feature of the flavour chemistry is that no attempt is typically made by the scientists to identify the specific aldehyde(s) that are responsible for the soapy/unpleasant taste in coriander-dislikers.

5. When did people first start to describe coriander as tasting soapy?

It is hard to find historical mentions of people complaining about the soapy taste of coriander leaf prior to Julia Child (1912–2004; Petruzzello, n.d.). At the same time, however, one might also wonder why it is that people never complain that soap, or washing powder, smells of coriander? Here, this may link back to the general point that our first experiences of particular tastes/flavours/aromas play an especially important role in dominating our subsequent responses to them (McGee, 2020; Spence, submitted b). Could it be that soap as a referent only emerged in the twentieth century with the advent of industrial chemistry. As such, perhaps people before didn't have a soapy referent and hence did not find the taste off-putting. Clay tablets documenting the existence of soap go back at least 4500 years (Cassidy, 2020). In fact, the first documented use of soap is described on a cuneiform tablet written 4500 years ago that was found in Girsu. However, it turns out that the first soaps were created from ash (from the fire) mixed with animal fat (Salzberg, 1991). By contrast, what people nowadays mean by the term 'soapy' may well be associated with foaming surfactants such as sodium laureth sulfate, or sodium lauryl ether sulfate (SLES); these are detergents/surfactants that are found in many home-and-personal-care (HPC) products (soaps, shampoos, toothpastes, etc.). These compounds act as inexpensive and effective foamers.

Prior to the emergence of the soapy descriptor, coriander leaf was typically described as smelling bug-like. According to *The New Oxford Book of Food Plants*: "All parts of the fresh plant, when crushed, give off a foetid odour reminiscent of bed- or shield bugs" (Vaughan and Geissler, 1997, p. 148). Meanwhile, according to *The Oxford Companion to Food,* both the foliage and unripe seeds of coriander "have an odour which has been compared with the smell of bug-infested bed-clothes," supporting the suggested origin from Greek koris, meaning "bed bug." (Davidson, 1999, pp. 216–217). In an intriguing article published in the food journal *Gastronomica*, Helen Leach highlights how for several centuries those who found coriander leaf unpleasant would describe it as having a bug-like odour. She goes on to note that during this period, the internal heating of homes improved, meaning that far more people were likely exposed to the smell of bed bugs than ever before (see Liu and Liu, 2015, on the human odour perception of bed bugs). At the same time, however, Leach also identifies and traces the longstanding etymological confusion related to whether the term for coriander may have been derived from, or the same as, the word for bug (see several of the above quotes for evidence on this very theme).

6. Conclusions

Coriander is an increasingly popular culinary herb in the west (Parker, 2004). In part, this presumably reflects the growing popularity, and acceptance, of those ethnic cuisines such as Mexican and Thai that make extensive use of the fresh herb (Leach, 2001). The leaves and stems (the herb) and the seeds (the dried ripe fruit, which is actually a spice) are intriguing given that coriander leaf is a most divisive culinary ingredient, hedonically-speaking. While various herbs/spices contain many of the same compounds in their root, leaves, seeds, fruits, and or/flowers, coriander appears to be distinctly different in this regard. For instance, contemporary complaints about the soapy taste of coriander leaf would appear to be restricted to the fresh leaves, and are rarely, if ever, associated with the ripe seeds/fruit. In particular, the soapy or pungent aroma of coriander leaf is thought to be triggered by several of the aldehydes that are present only in coriander leaf (i.e., and not in ripe coriander fruit/seeds). It has been suggested that olfactory receptor *OR6A2* contributes to the soapy smell from cilantro (Eriksson et al., 2012). It remains an open question as to whether complaints about the soapy taste of coriander leaf have become more common (at least in print) in recent history.

It is interesting to note how the description of those who dislike the aroma of coriander leaf have, over the centuries switched from describing it as having a bug-like aroma to it having a soapy taste. It is suggested, albeit speculatively, that this change may relate to the emergence of industrial surfactants, such as SLS in our washing products, and hence the emergence of different referents, for what, exactly 'soapy' tastes like (along, perhaps, with the reduced incidence of bed bugs, see Leach, 2001, on the latter point).

[18] According to one online source: There are two types of coriander. One species, *Coriandrum sativum vulgare*, comes mainly from Morocco and India and has large seeds (>3 mm) and leaves with a mild aroma. The other, *Coriandrum sativum microcarpum*, originates mainly from Russia and Central and Southern Europe. This variety has smaller seeds (<3 mm) that are strongly flavoured and resemble peppercorns with grooves in them. However, the leaves of this variety are not used (see also Coşkuner and Karababa, 2007).

[19] However, the green seeds may have a more similar profile to the leaves (Rohde, 1940, p. 23). Relevant here, changes in the composition of the essential oil of coriander fruits has been reported during three stages of maturity (Carruba & la Tore, 2002; Msaada et al., 2007). In particular, Msaada et al. reported that geranyl acetate (46%) and linalool (11%) were the main compounds of the essential oil of immature fruits, while essential oils of mature fruits consisted mainly of linalool (88%) and *cis*-dihydrocarvone (2%).

Implications for gastronomy

Chefs need to consider carefully whether or not to incorporate fresh coriander leaf into the dishes they prepare given that many consumers (estimated at between 3 and 21% depending on the ethno-cultural group) complain that the herb tastes soapy, rather than citrusy. Intriguingly, the incidence of this hedonically-negative response is genetically determined. What is more, unlike many other initially challenging/aversive tastes that people can sometimes acquire a liking for (e.g., as a result of repeated exposure), there is little evidence to suggest that those who initially find coriander leaf to taste soapy will ever acquire a liking (and nor do its perceptual qualities appear to change). Coriander seeds do not evoke the same polarizing response in people, though tend to serve a much different culinary/gastronomic purpose. What is more, the soapy response would appear to be more common nowadays. It is speculatively suggested that the use of descriptor soapy may be a relatively recent association, one that is perhaps formed by those consumers (with the relevant OR gene) who have been exposed to surfactants in the laundry/home-and-personal care (HPC) product categories.

Declaration of competing interest

The author confirms that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome. I confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. I further confirm that the order of authors listed in the manuscript has been approved by all of the authors. I understand that the Corresponding Author is the sole contact for the Editorial process (including Editorial Manager and direct communications with the office).

Data availability

No data was used for the research described in the article.

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