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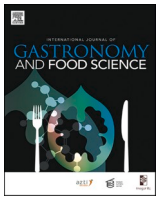

# Cinnamon: The historic spice, medicinal uses, and flavour chemistry

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ABSTRACT

Cinnamon has long been a popular culinary (and medicinal) spice. Nowadays, in the West, it is predominantly found in sweet foods (e.g., desserts, traditional, and/or seasonal baked foods, such as cinnamon rolls, plum pudding, mince pies, and mulled wine), as well as in many cola beverages, perhaps explaining why it is widely considered to be a 'sweet' spice, despite having a slightly bitter taste. Historically, it was commonly used in savoury dishes as well. In the Middle East and India, the spice retains its association with savoury cuisine (e.g., in dishes such as curry and pilau, as well as meat tagines in Morocco). The four major commercially-viable species of cinnamon (*Cinnamomum verum, C. cassia, C. burmannii*, and *C. loureiroi*) have distinct flavour profiles, meaning that care should be taken when using this spice in the kitchen, especially given the naming confusion that exists between cinnamon and cassia. Although essential oil is extracted from many parts of the cinnamon tree, only the bark from the lateral shoots tends to be used in cuisine nowadays. Cinnamon is used as the quills (whole or broken parts), as the dried ground powder or, in the food industry, as the essential oil (i.e., as a flavouring agent). The scent of cinnamon also appears in various perfumes/fragrances as well as being a popular element in festive potpourri. There is currently growing interest in cinnamon's potential neutraceutical, neuroprotective, and prebiotic properties.

## 1. Introduction

Cinnamon is one of the oldest known spices (Wijesekera, 1978), and has been used in cooking and traditional herbal medicine for millennia (Thomas & Duethi, 2001). In fact, cinnamon was one of the first spices to reach the Mediterranean. According to Rehman et al. (2023), it is currently also one of the world's most commonly used spices (see also Rao & Gan, 2014). Native to Sri Lanka and Southern India (specifically the Malabar Coast; Drieberg, 1936; Radhakrishnan et al., 1992),[1] the cinnamon tree typically grows to a height of 7–10 m (Thomas & Duethi, 2001; though there are reports of trees as tall as 17 m). Cinnamon is the name given to the bark of the thin lateral shoots taken from the foot of several tropical evergreen trees of the genus *Cinnamomum*. Trees tend to be harvested every two to three years (Moragoda, 2021; cf. Atal & Kapur, 1982). The outer bark is removed (scraped off) first and the inner bark is then cut into strips that curl on drying, giving the resulting quills their distinctive shape (Thomas & Duethi, 2001).

Cinnamon is used in cooking as either entire quills (or broken pieces thereof), or as the dried ground spice. The essential oil extracted from the dried inner bark of the cinnamon plant has long been used as a flavouring agent in foods, beverages (e.g., cola beverages such as Coca-Cola), candies, and chewing gums (where it can apparently help to tackle bad breath; Jakhetia et al., 2010; see also Arangannal et al., 2019), etc. As a spice, mention of cinnamon dates back to Chinese writings from 4000 BC. The botanical name *Cinnamomum* derives from the Hebraic and Arabic term *amomon*, meaning fragrant spice plant. Cinnamon is mentioned repeatedly in both the Old Testament (in the book of Exodus and The Song of Songs, see Northcote, 1903) and in Sanskrit writings. Cinnamon was used medicinally as well as a flavouring agent, and in embalming in ancient Egypt (Baumann, 1960), its use attributable to the spice's antibacterial properties.

According to Thomas and Duethi (2001, p. 143), the spice was highly prized by the Greeks and Romans, though it has also been suggested that in ancient Rome, cinnamon may primarily have been considered as a medicine.[2] The latter suggestion perhaps helps to explain why it is that there are so few (i.e., only two) mentions of the spice in the recipes found in Apicius (1936). Cassia leaf was known in Rome as *malabathrum*. Tannahill (1973, p. 87) writes: "Strangely, Apicius mentions

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[1] In fact, the Portuguese invaded Sri Lanka immediately after reaching India in 1536 mainly for the cinnamon (Thomas & Duethi, 2001).

[2] It has been recorded that, in the year AD 66 the Roman Emperor Nero burned a years' supply of Rome's cinnamon (at the time a luxury good) at the funeral rites of his Queen Poppea as a measure of his grief (Rosengarten, 1969; Wijesekera, 1978).

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*malabathrum* only three times, and cinnamon bark not at all, but there is scarcely a single recipe that does not make use of pepper." At the same time, however, it is also somewhat surprising to find that cinnamon has not always been a culinary ingredient, given Sherman and Billing's (1999, p. 460) suggestion that it is one of the few spices that has a sensory profile that most people find intrinsically appealing.[3] That said, according to Reed and Knaapila (2010), there may also be a heritable component to the pleasantness of the smell of cinnamon.

The mixing of cinnamon and ginger was a favourite of French medieval cooking, and thus is found in most surviving recipes from that time. By contrast, cinnamon appears in less than 10% of English recipes during the same period (Laurioux, 2021). According to Bruno Laurioux, it is not until the 9th or 10th centuries that the use of cinnamon really starts to develop in European cookery (Laurioux, 1983, 1985). At the end of the 10th century, the European spice trade dealt essentially with pepper, cinnamon, ginger, galangal and cloves. Spices started to be widely used in cookery for feasting meals in the 13th and 14th centuries. The *major spices* (such as pepper, ginger and cinnamon) were distinguished from the *minor spices* of lesser use (depending on the time, the country or the recipe book under consideration). In the 14th century, the King of France, Jean le Bon, bought more cinnamon flowers than cinnamon (which happened to be five times less expensive).[4] Cinnamon flowers, probably the dried flower buds of the Indonesian cinnamon or cassia (*cinnamomum cassia*), were also used in medieval gastronomy. Laurioux has suggested that their flavour was 'choicer' than that of cinnamon, though they are difficult to find in Europe nowadays.

In the Middle Ages, cinnamon was both an important culinary and medicinal spice (Freedman, 2015). As Freedman (2012, p. 326) puts it: "Spices were ubiquitous in medieval gastronomy and also in medieval pharmacology." Freedman (2012, p. 324) goes so far as to describe the European demand for spices in the late Middle Ages (A.D.1200-1500) as 'insatiable'. The 14th century Medieval cookbook, *Le Viandier de Taillevent* (Scully, 1988), included one of the favourite recipes of the period for 'cameline sauce' in which cinnamon was the essential ingredient (Tannahill, 1973, p. 183). During the Middle Ages in Europe cinnamon was also used to make hypocras, a wine sweetened with honey, and spiced with cinnamon and ginger (Chartier 2012, p. 171). It should be noted that the addition of spices such as cinnamon and cloves to wine (Schivelbush, 1992, p. 5) would have had an antiseptic effect on the intestines (see Tannahill, 1973, p. 167). At the same time, Freedman (2012, p. 329) notes how: "According to a twelfth-century manual …. Cinnamon soothes digestive problems and when heated in wine heals decaying gums." According to Freedman (2012, p. 325): "Spices conferred a kind of social prestige and status was closely joined to the ability to provide a fragrant environment including, but not limited to, food." Schivelbusch (1992, p. 5) notes that when the king of Scotland visited his fellow monarch Richard 1I of England in 1194, he received amongst other gifts four pounds of cinnamon and two pounds of pepper a day.

Cinnamon was an important spice in 15th century England (see Woolgar, 2018). Tannahill (1973, p. 182) comments on the 'fearsome' use of spices such as ginger, pepper, saffron, cinnamon, cloves, and mace by medieval cooks. Indeed, the spice's popularity in English cooking had grown markedly by the 17th Century, with 'Cinamon' (sp.) being mentioned 284 times in the English professional cook Robert May's (1660) *The accomplisht cook or, The art & mystery of cookery*; For comparison, this is exactly as many mentions as one finds for ginger. By the 19th century, popular English-language cookbooks, such as that of Soyer (1849), mention cinnamon 26 times. By contrast, the spice is mentioned only 10 times in Francatelli's (1861) cookbook, and 38 times in Beeton (1861). Hazlitt's (1902) cookbook only contains a couple of mentions of the spice. So while cinnamon featured regularly in early-modern cookbooks such as that of May (1660), its use declines and is relegated to desserts (thus inking it to sugar/sweetness once again). Chartier (2012, p. 325) writes of desserts as "a kind of home in exile for spices such as cinnamon, cardamom, or nutmeg". This perhaps hints at how in the modern period is characterized by a much less piquant cuisine than what preceded it. Similarly, Freedman (2012) notes how the development of what came to be known as classic French cuisine in the 17th and 18th centuries was defined in part by a rejection of spices such as cinnamon. Here it is worth noting how several excellent volumes have been written charting the history of spices and the spice trade, and providing explanations for the rise and fall in popularity of various spices (Freedman, 2008, 2020; Keay, 2005; Schivelbusch, 1992; Turner, 2005).

One question here concerns how the culinary use of cinnamon relates to that of other popular spices of the epoch, such as, for example, pepper (Spence, submitted-a), or ginger (Spence, 2023b)? According to Freedman (2012, p. 328): "Pepper, saffron, cinnamon, and ginger and sugar were the most common spices used in medieval cooking". Around 1500, pepper, ginger, cinnamon, and sugar were the least expensive of the spices (Freedman, 2012). By contrast, cloves and nutmeg were perhaps three times the price of pepper, while saffron 10 to 15 times more expensive (see also Van der Wee, 1963).

The pairing of cinnamon and chocolate in the form of a beverage was also popular in mid-16th century Spain, when it first arrived there (Coucquyt et al., 2020; Tannahill, 1973, p. 242). Cola beverages, many of which include cinnamon,[5] started to become popular in North America at the end of the 19th Century, thus presumably further helping to popularize/ubiquitize the flavour of this spice. Coca-Cola was first produced in the 1880s in Atlanta, and the growing popularity of this beverage over the ensuing decades around the world will presumably have changed people's culinary associations with this spice somewhat. Although for Segnit (2010), the taste/aroma of cassia is "so redolent of cola you can hear it burp".

## 2. Flavour profile of the major varieties of cinnamon

There are four main economically important species of cinnamon in the genus *Cinnamomum* (a member of *Lauraceae*, like bay; see Spence, 2023a). *Cinnamomum verum*, translated as "true cinnamon"; It is also called Sri Lankan, or Ceylon, cinnamon.[6] Historically, Sri Lanka was the only regular supplier of true cinnamon bark and leaf oils (the latter high in eugenol; cf. Dongmo et al., 2007; Mallavarapu et al., 1995; Thomas & Duethi, 2001).[7] *C. verum*'s older botanical name, *Cinnamomum zeylanicum* is derived from Sri Lanka's former name, Ceylon. The other three major species of cinnamon are *Cinnamomum cassia* (*C. aromaticum*, also called Chinese cinnamon, or 'bastard cinnamon' in French), *Cinnamomum burmannii* (also called Korintje, Java, or Indonesian cinnamon), and *Cinnamomum loureiroi* (known as Vietnamese or Saigon cinnamon). Cassia was used in China long before the introduction of true cinnamon but is now widely considered an inferior substitute (Thomas & Duethi, 2001, p. 143). It is thought that *C. cassia* may have originated in

[3] These researchers also place basil and thyme in the same category.

[4] In contrast to herbs (which would typically have been foraged locally; La Cerva (2021), the consumption of spices has long been heavily influenced by fashion, price and social status (e.g., Schivelbusch, 1992, 2005; Spence, 2021).

[5] A key component of the flavour profile of many cola beverages, including Coca-Cola, comes from the combination of vanilla and cinnamon (e.g., Lorjaroenphon & Cadwallader, 2014), with trace amounts of essential oil, as well as spices such as nutmeg. Segnit (2010) identifies cola beverages with the cheaper cassia.

[6] As one early commentator noted: "As a fruit is better in one country than in another, so the cinnamon of Ceylon is better than all others – Garcia da Orta (1563)" (as cited in Moragoda, 2021, p. 250). Moragoda herself describes "The delicately nuanced, slightly citrusy, spicy, but sweet *Cinnamomum zeylanicum* of Sri Lanka".

[7] Though see Angmor et al. (1972) for a gas chromatography analysis of the flavour chemistry of the *Cinnamon verum* grown in Ghana.

South-East China (Thomas & Duethi, 2001). Crucially, cassia tends to have a darker and thicker bark than true cinnamon (see Fig. 1).

In addition to these four common and economically valuable species of cinnamon (Wijesekera, 1978), there are also a number of other non-commercial or lesser-known cinnamons that are used in local trade as a spice or an ingredient in medicinal preparations,[8] such as, for instance, indigenous Cinnamon (*Cinnamomum osmophloeum*; Yeh et al., 2013). However, these rarer varieties have seemingly yet to pique the interest of the foodies (i.e., in quite the same way, say, that the market for exotic peppers and salts have; Spence, submitted-a). In 2017, just four countries accounted for 99% of the total world production of cinnamon, namely Indonesia, China, Vietnam, and Sri Lanka (UN Food and Agriculture Organization, 2018). According to Moragoda (2021): "As of 2019, Sri Lanka accounted for 90% of the world's supply of *C. zeylanicum.* However when taking all cinnamon species into consideration, the island's cinnamon ranks fourth in worldwide production after *C. burmanii, C. cassia*, and *C. loureiroi,* grown respectively in Indonesia, China and Vietnam. These three species are commonly referred to as cassia, and can be two to six times cheaper than Sri Lankan cinnamon."

*C. verum*'s flavor is often considered to be the most delicate and complex of the major species of cinnamon. It tends to be sweeter and not as strong as cassia. North Americans are, however, typically more accustomed to the strong, spicy-sweet aroma and flavour of *C. cassia* and *C. loureiroi*. *C. loureiroi* has a stronger flavour and routinely has high cinnamaldehyde and volatile oil content.[9] Meanwhile, *C. burmannii*, although high in cinnamaldehyde, has a smoother taste with less bite than *C. cassia* and *C. loureiroi* (see Table 1). Those readers interested in visualizing the chemical structure of the key compounds commonly found in cinnamon are directed to Rao and Gan (2014). Cassia cinnamon tends to be used more often in the food industry given the high cost of true cinnamon. So, for example, cassia oil is purportedly used in Coca-Cola (Thomas & Duethi, 2001, although note that the exact formula/recipe remains a closely-guarded secret). Research by Blank and Mattes (1990) suggests that the majority of North Americans associate the smell of ground cinnamon with sweetness,[10] hence leading to these authors' early suggestion that its increased use in cuisine might present an effective opportunity to help reduce the sugar content of foods (cf. Fial, 1978; Peters et al., 2018). However, just as for many other studies, the authors fail to specify which kind of cinnamon they used in their study. Nevertheless, according to Kumar et al. (1997), when combined with sweet food, the sweet sensation is enhanced because of the synergetic effect between the sweet taste of sugar and the sweet aroma of cinnamon.[11] Thomas and Duethi (2001, p. 144) suggest that the sweet taste of cinnamon is attributable to the presence of cinnamaldehyde. However, it should be stressed that cinnamon actually has a slightly bitter taste (Blank & Mattes, 1990).


**Fig. 1.** Cinnamon bark (a) *C. verum* J. Presl and (b) *C. cassia* L. Note that the cassia is darker in appearance and has a thicker bark than true cinnamon. [Reprinted from Newerli-Guz and Smiechowska (2022); CC BY 4.0].

**Table 1**
The four main economically important species of cinnamon in the genus Cinnamomum.

| Species of cinnamon | Sensory profile | Flavour chemistry |
|---|---|---|
| *Cinnamomum verum J. S.* Presl. (syn. C. zeylanicum Nees); Sri Lankan (or Ceylon) cinnamon | Most delicate and complex flavour (used in English/ Mexican sweets) | Sweet and slightly citrusy aroma (attributable to the high cinnemaldehyde content, for sweetness; linalool, limonene, and geranial responsible for the citrusy note) |
| *C. cassia Blume* (C. aromaticum Ness) Chinese cinnamon | Strong spicy-sweet aroma and flavour (popular in N. American sweets) | Cinnamaldehyde, cinnamic acid, cinnamyl alcohol, and coumarin |
| *C. loureiroi* Vietnamese (or Saigon) cinnamon | Strong spicy-sweet aroma and flavour (popular in North American sweets) | High cinnamaldehyde and volatile oil content |
| C. burmanini Blume; Korintje, Java, Sumatra, or Indonesian cinnamon | Smoother taste and less bite than C. cassia or C. loureiroi | High in cinnamaldehyde |

## 3. Flavour chemistry of cinnamon

Analysis and evaluation of the composition of the essential oil of cinnamon barks using a range of techniques (Cheng and Yu, 1993; Li et al., 2013) reveals a volatile essential oil content of up to 4%, as compared to 1–2% for cassia bark (Thomas & Duethi, 2001). The latter researchers also report that freshly ground cinnamon bark of good quality contains 0.9–2.3% essential oil depending on the variety. The bark oil primarily consists of cinnamaldehyde (80–90%), the key active ingredients of cassia bark 67–83% (Shen et al., 2002), together with much smaller amounts of eugenol, eugenol acetate, cinnamyl acetate, cinnamyl alcohol, methyl eugenol, benzaldehyde, benzyl benzoate (see also Kaul et al., 2002; Nath et al., 1996), linalool, caryophyllene, safrole, pinene, phyllandrene, cymene, and cineol (Thomas & Duethi, 2001, p. 144; see also Senanayaka et al., 1978; Senanayake & Wijesekera, 2004; Variyar & Bandyopadhyay, 1989). When He et al. (2005) assessed a wide number of samples of cassia bark, four characteristic components were identified, namely cinnamaldehyde (which tends to dominate the aroma; see Chartier, 2012, p. 169), cinnamic acid, cinnamyl alcohol, and coumarin (delivering a vanillin aroma; see Chartier, 2012).

Several additional compounds present in the bark of *Cinnamomum cassia* have been identified subsequently (He et al., 2016; Hohara et al.,

[8] Note here that according to Thomas and Duethi (2001, p. 143), the genus *Cinnamomum* has 250 species and many of them are aromatic and flavouring. Around 20 of the species are native to India (Jayaprakasha & Rao, 2011).

[9] As is the case for other herbs and spices, the characteristic flavour and aroma of cinnamon comes from its aromatic essential oils. The strength of the flavour of cinnamon is thus dependent upon the essential oil content: The higher the level, the stronger the flavour.

[10] Though, as Blank and Mattes (1990) note, cinnamon powder is actually rated as tasting bitter by itself.

[11] According to a growing body of food science research, such effects might be best described in terms of odour-induced taste enhancement (OITE; Spence, 2022). According to the literature, it is unclear whether the taste properties (like sweetness) that are associated with various odorants are intrinsically sweet, or only become so after regular co-exposure with a sweet taste.

1982). For instance, it has been suggested that *E*-cinnamaldehyde and *o*-methoxy cinnamaldehyde are the most potent bioactive compounds in extracts of cinnamon (*C. zeylanicum* and *C. cassia*) as far as the spice's anti-inflammatory activity is concerned (Gunawardena et al., 2015). There has also been interest amongst researchers in the bioactive potential of the A-type proanthocyanidins that have been found in *Cinnamomum cassia* (Killday et al., 2011). Just as is the case for other herbs and spices, the exact composition of the volatile oil of cinnamon is likely to depend on the particular extraction method that is used, as well as growing conditions etc. Singh et al. (2007) noted that cinnamon absorbs oxygen as it ages, and this gives rise to a darker colour as well as the development of resinous compounds.

Essential oil is also extracted commercially from various other parts of the cinnamon tree, including the leaves (which tend to be high in eugenol; cf. Dongmo et al., 2007; Yeh et al., 2013), flowers, petioles (i.e., the leaf stalk; Rao et al., 2007), twigs, and root bark (which tends to be rich in camphor; Angmor et al., 1972). The essential oil yields of the different plant parts tend to be lower than for the inner bark (see Kaul et al., 2002): tender twigs, pedicels of buds and flowers, buds and flowers, pedicels of fruits, and fruits all have essential oil content of less than 0.5%. However, these essential oils are mostly used in perfumery (e.g., Chakraborty et al., 2015; Joy et al., 1998; Kaul et al., 1996, 2002). Some examples of classic fragrances/perfumes with a strong cinnamon note include Spicebomb by Viktor&Rolf, Pure XS by Paco Rabanne, and Cinnabomb by Be Layered (see https://www.fragrantica.com/notes/Cinnamon-65.html for a more complete current list).

The tender twig oil is also richer in α-phellandrene (3%), limonene (2%), and (E)-cinnamaldehyde (4%) than the bark. Meanwhile, the volatile oils from pedicels are richer in (E)-cinnamyl acetate (58–65%), *β*-caryophyllene (10–11%), and neryl acetate (1–2%). Higher amounts of (Z)-cinnamyl acetate (6%), α-humulene (2%), δ-cadinene (2%), humulene epoxide I (5%), *α*-muurolol (5%) and *α*-cadinol (2%) were obtained in the oil of buds and flowers. The fruit oil contained greater concentrations of α-pinene (4%), *β*-pinene (2%), and linalool (27%). However, all of the oils contained some amount of linalool (4–27%), (E)-cinnamyl acetate (22–65%) and *β*-caryophyllene (7–11%) as their major compounds (all of the percentages reported in this paragraph come from Kaul et al., 2002). The fruit oils of cinnamon from different locations have been found to contain linalool, *α*-pinene, *β*-pinene, (*E*)-cinnamyl acetate, *β*-caryophyllene, *γ*-cadinene, *δ*-cadinene, *α*-muurolol, and cubenol (Jayaprakasha et al., 1997; Mallavarapu & Ramesh, 2000; Syamasundar et al., 2000). As noted by Coucquyt et al. (2020), cinnamon tends to be more citrusy than cassia, given the greater concentration of the orange-like linalool, as well as limonene and geranial.

Cinnamon, like bay, is part of the *Lauraceae* family (Spence, 2023a). However, it is the methyl cinnamate that is present in various cultivars of basil, especially in so-called cinnamon basil (see Spence, submitted-b, for a review), that provides a salient cinnamon note (e.g., see McGee, 2004; Segnit, 2010).

## 4. Medicinal properties of cinnamon

Irrespective of the species, cinnamon and its extract have long been associated with a variety of health benefits. In traditional medicine, for example, cinnamon bark is reportedly used to treat a wide range of conditions, including digestive disorders, diabetes, and respiratory tract infections (Ranasinghe et al., 2013; Rao & Gan, 2014). Cinnamon is thought to ease digestion, while also acting as a stimulant and astringent. Over recent decades, the published research has demonstrated cinnamon's potential antioxidant (Mancini-Filho et al., 1998; Mathew & Abraham, 2006; Murcia et al., 2004),[12] anti-bacterial (Lee & Ahn, 1998), and antimicrobial activity (e.g., Ooi et al., 2006; Shan et al., 2007). The dietary consumption of cinnamon can also play a role in glucose and lipid control (Anderson, 2008; Anderson et al., 2004; Baker et al., 2008; Khan et al., 1990, 2003). Taken together, then, the available *in vitro* and animal *in vivo* evidence supports claims that the consumption of cinnamon has anti-inflammatory, anti-fungal (Bullerman, 1974; Bullerman et al., 1977; Sinha et al., 2008), antimicrobial (Velluti et al., 2003), antiproliferative (Alizadeh Behbahani et al., 2020), antioxidant, antitumor, cardiovascular, cholesterol-lowering, and immunomodulatory effects (e.g., Gruenwald et al., 2010). Cinnemaldehyde, the principal component of cinnamon essential oil, has also been shown to exert a bronchodilatory effect (Rehman et al., 2023). Indeed, in some Arab countries, cinnamon is used together with other ingredients to relieve bronchospasm and treat airways-related disorders.

It is, though, important to note that feeding studies and clinical trials involving natural products and their extracts sometimes give rise to different, or inconsistent, results. Crucially, studies of cinnamon are no exception in this regard. For instance, while Khan et al. (2003) reported that cinnamon improved glucose and lipid levels in those individuals with Type-2 diabetes, Vanschoonbeek et al. (2006) did not arrive at the same conclusion. Although both research groups reported using *Cinnamomum cassia* in their studies, neither group attempted to identify the cinnamon samples by source,[13] or to characterize the chemical composition of the cinnamon samples before conducting their studies. Thus, it is impossible to tell how different their respective samples were chemically, and also whether or not the cinnamon used was, in fact, *Cinnamomum cassia*.

In a small crossover trial involving 14 healthy participants, Hlebowicz et al. (2007) reported that adding 6 g of cinnamon (once again, they do not identify the type) to 300 g of rice pudding reduced postprandial blood glucose levels while, at the same time, delaying gastric emptying (all without affecting satiety). Interestingly, cinnamon had the most pronounced insulin-like biological activity of any of the culinary and medical plant aqueous extracts that were tested *in vitro* by Broadhurst et al. (2000).[14] Meta-analyses provide further empirical support for cinnamon's role in helping to manage Type-2 diabetes (Allen et al., 2013). Finally here, it has been suggested that cinnamon may also help relieve arthritis/joint pain (Thomas & Duethi, 2001). However, it may be difficult to distinguish whether any such effects should be attributed to the sweet aroma of the spice (cf. Prescott & Wilkie, 2007), and/or to some analgesic component in the spice itself.

### 4.1. Adverse reactions to cinnamon, possibly linked to its adulteration

There have also been rare reports of people developing an allergy to cinnamon, in the context of cinnamon-flavoured toothpastes and chewing gums (e.g. Calapai et al., 2014; Thomas & Duethi, 2001). Another slight concern here is related to the occasional clinical reports of cinnamon-induced contact stomatitis that have been documented (Endo & Rees, 2006). Somewhat more worryingly, though (given its possibly negative health impact if consumed in sufficient quantities), coumarin has also been detected in samples of cinnamon in a number of retail markets (Blahová & Svobodová, 2012; Lungarini et al., 2008; Woehrlin et al., 2010). However, while *C. cassia* contains as much as 1% coumarin (benzo-*α*-pyrone), *C. verum* typically contains only a trace amount.

Adulteration has long been a problem in the world of spices, given their expense at Mny points in history. However, in contrast to saffron (Spence, 2023c) or black pepper (Spence, submitted-a), that have

[12] See Lin et al. (2003) on the antioxidant activity of *Cinnamomum cassia* Presl, and Mathew and Abraham (2006) for the antioxidant activity of *Cinnamomum verum*.

[13] This despite the fact that techniques exist to clearly differentiate between the four major different types of cinnamon (see Chen et al., 2014; He et al., 2005).

[14] These researchers evaluated allspice, cinnamon, bay leaf, cloves, nutmeg, witch hazel, oregano, along with black and green tea.

typically been adulterated with all manner of other materials (both edible and inedible), in the case of cinnamon the issue would appear to be the use of the much cheaper cassia in place of the more expensive true cinnamon. However, this is potentially especially problematic given that the hepatotoxic and carcinogenic compound coumarin, is found in cassia but not in true cinnamon (Abraham et al., 2010). This is why the EFSA advocates against the regular long-term use of cassia (see European Food Safety Association, 2008).

## 5. Contemporary culinary uses of cinnamon

A large proportion of the total usage of cinnamon is for culinary purposes. It can be bought as whole sticks (or quills), and used to flavour rice and meat dishes. However, some recipes specifically call for ground cinnamon. Cinnamon, being more delicate than cassia, is mostly used in desserts. According to Thomas and Duethi (2001), hot apple cider just does not taste the same without a cinnamon stick. Cinnamon and apple are also commonly combined in desserts such as American apple pie through to the classic French *tarte aux pommes* (Coucquyt et al., 2020). Cinnamon appears in seasonal baked goods, and breakfast cereals, include muesli (Blank & Mattes, 1990). It is used to spice mulled wines, creams and syrups in Europe. Cinnamon is also commonly used in compotes and jams (Chartier, 2012, p. 171). According to Blank and Mattes (1990), cinnamon is also added to coffee in North America. In Mexico, the largest importer of Sri Lankan cinnamon, it is drunk with coffee and chocolate or brewed as a tea (Chartier, 2012, p. 171). In Mexico, mole, combining chocolate and cinnamon, is a hugely important sauce (see Youssef & Spence, 2021). English and Mexican sweets are typically flavoured using *C. verum*. Cinnamon leaves, which have a stronger clove-like (e.g., eugenol) scent are sometimes used in herbal teas or as a substitute for bay leaves in Jamaican stews, curries and pilafs, according to Coucquyt et al. (2020).

Cinnamon sticks are used in beverages, boiled beef, pickles, as well as being a popular ingredient in condiments such as chutneys and ketchup. Cinnamon undoubtedly does more than add flavour to cakes, cookies, ice creams and other high fat desserts. (Thomas & Duethi, 2001, p. 148). Although in Western cuisine, it is mainly used in sweet dishes, its primary use is within savoury dishes in the East. In India, for example, cinnamon is used in curries and *pilaus,* as well as being an important ingredient in *garam masala* (Thomas & Duethi, 2001). In China, ground cassia along with star arise, cloves, fennel seeds, and Sichuan peppercorns appear in the popular 5-spice powder (Coucquyt et al., 2020). In Morocco, pigeon pie (*B'stilla*) is seasoned with cinnamon, and is typically served at weddings and other festive occasions.[15] One might also consider Cinnamon's use in Moroccan chicken tagine with apricots and almonds (Coucquyt et al., 2020). It is common in many Middle Eastern, North African dishes in flavouring lamb tagines or stuffed aubergines (Segnit, 2010).

### 5.1. Festive/seasonal use of, and appreciation for, cinnamon in the west

The festive use of cinnamon in the West is perhaps linked to the fact that it is considered a 'warming' spice (Chartier, 2012), like ginger (though see Parrish, 2021). Segnit (2010) talks of walnuts having a kinship with sticky-sweet autumnal flavours like cinnamon. There is also an association with Christmas and mulled wine in the West. Indeed, it is noticeable how cinnamon so often appears in recipes for Christmas favourites such as English plum pudding (where it is the dominant spice by weight; e.g., see https://www.epicurious.com/recipes/food/views/superb-english-plum-pudding-20010), as well as in recipes for the mincemeat that would have been used to fill mince pies (where once again it is the dominant spice in many recipes; e.g., https://www.deliaonline.com/recipes/books/delias-happy-christmas/home-made-christmas-mincemeat). Amongst the sensory associations that many North Americans have with Thanksgiving is the prominent presence of cinnamon/spiced pumpkin olfactory notes linked to pumpkin pie (e.g., Bry, 2015; Danziger, 2017). Cinnamon is also a popular ingredient in Christmas potpourri recipes (Northcote, 1903).

Seo et al. (2009) conducted a study showing that Germans rate the smell of cinnamon as more familiar and pleasant during the Christmas season than during the summertime. In an initial test of 100 adults, the smell of orange, cinnamon, and cloves, were all associated with Christmas (especially cinnamon), whereas the aroma of rose and pineapple were all associated with the summertime instead. Twelve odours were then presented to different groups of German participants in either the summertime (August, N = 41 participants) or during the Christmas season (N = 51 participants). The participants rated the scent of cinnamon, orange, liquorice, clove, and rose as significantly more familiar at Christmas time, whereas those tested in the summer rated the odour of banana and coffee as more familiar. In terms of the participants' hedonic ratings, the scent of cinnamon, pineapple, and rose were all rated as significantly more pleasant at Christmas than during the summertime.

All of this raises the question of when cinnamon first became associated with Christmas. According to Borgan (2022), while cinnamon, cloves, ginger and figs were already being consumed in Norway during the Middle Ages, these exotic goods probably only became a Christmas tradition at the end of the 19th century.

### 5.2. Regional preferences

There are regional differences both in whether cinnamon is primarily associated with sweet (West) or with savoury dishes (East), as well as the preference for the kind of cinnamon that is used to flavour foods in different markets. For instance, the stronger flavour of cassia is apparently preferred in chocolate manufactured in Germany and Italy and is used less frequently in the kitchen. At the same time, however, it is also important to note how cinnamon has largely been replaced by vanilla in contemporary chocolate recipes (see Segnit, 2010, p. 217). In North America the red hot cinnamon candies have long been a popular confection (Spence et al., 2019). In fact, it has been suggested that the ubiquity of these candies may be responsible for North Americans associating the smell of cinnamon with a red colour whereas in Europe the scent is more strongly associated with the dusty brown colour of the spice itself (Demattè et al., 2006).

Cinnamon is, of course, also used in bakery products, sauces, confectionery and liqueurs. Dried unripe fruit, or Chinese cassia buds, have the odour and taste of the bark, and are rather like small cloves in appearance. They are used in confectionery and in the making of potpourri (Tannahill, 1973). Cinnamon buds are as good for flavouring and spicing as the bark itself. According to Farrell (1985), the major importer of cinnamon is Mexico followed by West Germany, the USA, and Great Britain. Other significant importers include Saudi Arabia, Taiwan, Singapore, Hong Kong and France.

### 5.3. Cinnamon as a flavouring vs. colouring ingredient

Cinnamon's primarily role in food and drink is as a flavouring agent. At the same time, however, it is also used by commercial bakers as a colouring agent. Indeed, when commercial bakers wish to give their baked products a noticeable cinnamon colouring with only a mild cinnamon flavour, a red-coloured cinnamon (cassia) with a moderate oil content is likely to be desirable, or perhaps a cinnamon blend (in which various grades are mixed to give a desired sensory outcome). In fact, the blending of different cinnamon varieties or grades to create tailor-made cinnamon spice mixes for various categories of baked foods has now become standard practice amongst commercial bakers (see Thomas & Duethi, 2001, p. 149). Aromatic baked cinnamon rolls are undoubtedly hugely popular amongst many. In fact, 2020 statistics show that

[15] https://www.saveur.com/article/recipes/moroccan-pigeon-pie-bstilla/.

breakfast pastry sales in the US were dominated by cinnamon rolls (67.5 million consumers), more than twice the figure for any other breakfast pastry (e.g., honey buns or Danish pastry; https://www.statista.com/statistics/280102/us-households-types-of-breakfast-pastries-consumed/).

### 5.4. Innovative gastronomic uses for cinnamon

In one intriguing dish presented by top chef Heston Blumenthal a few years ago, a cinnamon and vanilla ice-cream was presented together with two squeezy bottles, one containing cinnamon sticks, the other vanilla pods (Blumenthal, 2008). Diners were first encouraged to taste the ice-cream and evaluate the flavour. Next, they were instructed to inhale the contents of one bottle while squeezing it repeatedly. This resulted in selective adaptation to the contents of the bottle (the aroma of cinnamon, say). When the diner then tasted the ice-cream again, its flavour would seemingly have changed and be dominated by the other flavour (e.g., vanilla in the case of inhaling the aroma of the cinnamon bottle). British cookery writer Delia Smith has the cinnamon sticks flying off the shelves of UK supermarkets back in 2009 after having recommended their use in one of her TV recipes (Singh, 2009).

## 6. Conclusions

As highlighted by this review, cinnamon has long been a hugely popular culinary and medicinal spice. There is, however, often confusion between the different types of cinnamon bark having quantitatively distinct essential oil compositions, and hence also rather distinct aroma/flavour profiles. *C. verum* and *C. cassia* tend to be available commercially in the USA and European markets, though the names "cinnamon" and "cassia" are often used interchangeably in the United States, thus leading to widespread confusion (Thomas & Duethi, 2001). The key aromatic volatile in the essential oil of cinnamon is cinnamaldehyde. Looking to the future, researchers have been experimenting with the addition of cinnamaldehyde essential oils to microcapsules to help add a pleasant aroma to 3D printed foods when heated by microwave (Guo et al., 2021).

Cinnamon is widely considered as a 'sweet' spice in the West (Blank & Mattes, 1990), this despite the fact that the spice itself tastes slightly bitter. Some researchers have been interested in the use of sweet-smelling cinnamon aroma to potentially help reduce the sugar content in food and drink. At the same time, there is also growing interest in the effects of cinnamon powder on glucose metabolism in diabetic mice (Liu et al., 2023). There is also growing interest currently in the use of cinnamon as a neutraceutical (Mohsin et al., 2023), neuroprotective (e.g., for Parkinson's disease; see Angelopoulou et al., 2021), and prebiotic (Lu et al., 2017).

The taste, aroma, and flavour of the four main commercial types of cinnamon vary, reflecting differences in their chemical (and essential oil) composition. From a culinary perspective, it is important to note that such differences may deliver a multisensory flavour profile that is best suited for different dishes. This is something that commercial bakers know only too well as they select cinnamons that deliver just the right balance of flavour vs. brown colouring to the products they make. Intriguingly, the aroma of cinnamon is considered so appealing that it is one of the few spices that is used in olfactory sensory marketing in a retail setting. In particular, the Cinnabon chain in North America reportedly bake sheets of baking paper dusted with cinnamon and sugar in their in-store ovens at quiet times in order to provide a desirable aroma to any shoppers who may be passing by (Nassauer, 2014). In the opening years of the 21st century Nestlé introduced a limited edition cinnamon Kit Kat (see Segnit, 2010; and see Flager, 2019, for subsequent interest in cinnamon-themed chocolate). Meanwhile, Scentee, a plug-in digital scent release device for mobile devices, came out with its own distinctive scent of cinnamon rolls a decade ago (see Harris, 2013). It has even been suggested that releasing the odour of cinnamon might help enhance the alertness and mood of drivers (Raudenbush et al., 2009). In fact, even simply reading the word 'cinnamon' can lead to an increase in neural activity in olfactory brain areas (González et al., 2006).

## Implications for gastronomy

Cinnamon has long been a popular culinary spice, used in a wide range of foods and drinks. Historically, it was used more in savoury dishes (e.g., such as curry and pilau in India), while nowadays, in the West, it is more commonly found in sweet foods, such as desserts, traditional/seasonal baked goods. As one of the 'warming' spices, it is strongly associated with Christmas and festive foods/drinks. Along with vanilla, cinnamon is an important element in the flavour of many cola beverages, such as Coca-Cola. There are several commercially viable species of cinnamon, with *Cinnamon verum* (originally from Ceylon/Sri Lanka) having a lighter, sweeter, more refined, taste/flavour than *Cinnamon cassia* (originally from China), which has a stronger, harsher taste/flavour. Cassia is often referred to as cinnamon (e.g., in the United States) leading to confusion amongst consumers/cooks. Cinnamon is described as a sweet spice (with the sweetness sometimes being attributed specifically to the presence of cinnamaldehyde), and hence it may potentially have a role to play in helping to replace sugar. The spice is used as the dried quills (the inner bark from the lower branches of the cinnamon tree), or as ground powder. The latter is also used to add a brown colour in the bakery category. There is growing interest in the neutraceutical use of cinnamon for a variety of real-world situations.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Data availability

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

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