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VOLATILE AROMA CONSTITUENTS OF SRI LANKAN GINGER

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Key Word Index—*Zingiber officinale*; Zingiberaceae; ginger; aroma volatiles.

Abstract—Two types of Sri Lankan ginger were examined (Sidda and Chinese varieties) and essential oils of both fresh and dried samples were prepared by standard procedures. Both varieties yielded relatively high percentages of oil (between 1.8 and 4.3 %) and total aroma volatiles (*ca* 5 mg/g for dried samples). Analysis by GC and GC/MS showed terpenes to be the main aroma components (*ca* 99 % for all samples). A number of the identified compounds have not previously been reported as ginger volatiles, including *trans*-β-ocimene, thujyl alcohol, terpinen-4-ol, myrtenal, guaiene, α-cubebene, δ-cadinene and farnesol. On drying, both varieties of Sri Lankan ginger showed considerable decrease in monoterpene content and very high increase in sesquiterpene concentration. Comparing the aroma volatiles of Sri Lankan dried ginger with those previously reported for dried ginger from some other countries, it was concluded that Sri Lankan ginger was as good as, if not superior to, other types. In particular, Sri Lankan dried ginger showed high levels of *ar*-curcumene together with reasonable levels of citral isomers and all other constituents previously claimed to be important to ginger aroma. Sri Lankan ginger would appear to be unusual in containing very low amounts of zingiberene but very high amounts of β-bisabolene.

INTRODUCTION

Ginger (*Zingiber officinale* Roscoe) is one of the most widely used spices, and it is a common additive in a number of compounded foods and beverages. The United Kingdom is one of the world's principal consumers of this spice, importing annually about 4000 tons of dried ginger. Clearly, the most important attributes of ginger are its flavour and pungency, and many studies have been carried out over the last two decades into the nature of the important volatile and non-volatile flavour constituents. However, despite a huge world trade in ginger, there have been very few investigations, compared with, for example, pepper [1], to evaluate the differences between ginger from the many different growing regions of the world, between different regional varieties grown in the same country, and also between the same variety grown in different areas [2]. To date, there has been no detailed examination of the aroma constituents of ginger from Sri Lanka and no comparison with data for ginger grown elsewhere, and the present paper describes the result of such a study. In the world league, Sri Lanka is not a major exporter of ginger, but it is hoped to improve this position, and as part of this process it is necessary to evaluate the Sri Lankan product in comparison with better-known ginger.

Invariably, fresh ginger is air-dried in the country of origin before export. The fresh rhizomes may or may not be peeled, and sun-drying is usually adopted. The exact nature of the drying process can, however, have a considerable effect on the quality of the product, and some comparative surveys have been carried out [3, 4]. In the present work the effects of drying on the aroma constituents of fresh ginger were also investigated.

RESULTS AND DISCUSSION

Although several varieties of ginger are present in Sri Lanka, only two are commonly cultivated, and hence were the only ones studied in this project. These are the so-called Local (or Sidda) variety and the Chinese variety. They are readily distinguishable from each other, the rhizomes of the former being small and highly branched, whereas those of the latter are larger and thicker with very much less branching. It is uncertain whether the Chinese variety has any formal relationship with varieties of ginger grown in China, or whether it is so-named simply due to its morphological similarity.

Preliminary assessment of drying techniques indicated that use of either whole unpeeled or sliced unpeeled rhizomes gave products of superior quality, and that drying in a laboratory oven at 60° to a final moisture content of 10.5–11.5 % was also appropriate (and about equivalent to sun-drying for 5 days) [5]. Moisture contents of *ca* 8–14 % have been reported for ginger dried by different procedures [3, 4], but 10–11 % would seem to be the normal level. It was found that grinding the dried rhizomes in a Waring blender limited heat generation, and hence helped retain a high level of the important volatile monoterpenes. A particle size of *ca* 1 mm was found to be optimum, larger sizes giving inferior results [5]. Also, the quality of the essential oil was improved by grinding the rhizomes immediately prior to distillation [5].

Fresh ginger (moisture content *ca* 85 %) was shredded in a Waring blender, and the slurry distilled in the same manner and for the same length of time as for dried samples. The percentages of ginger oil thus obtained, on a dry weight basis, were as follows: Sidda variety—fresh 2.8, dried 4.3; Chinese variety—fresh 1.8, dried 3.0. These levels are quite high, and can thus be considered a desirable feature of Sri Lankan ginger, with the Sidda variety being superior. Normally, the volatile oil content of dried ginger is in the range 1.0–2.5 %, although levels of *ca* 4 % have been reported [2]. The difference in the percentages for fresh and dried samples here is probably due to the higher moisture content of the fresh rhizomes and the consequent requirement for longer distillation times to expel completely all the oil. The four ginger oils obtained in this manner were light yellow mobile liquids, and all possessed a pleasant ginger odour.

The ginger oils were analysed by conventional GC and GC/MS, and the results are given in Table 1. A number of GC columns were employed, including capillary and packed columns, and using PEG 20M, SE30 and OV101 stationary phases. The qualitative data given in Table 1 were obtained mainly with a packed OV101 column, but some components were best characterized by GC/MS using a PEG 20M column. Kováts retention indices [6, 7] of some components are also included in the table, and they confirm the general elution sequence. In all instances where positive identities are given, the mass spectra obtained on GC/MS agreed with those in the literature, so none need be reported here. Reference spectra of some constituents are in general compilations of mass spectra [7, 8], but there are also very useful, more specific collections of spectra of monoterpenes (hydrocarbons [9], alcohols [10], aldehydes and ketones [11], esters [12]) and sesquiterpene hydrocarbons [13]. Mass spectra of *ar*-curcumene [14] and of *δ*-cadinene and elemol [15] have been individually reported, and the spectra of the important sesquiphellandrols of ginger have been detailed and discussed by Bednarczyk *et al.* [16]. Eudesmol was originally referred to as zingiberol by Brooks [17], who reported that this sesquiterpene alcohol imparted a mild, characteristic ginger odour to ginger oil. Subsequently, Verma *et al.* [18] identified zingiberol in ginger as a mixture of *cis*- and *trans*-*β*-eudesmol, although some other workers [19, 20] have not been able to locate these compounds in their samples. In our work, from the evidence available, it was not possible to be certain whether peak 38 was the *cis*- or *trans*-stereoisomer, or a mixture of both.

The quantitative data in Table 1 show that in total *ca* 755, 5060, 735 and 5215 mg of aroma components were obtained per kg, respectively, for fresh and dried Sidda ginger and for fresh and dried Chinese ginger. Taking into account the different moisture contents of fresh and dried samples, there is reasonable agreement between these figures. There is also close similarity between both sets of results (fresh and dried) for the two varieties. Sri Lankan dried ginger therefore contains *ca* 0.5 % aroma volatiles, which would seem a very reasonable level, although comparative figures for other types of ginger are not readily available.

Table 1 shows that Sri Lankan ginger oils contained 61 main components, of which 44 (comprising *ca* 97 % of the sample) were positively identified, with a further 5 (*ca* 2 %) partially or tentatively characterized; the 12 unidentified components are not included in the table. The majority of identified compounds are terpenes, and only traces of three other constituents were detected. However, some previous workers [21, 22] have found a wider range of non-terpenoid constituents, although always in trace amounts. A surprisingly large number of compounds in Table 1 have not previously been reported as aroma volatiles of ginger. These are *trans*-*β*-ocimene, thujyl alcohol, terpinen-4-ol, myrtenal, guaiene, *α*-cubebene, *δ*-cadinene and farnesol. However, all but the last two were obtained only in small or trace amounts and were identified only when using packed columns for GC/MS, showing the advisability of using such high capacity columns, as well as capillary columns, in order to detect and identify possibly important minor components. The sesquiterpene alcohols are particularly interesting additions to the list of ginger aroma volatiles.

Before considering the results in Table 1 in detail, it is relevant to record which compounds have been considered by previous workers to be particularly important to ginger aroma. These include the already mentioned eudesmol [17], neral, geranial and citronellyl acetate [20], *β*-sesquiphellandrene and *ar*-curcumene [23], and sesquiterpene alcohols in general [24]. However, probably the most accurate work in this area was carried out by Bednarczyk and Kramer [25], who determined that 85 % of characteristic ginger aroma was due to *α*-terpineol, neral, geranial, *β*-sesquiphellandrene, *ar*-curcumene, nerolidol and *cis*-*β*-sesquiphellandrol. Our own results, based on odour assessments of GC peaks at an odour port on elution from the GC column (see Table 1), indicate that the following compounds appear to be important contributors to ginger aroma: neral, geranial, bornyl acetate, *β*-zingiberene, *β*-eudesmol and *trans*-*β*-sesquiphellandrol. Table 2 summarizes percentage data for all these components and also includes total percentages for some classes of compounds. The table also contains some similar data from analyses of ginger from other countries; a blank in these entries means that this information was not reported.

Considering first the results for Sri Lankan ginger and comparing the two varieties in their fresh state, it is noticeable that the Sidda variety contained mainly sesquiterpenes, whilst the Chinese variety contained mainly monoterpenes. It is likely that monoterpenoids are chiefly responsible for the aroma of fresh ginger, since they generally have a strong odour, whereas the sesquiterpene hydrocarbons are only weakly odorous [19], and although sesquiterpene alcohols as a group are important, their individual contribution is claimed to be small [24]. With respect to specific components, Sidda ginger might be considered the better product because of its higher content of the desirable *ar*-curcumene and sesquiterpene alcohols, but the Chinese variety has a higher content of the important neral, geranial and certain other monoterpenes and, on balance, the Chinese variety is probably the superior of the two.

On drying, both varieties of Sri Lankan ginger showed considerable decrease in monoterpene content and very high increase in sesquiterpene concentration (Table 2). This is not surprising in view of the greater volatility of the former group of compounds, but clearly, for the reasons already given, this would be expected to decrease flavour potency, and therefore drying methods should be as mild as possible to preserve desirable monoterpenes. In particular, neral and geranial are very important, and in TLC and sensory analyses of different ginger oil samples, the intensity of neral and geranial spots on the TLC plate were found to parallel the ranking order for quality [26]. Furthermore, Cochin (India) ginger is especially valued for its 'lemony' (citral) note [27], and it has been shown that fresh or mildly dried gingers have a lemon or citrus character, whereas dried or commercial gingers are devoid of this attribute [2, 28]. With regard to the Sri Lankan varieties, Chinese ginger maintained its higher level of neral and geranial on drying (Table 2), and therefore is the superior product of the two in this respect.

Some sesquiterpene hydrocarbons (e.g. zingiberene, *β*-

Table 1. Volatile constituents of Sri Lankan ginger

Peak no.*	Component	R_t (min)	Kováts index (lit.)†	Sidda variety				Chinese variety				Odour quality
				Fresh		Dried		Fresh		Dried		
				% Rel. abund.	mg/kg	% Rel. abund.	mg/kg	% Rel. abund.	mg/kg	% Rel. abund.	mg/kg	
‡	Ethyl acetate	‡	595	n.d.	n.d.	tr	tr	n.d.	n.d.	tr	tr	—
‡	3-Methylbutanal	‡	649	n.d.	n.d.	tr	tr	n.d.	n.d.	tr	tr	—
1.	Cyclohexane	1.8	677	tr	tr	tr	tr	tr	tr	tr	tr	—
3.	α-Pinene	4.8	942	3.3	24.9	0.7	35.4	3.5	25.6	0.2	10.4	Pine, cedar wood
4.	Camphene	5.2	954	14.1	106.6	3.5	177.1	14.1	105.4	0.9	47.0	Camphor, moth balls
5.	β-Pinene	5.8	981	0.5	3.8	0.1	5.1	0.5	3.7	tr	tr	Polish, varnish, solvent
6.	Myrcene	6.3	986	1.3	9.8	0.4	20.2	1.7	12.4	0.1	5.2	
7.	α-Phellandrene	6.7	1002	0.1	0.8	0.1	5.1	0.2	1.5	tr	tr	Sweet, sickly fruity, estery
8.	p-Cymene plus β-phellandrene plus 1,8-cineole plus limonene	7.5	1020 1026 1027 1030	9.4	71.1	4.9	247.9	12.2	89.3	2.1	109.6	Camphoraceous
9.	*trans*-β-Ocimene	8.6	1038	tr	tr	tr	tr	tr	tr	tr	tr	—
10.	α-Terpinene	9.9	—	0.8	6.0	0.2	10.1	1.3	9.5	tr	tr	Floral, fragrant
11.	A monoterpene	10.5	—	0.3	2.3	0.1	5.1	0.3	2.2	0.1	5.2	Honeysuckle, roses
‡	Linalool	‡	1092	tr	tr	0.1	5.1	tr	tr	0.1	5.2	—
12.	Thujyl alcohol	12.3	—	0.1	0.8	0.4	20.2	0.1	0.7	0.4	20.9	Slightly citrus
14.	Camphor	12.6	1136	0.1	0.8	0.1	5.1	0.6	4.4	0.1	5.2	Camphor, earthy
15.	Borneol	13.7	1164	2.2	16.6	1.0	50.6	2.4	17.6	1.1	57.4	Terpene, flat, polish, slightly green
16.	Terpinen-4-ol	14.6	1175	tr	tr	0.2	10.1	tr	tr	0.2	10.4	Sea-food
17.	α-Terpineol	15.3	1185	0.8	6.0	0.4	20.2	1.3	9.5	0.4	20.9	
18.	Myrtenal	17.1	—	tr	tr	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	Citrus
19.	Neral	18.0	1227	4.9	37.0	2.5	126.5	10.1	73.9	3.1	161.8	Citrus, burnt, pungent
‡	Geraniol	‡	1243	0.6	4.5	0.1	5.1	0.4	2.9	0.3	15.7	—
20.	Geranial plus bornyl acetate	19.8	1252 —	8.1	61.2	1.8	91.1	15.3	112.0	2.5	130.5	Citrus, fruity, pungent Ginger
22.	δ-Elemene plus guaiene	23.6	— —	tr	tr	tr	tr	tr	tr	tr	tr	— —
23.	α-Cubebene plus citronellyl acetate	24.9	— 1335	tr	tr	0.1	5.1	0.1	0.7	tr	tr	Floral, fragrant
24.	β-Sesquiphellandrene	25.4	—	0.3	2.3	0.3	15.2	0.2	1.5	tr	tr	Floral, fragrant, sweet citrus
25.	β-Elemene	26.1	—	0.2	1.5	0.4	20.2	0.5	3.7	0.5	26.1	

Table 1. (*Continued*)

Peak no.*	Component	R_t (min)	Kováts index (lit.)†	Sidda variety				Chinese variety				Odour quality
				Fresh		Dried		Fresh		Dried		
				% Rel. abund.	mg/kg	% Rel. abund.	mg/kg	% Rel. abund.	mg/kg	% Rel. abund.	mg/kg	
‡	*β*-Farnesene	‡	—	1.2	9.1	0.5	25.3	1.2	8.8	0.5	26.1	—
26.	*α*-Zingiberene	27.2	—	0.1	0.8	0.6	30.4	0.4	2.9	0.4	20.9	Citrus
27.	*β*-Caryophyllene	28.3	1428	tr	tr	0.1	5.1	tr	tr	0.2	10.4	Floral, fragrant
28.	Sesquiterpene hydrocarbon	29.2	—	0.6	4.5	1.0	50.1	0.5	3.7	1.1	57.4	Fruity, mango
29.	*β*-Bisabolene	30.6	—	22.1	167.1	45.7	2312.4	20.1	147.1	60.4	3152.3	Tangerine, orange peel
30.	*ar*-Curcumene	31.9	—	14.5	109.6	27.1	1371.3	5.7	41.7	17.7	923.8	Musty orange peel
‡	? *α*-Elemene	‡	—	0.6	4.5	0.3	15.2	0.4	2.9	0.3	15.7	—
31.	*δ*-Cadinene	33.2	1524	0.9	6.8	0.4	20.2	0.3	2.2	0.8	41.8	Sweet pine
‡	Nerolidol	‡	1530	0.6	4.5	0.9	45.5	0.7	5.1	1.0	52.2	—
‡	Elemol	‡	—	0.4	3.0	0.7	35.4	0.1	0.7	0.7	36.5	—
36.	*β*-Zingiberene	34.9	—	1.2	9.1	0.3	15.2	0.4	2.9	0.4	20.9	Sweet ginger
37.	Farnesol	35.8	—	2.8	21.2	1.2	60.7	2.0	14.6	1.6	83.5	Oil of wintergreen
38.	*β*-Eudesmol	36.9	—	5.4	40.8	1.3	65.8	1.0	7.3	1.4	73.1	Musty lemon peel, pungent
41.	*trans*-*β*-Sesquiphellandrol	38.6	—	1.2	9.1	1.1	55.7	1.0	7.3	0.2	10.4	Pungent, musty lemon, geranium
43.	Sesquiterpene alcohol (M = 220)	39.8	—	tr	tr	0.1	5.1	tr	tr	tr	tr	Lemon
44.	Sesquiterpene	40.9	—	0.5	3.8	0.2	10.1	0.4	2.9	0.1	5.2	Lemon, geranium
45.	*cis*-*β*-Sesquiphellandrol	46.1	—	tr	tr	tr	tr	tr	tr	0.1	5.2	—

*Order of elution from an OV 101 GC column.

†Literature = [6,7]; tr = trace (< 0.1 %); n.d. = not detected.

‡Component only detected using a PEG 20 M GC column.

Table 2. Percentage relative abundances of some classes of aroma compounds and of specific important aroma constituents of Sri Lankan ginger and of ginger from some other countries

	Sri Lankan							
Compound	Fresh Sidda	Fresh Chinese	Dried Sidda	Dried Chinese	Indian [21]	Australian [19] 35 samples	Japanese [29]	Fijian [30]
Monoterpenes	46.6	64.0	16.6	11.6	11.6	4–32.2	85.7	
hydrocarbons	27.1	30.3	8.5	2.7	5.6	tr–2.2	0.2	
alcohols	3.7	4.2	2.2	2.5	3.6		27.5	
aldehydes	9.0	17.8	3.5	4.6	2.2	4–30	24.5	28–66
esters	4.0	7.6	0.8	1.0	0.1		29.4	
Sesquiterpenes	52.6	35.0	82.3	87.4	82.4	38–58	9.4	
hydrocarbons	41.7	29.8	76.8	82.3	65.7	38–58	9.4	13–57
alcohols	10.4	4.8	5.3	5.0	16.7			
α-Terpineol	tr	tr	0.2	0.2	n.d.		0.9	
Neral	4.9	10.1	2.5	3.1	0.8	1–10	11.8	28–66
Geranial	4.1	7.7	1.0	1.5	1.4	3–20	12.7	
Bornyl acetate	4.0	7.6	0.8	1.0	0.1		n.d.	
Citronellyl acetate	tr	tr	tr	tr	n.d.		n.d.	
β-Sesquiphellandrene	0.3	0.2	0.3	tr	n.d.	7–11	n.d.	
ar-Curcumene	14.5	5.7	27.1	17.7	17.7	6–10	4.8	
β-Zingiberene	1.2	0.4	0.3	0.4	35.6*	20–28*	1.8*	
Nerolidol	0.6	0.7	0.9	1.0			n.d.	
β-Eudesmol	5.4	1.0	1.3	1.4			n.d.	
trans-β-Sesquiphellandrol	1.2	1.0	1.1	0.2			n.d.	
cis-β-Sesquiphellandrol	tr	tr	tr	0.1			n.d.	

*Also includes α-zingiberene.
tr = Trace (< 0.1 %); n.d. = not detected.

sesquiphellandrene) are thought to undergo conversion into *ar*-curcumene (basically aromatization) on storage of ginger oil or heat treatment [19, 20], and therefore the much increased amounts of *ar*-curcumene in dried Sri Lankan ginger (Table 2) is not unexpected. Because of the reported importance of this compound to good ginger aroma [23, 25], this could be considered to be one of the few benefits of the drying process. Although dried Sidda ginger contained a greater percentage of *ar*-curcumene compared with dried Chinese ginger, the latter showed a three-fold increase on drying whilst the former gave less than a two-fold increase, so again the dried Chinese variety could be considered to have an advantage. There were no other significant differences between the two varieties of dried ginger, with regard to important aroma constituents.

In Table 2 the results for dried Sri Lankan ginger are compared with a selection of results for dried ginger from other countries. Although Indian ginger [21] contained a higher proportion of sesquiterpene alcohols, surprisingly it had much less neral despite its reputation for a strong citral note [27]. It also contained less bornyl acetate, no more *ar*-curcumene, and α-terpineol, citronellyl acetate and β-sesquiphellandrene were not reported [21]. Dried Sri Lankan ginger thus appears to be superior to Indian ginger.

A large number (35) of samples of Australian ginger oil have been studied [19]. Compared with Sri Lankan ginger, it would seem that Australian ginger oil contains less monoterpene hydrocarbons and *ar*-curcumene, but more neral and geranial and much more β-sesquiphellandrene.

From reported data, Japanese ginger [29] would be expected to have a very flowery and lemony aroma with little of the characteristic spicy ginger odour [2]. Thus, oxygenated monoterpenes were found to be dominant (in particular, geranyl acetate, *ca* 29 %; geraniol, *ca* 23 %; geranial, *ca* 13 % and neral *ca* 12 %) rather than sesquiterpenes and surprisingly, no β-sesquiphellandrene nor any sesquiterpene alcohols were detected. In addition, the samples contained relatively little monoterpene hydrocarbons and *ar*-curcumene, and bornyl acetate and citronellyl acetate were not reported [29]. Overall, this Japanese ginger has a very different composition from the Sri Lankan, Indian or Australian gingers.

A recent analysis of the aroma volatiles of Fijian ginger oil [30] showed some similarities with the Japanese results [29]. Thus, large amounts of oxygenated monoterpenes were found and unusually low amounts of sesquiterpenes, but β-sesquiphellandrene was definitely identified. The concentrations of neral and geranial were extremely high, exceeding those of any other ginger previously examined, and not surprisingly the Fijian oil was reported to have a strong sweet odour of citral [30]. This ginger is again quite different from Sri Lankan varieties.

Overall, from Table 2, it would appear that the two dried Sri Lankan ginger varieties are particularly good in flavour terms on the basis of their high content of *ar*-curcumene, a desirable constituent with regard to ginger aroma [23, 25]. However, their content of the important citral isomers was only average, or somewhat below. All other aroma constituents previously claimed to be important to characteristic ginger aroma [17, 20, 23–25] were present in reasonable amounts, often rather above average.

It is noticeable from Table 2 that the Sri Lankan varieties were unusually low in zingiberene but, on the other hand, they were extremely (and uniquely) high in β-bisabolene. Table 1 shows levels of β-bisabolene of *ca* 46% and *ca* 60% for dried Sidda and dried Chinese ginger, respectively, compared with corresponding figures for Indian (*ca* 0.2%), Australian (*ca* 5–9%) and Japanese (*ca* 3%) ginger. This may prove to be a determinant characteristic of Sri Lankan ginger. There is no obvious reason for the very high concentration of β-bisabolene and, for example, it is not reasonable to associate it chemically or biosynthetically with the very low zingiberene content. Also taking into account the odour quality of β-bisabolene, as indicated in Table 1, it might be expected that the high concentrations of this compound might endow Sri Lankan ginger with its own characteristic aroma quality, but it would not be expected that this would necessarily be detrimental (compare the odour description for *ar*-curcumene). However, that specific odour quality was not obviously detectable in any of the Sri Lankan samples.

From the results obtained in this investigation and comparison with previous results for ginger from some other countries, it is obvious that the aroma volatiles of ginger may vary considerably depending upon chemotaxonomic differences between cultivars and region of production. Doubtless other factors, such as climate, growing conditions, etc., may also have effects. With regard to the important aroma constituents, the Sri Lankan varieties studied gave somewhat similar (or slightly superior) results to those previously reported, for example, for the popular Indian ginger [21] and, therefore, there is no reason why, in this respect, either Sri Lankan variety should not be equally acceptable on the World Market.

EXPERIMENTAL

At least 10 kg batches of both types of Sri Lankan ginger (Local, or Sidda, variety and Chinese variety) were obtained, and representative samples taken for analysis.

Sample preparation. (a) Fresh ginger. Unpeeled rhizomes were washed, sliced, and 200 g shredded in a Waring blender with 500 ml H_2O. The slurry was distilled for 4 hr, using a Clavenger light oil arm, to yield the ginger essential oil. (b) Dried ginger. Unpeeled rhizomes were washed, sliced and air-dried in a laboratory oven at 60° for *ca* 6 hr until moisture content was lowered to 10.5–11.5%. The dried ginger was ground in a Waring blender and reduced in particle size to *ca* 1 mm; this was carried out immediately prior to distillation. Powdered ginger (40 g) was mixed with H_2O (600 ml) and distilled for 4 hr exactly as for fresh samples. All essences prepared in this manner (from both fresh and dried ginger) possessed a pleasant, characteristic ginger odour.

GC. FID-GC: 3 m × 3 mm i.d. stainless-steel column packed with 10% PEG 20M (or 15% SE 30); argon, 25 ml/min; temp. programme, 50°–195° at 4°/min; detector and injection point heaters, 250° and 200°, respectively; injection volume, typically 0.1 μl. Other columns used were 5.5 m × 4 mm i.d. glass packed with either 10% PEG 20M or 3% OV 101, 25 m × 0.25 mm i.d. fused silica containing either BP20 bonded phase (equivalent to PEG 20M) or BP1 bonded phase (equivalent to OV 101). For capillary column work, He was carrier gas (0.8 ml/min) and typically 0.04 μl was injected using a conventional inlet splitter. Peak areas were calculated using a Pye-Unicam DP 88 computing integrator.

GC/MS. A Kratos MS25 instrument was used, linked on-line to a Kratos DS50 data processing system. The same GC conditions as above were used, with He as carrier gas. Best results were obtained using the 5.5 m glass columns, but the fused silica columns were also used. The single stage all glass jet separator was at 250°. Significant operating parameters of the MS were: ionization voltage, 70 eV; ionization current, 100 μA; source temp., 220°; accelerating voltage, 1.33 kV; resolution, 1500; scan speed, 1 sec/decade (repetitive throughout run).

Quantitative assessment. Samples were prepared in such a manner that known aliquots of the ginger samples were analysed. Quantitative data were then derived both from the TIC trace during GC/MS, and from the GC-FID trace using the computing integrator.

Odour assessment. Aromas of the separated components of the ginger oils were assessed at an odour port following GC. An outlet splitter at 10:1 diverted the major fraction of the eluate through a heated line to the outside of the GC oven for aroma assessment by two subjects.

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