Progress in Essential Oils

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Vetiver Oil

Vetiver oil is obtained from the steam distillation of the air-dried roots of *Vetiveria zizanioides* (L.) Nash (syn. *Andropogon muricatus* Retz.; *A. squarrosus* Hook. f. non L.f.; *Anatherum zizanioides* (L.) (Hitchcock et. Chase) perennial, densely tufted grass members of the Poaceae (syn. Graminae) family. It is grown throughout the tropical regions of the world as a soil conservation plant as well as for the production of root oil (Grimshaw 1990). Commercial vetiver root oil distillation can be found in Brazil, China, Haiti, India, Indonesia and Dominican Republic. Limited quantities are also produced in Vietnam, El Salvador, Madagascar, Reunion and Nepal (Peyron 1995). Vetiver can be found growing in its natural environment in the swampy areas of Northern India, Bangladesh and Burma (also known as Myanmar) (Oyen and Dung 1999). However, world production of the oil in 1984 (Lawrence 1985), 1988 (Peyron 1989) and more current estimate can be seen in **T-1**.

A survey of the literature revealed that Yoshikoshi (1970) reviewed the pre-1970 chemistry of vetiver sesquiterpenoids.

Anderson (1970a) analyzed samples of vetiver oil of Haitian, Reunion and North Indian origin and showed that the oil produced from roots grown in Northern India represented a chemically different race to that grown commercially in Haiti or Reunion. Anderson (1970b) showed that North Indian vetiver oil contained levojunenol [eudesm-4(15)-6-ol] and α-amorphene (old name zizanene).

Trivedi et al. (1971) analyzed an oil of North Indian origin and found that it contained γ-cadinene, α-muurolol (old name δ-cadinol) and khusimol. The authors reported that γ-cadinene co-occurred with γ_2-cadinene, another constituent of the same oil.

Maurer et al. (1972) characterized the presence of (1S,10R)-1,10-dimethylbicyclo[4.4.0]dec-6-en-3-one and (6S,10S)-6,10-dimethylbicyclo[4.4.0]dec-1-en-3-one in a vetiver oil of Reunion origin.

Examination of the alcohol fraction of North Indian vetiver oil led Kalsi et al. (1972) to the characterization of epi-khusinol.

Kaiser and Naegeli (1972) identified 10-epi-γ-eudesmol, β-bisabolol, acora-4,9-diene, acora-4,7-diene, α-cedrene, α-cedrenol, α-cedrenal, α-funebrene, α-funebrenol, α-funebrenal and α-funebrenic acid.

Garnero (1972) reviewed the data published up to 1971 on the composition of vetiver oil. Unfortunately, the author did not present any quantitative data nor did he comment on the accuracy of the studies he reviewed. He did list that 19 hydrocarbons, 23 alcohols, five carbonyls and six acids had been characterized prior to 1971 in vetiver oil.

Hayama et al. (1973) extracted vetiver oil with a solution of 10% Na_2CO_3 with diethyl ether. After acidification and a series of washes, the author structurally elucidated zizanoic acid and epi-zizanoic acid in the acid fraction.

Ganguly et al. (1978ab) reported that in addition to zizaene and prezizaene another tricyclic tertiary alcohol that they named allo-khusiol was found in vetiver oil of North Indian origin.

Karkhanis et al. (1978) analyzed a sample of North Indian vetiver oil and found that isovalencenol, vetiselinenol and isovetiselinenol were minor constituents of the oil.

Commercially available vetiver oils were analyzed by Lemberg and Hale (1978 and 1979). A summary of the results of their analyses is presented in **T-2**. As can be seen, the authors did not bother with the hydrocarbons, all they characterized were the oxygenated sesquiterpenes.

Kalsi et al. (1979) examined the minor alcohol fraction of North Indian vetiver oil. In this fraction they characterized α-cardinol, cadina-4α,10β-diol and khusenediol (khusinodiol).

Masada et al. (1982) isolated and structurally elucidated khusimol,

Stay Tuned…

Check out the November issue of *Perfumer & Flavorist* magazine for the references to this article in addition to some base structures of a number of the vetiver oil constituents.

zizanol, isovalencenol, vetiselinenol and eremophila-10,11-dien-7-ol in vetiver oil. They also compared the percentage composition of three of the alcohols (khusimol, zizanol and isovalencenol) in oils from Reunion, Java, China and two from India (**T-3**).

Shibamoto and Nishimura (1982) isolated and identified 10 phenols and an acid in vetiver oil. The compounds characterized were:

methoxyphenol* (0.0048%)
o-cresol (0.0076%)
p-cresol (0.0062%)
m-cresol (0.0045%)
eugenol (0.0056%)
4-vinylguaiacol (0.154%)
(Z)-isoeugenol (0.0011%)
(E)-isoeugenol (0.132%)
4-vinylphenol (0.421%)
vanillin (0.0014%)
zizanoic acid (3.250%)

*correct isomer not identified

Nishimura et al. (1982) reported the same results on the phenols and acids of vetiver oil. Furthermore, they compared the relative amounts in various samples of vetiver oil of different geographic origin. The data from this study is summarized in **T-4**.

Jain et al. (1982) reported that the carbonyl fraction of vetiver oil possessed insect repelling activity. Analysis of this fraction revealed that it contained α-vetivone, β-vetivone, khusimone, zizanal, epi-zizanal and 1,10-dimethylbicyclo[4.4.0]dec-6-en-3-one. All of these six compounds were found to be repellent toward flies and cockroaches.

An oil produced from the roots of the 'Moosangar' cultivar of vetiver was found by Paknikar et al. (1983) to contain 2-epi-zizanone.

North Indian vetiver oil was found to contain nor-khusinol oxide (Kalsi 1985a) and khusitoneol (Kalsi 1985b) by the same scientific team.

Plavcan (1985) determined that the carbonyl containing compounds amounted to 17.67% of Indonesian vetiver oil. Column chromatographic separation of an aliquot of this fraction followed by preparative GC led to the isolation of 15 carbonyl compounds. Each compound was characterized by a combination of H-NMR, MS spectra and by comparison of spectral and GC retention time data with that of an authentic specimen wherever possible. The compounds identified were as follows:

zizanal (0.90%)
epi-zizanal (0.79%)
cadinenal* (0.14%)
dehydrocadinenal* (0.22%)
(E)-isovalencenal (0.43%)
khusimone (1.10%)
dimethyloctalone-1 (0.31%)
nor-isovalencenone (0.14%)
zizanone (0.16%)
epi-zizanone (0.13%)
(Z)-isovalencenal (0.23%)
dimethyloctalone-11 (1.26%)
nor-eudesmadienone* (0.68%)
β-vetivone (3.49%)
α-vetivone (4.48%)

*correct isomer not identified

Maheshwari (1985) compared the composition of two of the 13 different strains of Indian vetiver. Unfortunately, the authors did not characterize many components in the oils. They did, however, show that the four major components ranged as follows:

khusinal (0–33.61%)
khusinol (trace–56.2%)
khusimol (2.96–27.64%)
khusol (5.79–49.03%)

Gopalakrishnan and Narayanan (1987) reported that on re-extraction of a viscous very dark colored oleoresin of vetiver with liquid CO_2 at 25°C and 100 bar, a less viscous golden yellow colored volatile concentrate was obtained in 84–85%

Production of vetiver oil worldwide 1984–2006 **T-1**

Country	1984	1988	2004
Brazil	10	20	15
China	40	50	20–25
Dominican Republic	–	5	12
Haiti	100	20–30	100
India	10	10–15	20
Indonesia	80	45–50	80
Reunion	10	12–15	< 1

Chemical composition of the major comparative oxygenated components in various commercially available vetiver oils **T-2**

Compound	H	R	A	G	C	B	J
khusimol	13.4	21.5	21.8–27.9	21.4	20.0	21.7	13.6
β-vetivone	5.2	3.2	4.5–4.6	2.6	4.1	4.6	2.8
α-vetivone	3.2	5.8	4.7–5.1	1.5	5.2	4.9	4.0
unkn. ketone	5.3	10.5	14.8–15.3	1.1	7.3	14.7	7.1
elemol	2.3	0.7	1.7	0.4	0.8	1.6	0.7
10-epi-γ-eudesmol	2.2	1.2	1.1–2.0	–	1.5–1.6	1.6	1.8
β-eudesmol	5.5	8.4	6.0–6.9	7.5	6.5	6.6	7.0
vetiverenol + cyclocopacamphenol	6.6	6.8	7.0–7.5	6.7	6.2–6.8	6.9	6.1
vetiselinenol	11.2	11.1	11.0–13.6	11.8	13.9–19.5	11.2	10.3
unknown alcohol	4.2	3.7	1.3–2.4	5.5	2.0–3.0	4.3	3.5

H = Haiti; R = Reunion; A = Angola; G = Guatemala; C = China; B = Brazil; J = Java

T-3 Comparative percentage composition of the alcohols in vetiver oils

Oil origin	Khusimol	Zizanol	Isovalencenol
Reunion	14.0	3.2	4.6
Java	11.0	2.8	3.5
China	11.4	2.6	4.1
Kerala (S. India)	16.4	5.3	4.6
Katni (N. India)	5.3	3.4	1.1

T-4 Comparative chemical composition of the major oxygenated constituents of vetiver oil

Compound	Origin of oil: Tanegashima	Reunion	Haiti	Java	S. India
khusimol	18.2	16.7	10.8	9.2	12.5
isovalencenol	6.3	8.7	8.0	4.1	6.8
zizanol	2.4	1.7	1.3	1.6	1.8
β-vetivone	2.8	4.6	2.7	5.6	2.7
α-vetivone	2.7	7.2	3.0	6.0	3.5
zizanoic acid	4.4	3.0	0.2	2.3	2.0

yield that possessed only 5% non-volatile compounds. Furthermore, the two authors noted that the volatile concentrate retained all of the aroma qualities of the original oleoresin.

Kalsi and Talwar (1987) isolated a new sesquiterpene diol from North Indian vetiver oil. Using IR ^{1}H-NMR and derivatization, the authors were able to structurally elucidate the compound they named vetidiol.

Smadja et al. (1988) used silica gel column chromatography, GC retention indices and GC/MS to examine an oil of vetiver of Reunion origin. The compounds identified in elution order from a Carbowax 20M capillary GC column were:

decane
undecane
dodecane
tetradecane
α-gurjunene
α-cedrene
pentadecane
β-caryophyllene
aromadendrene
hexadecane
α-funebrene
allo-aromadendrene
δ-cadinene
cis-calamenene
trans-calamenene
octadecane
(1S,10R)-dimethylbicyclo[4.4.0]-6-decen-3-one
α-calacorene
β-calacorene
(6S,10S)-dimethylbicyclo[4.4.0]-1-decen-3-one
nonadecane
γ-calacorene
eicosane
epi-zizanol
docosane
tetracosane
β-vetivone
nootkatone
khusimol
α-vetivone
isozizanoic acid

Although the authors did not present any qualitative data, they did show chromatograms (OV-101 and Carbowax 20M) of this complex oil with the peaks named.

According to Cazaussus et al. (1988), Bourbon vetiver oil comprised sesquiterpene hydrocarbons (42 compounds, 25%), sesquiterpene alcohols (24 compounds, 45%), sesquiterpene ketones (10 compounds, 12%), sesquiterpene alcohols (2 compounds, 2.8%) and some acids (not defined by the authors). Using GC/MS and GC/MS/MS both in the E.C. mode and the C.I. mode the authors showed unequivocal characterization of the following compounds:

β-vetivenene
khusimone
zizanal

In addition, Cazaussus et al. showed the mass spectral collision activated dissociation fragmentation of khusimone.

Cazaussus et al. (1989) examined the composition of acetylated vetiver oil. In addition to showing that the acetylated oil contained 33 esters (53% of mixture), 36 sesquiterpene hydrocarbons, five bi- and tricyclic sesquiterpene alcohols, nine sesquiterpene ketones, three sesquiterpene aldehydes and five sesquiterpene acids the following esters were found:

zizanyl acetate
methyl isozizanoate
methyl zizanoate

They further pointed out that GC/MS/MS was found to be a suitable method for differentiation of isomers such as methyl zizanoate and methyl isozizanoate.

In 1991, Blatt and Ciola used a programmed temperature vaporizing injector between the supercritical fluid extract (SFE) and the GC/MS system to analyze vetiver root of Brazilian origin. The compounds characterized as compounds were:

β-vetivene
khusimone
zizanal
zizanol
bicyclovetivenol
α-vetivone
vetivenic acid

When a sample of Brazilian vetiver oil was compared with the SFE of vetiver the authors found that the SFE extract (100 atmos.) was richer in β-vetivene and khusimone than the oil, while the SFE extract (300 atmos.) was richer in α-vetivone, β-vetivone zizanal and vetivenic acid.

Using a combination of GC/MS with three different ionization modes such as electron impact (EI), positive-ion chemical ionization (PCI) and negative-ion chemical ionization (NCI), Sellier et al. (1991) characterized 20 components of Chinese vetiver oil. The compounds identified were:

α-cedrene
acoradiene
khusimene

γ-cadinene
δ-cadinene
α-calacorene
khusimone
α-eudesmol
nor-isovalencenone
zizanone
β-eudesmol
epi-zizanone
nor-eudesmadienone
cis-isovalencenal
trans-isovalencenal
β-vetivone
zizanol
α-vetivone
isozizanoic acid
zizanoic acid

In addition, the authors found that Chinese vetiver oil contained two sesquiterpene esters (0.27%), which were not found in vetiver oils of Reunion, Javan and Haitian origins. Although the esters were not structurally elucidated, the authors believed that one of them was probably benzyl isozizanoate.

Mookherjee et al. (1992) reported on the analysis of a sample of Haitian vetiver oil. Starting with an acid/base extraction followed by a Girard P isolation of the carbonyl compounds, the authors found that the oil contained acids/bases (5%), carbonyl compounds (15%) and other neutral compounds (80%). In the carbonyl fraction Mookherjee et al. characterized 11 compounds. A list of these carbonyl compounds and their odor descriptions can be seen in **T-5**.

Nikiforov et al. (1992) used headspace GC/MS and GC/FTIR to characterize 13 sesquiterpenoid compounds and 16 other constituents in a sample of vetiver oil from Reunion. Although the authors did not present any quantitative data nor any comparative data with the oil, they did characterize octane, 2-acetyl-5-methylfuran, 2-butylfuran, 2-pentylfuran, furfural, 2-methyl-2-butenal, p-cymene, α-thujene, α-pinene, β-pinene, camphene, myrcene, limonene, a carene, 1,8-cineole, 1-phenethyl acetate, α-calacorene, β-vetivenene, selina-4(14),7(11)-diene, γ-cadinene, α-amorphene, zizaene, pre-zizaene, α-cedrene, allo-aromadendrene, α-vetivone, β-vetivone, khusimol and isovalerenol in the oil.

Hossé et al. (1993) analyzed an oil of vetiver using a range of analytical techniques. The components characterized in this oil were:

prezizaene (2.95%)
khusimene (2.97%)
α-amorphene (5.01%)
khusimone (1.99%)
γ-muurolene (1.53%)
γ_2-cadinene (1.58%)
δ-cadinene (4.48%)
(E)-nerolidol (1.06%)
β-vetivenene (2.56%)
T-cadinol (1.79%)
α-cadinol (3.45%)
khusinol (5.23%)
khusimol (7.55%)
zizanoic acid (5.26%)
β-vetivone (1.60%)
α-vetivone (2.22%)

As it has been found that alcoholic perfumes that are rich in vetiveryl acetate can develop an unpleasant acidic or oxidized top-note on aging, Demole et al. (1995) investigated this phenomenon. GC/MS analysis of an alcoholic perfume rich in vetiveryl acetate having an off-odor revealed that the culprit compound(s) occurred at levels below 1 ppm. Careful static headspace analysis revealed that the off-odor was caused by a butene isomer and 1,1-diethoxyethane. It was believed that the peroxidic material, which was derived from hydrocarbon auto-oxidation, was able to oxidize a small portion of ethanol to yield acetaldehyde that was in turn readily converted into 1,1-diethoxyethane by acetylization with excess ethanol.

In 1996, Bombarda et al. treated the hydrocarbon fraction that was isolated from Reunion vetiver oil by silica gel column chromatography with m-chloroperbenzoic acid in methylene chloride at 0°C. Work up of this reaction mixture revealed that the major epoxides were:

zizaene-6(13)-epoxide
zizanene diepoxide (2 isomers)
valencene diepoxide (2 isomers)

Reduction of the oxidized hydrocarbon mixture revealed that zizanene diepoxide was not reduced by lithium aluminum hydride or lithium triethylborohydride. However, the two epimeric zizaene epoxides and valencene diepoxide were reduced to the corresponding alcohols. It is the belief of this reviewer that these oxidation and reduction products could be trace components in aged vetiver oil.

Dethier et al. (1997) examined the main component composition of vetiver oil produced from plants

Carbonyl compounds in vetiver oil and their odor descriptions **T-5**

Compound	Odor character
I. 11,12,13-tri-nor-eremophil-1(10)-en-7-one	weak, green-woody, amber-like
II. 11,12,13-tri-nor-eudesm-5-en-7-one	weak, woody, root-like
III. 13,4-di-nor-eudesma-5,7,9-trien-11-one	styrax and leather-like
IV. 13-nor-eudesma-4,6-dien-11-one	sweet, woody, musky, ambrette-like
V. 13-nor-eudesma-4(15),5-dien-11-one	strong, woody, amber-like, slightly musky
VI. spirovetiva-1(10),11-dien-2-one	weak, woody
VII. dehydro-β-vetivone (2-isomers)	(major) strong, rich, woody, peppery
VIII. α-vetivone	(minor) cedarwood-like
IX. β-vetivone	very strong, woody with citrus nootkatone-like character
X. 15-nor-eudesm-11-en-4-al	warm, woody, spicy
XI. ziza-6(13)-en-4-one	phenolic, woody

under various fertilizer treatments in Burundi. The main components were found to range as follows:

α-muurolene (0.5–1.2%)
valencene (0.8–2.8%)
β-vetivenene (1.4–5.8%)
α-cadinol (2.3–4.8%)
vetiselinenol (2.9–5.8%)
isocedranol (2.1–4.0%)
β-bisabolol (2.0–3.1%)
khusimol (19.4–29.5%)
isokhusimol (4.0–9.2%)
β-vetivone (4.3–9.8%)
nootkatone (3.5–10.2%)
α-vetivone (0.5–2.1%)

A vetiver oil produced from roots grown in Madagascar was analyzed by Möllenbeck et al. (1997). It was found to possess the following components:

α-terpineol (1.1%)
khusimic acid (32.3%)

In addition, trace amounts (< 0.1%) of α-pinene, β-pinene, limonene, 1,8-cineole, p-cymene, linalool and terpinen-4-ol were also found in this oil. The authors also found that the enantiomeric distribution of one minor and three trace constituents was as follows:

(4S)-(-)-limonene (100%): (4R)-(+)-limonene (0%)
(3R)-(-)-linalool (80%): (3S)-(+)-linalool (20%)
(4R)-(-)-terpinen-4-ol (66%): (4S)-(+)-terpinen-4-ol (34%)
(4S)-(-)-α-terpineol (100%): (4R)-(+)-α-terpineol (0%)

A sample of Haitian vetiver oil (1.1 kg) was separated into an acidic fraction (8.3 g) and a neutral fraction (1.09 kg) by Weyerstahl et al. (1997a & 2000a). Using flash chromatography (column chromatography) the neutral fraction was further fractionated into non-polar hydrocarbons fraction (160 g), a low-medium polar fraction (300 g), a medium-polar fraction (530 g) and a polar fraction (20 g). Vacuum fractional distillation of the low-mid polar fraction led to the characterization of numerous compounds.

The medium-polar fraction of the Haitian vetiver oil was converted into methyl ethers and they were separated by distillation and repeated flash chromatography. The alcohol constituents found in this methyl ether fraction were as follows:

12-nor-ziza-6(13)-2β-ol (1.1%)[a]
12-nor-ziza-6(13)-2α-ol (0.8%)
cyclocopacamphan-12-ol (2.4%)
epi-cyclocopacamphan-12-ol (3.3%)
eudesma-4(15),7-dien-3β-ol + 7,10-epoxy-10-hydroxy-salvialane (1.6%)
4α,7-epoxy-11-hydroxy-10βH-spirovetivene (0.3%)
khusian-2-ol (syn. helifolan-2-ol) + guaia-1(5),11-dien-3α-ol (0.3%)
helifol-4-en-14-ol + funebr-3(15)-14-ol + preziza-7(15)-en-3-α-ol + eudesma-6-en-4β-ol (4.0%)
ziza-6(13)-en-3α-ol + artefacts (4.9%)
ziza-6(13)-en-3β-ol + β-eudesmol + valerianol (2.9%)
eudesma-4(15),7-dien-12-ol + 11-epi-eudesma-4(15),7-dien-12-ol + eudesma-3,5-dien-1-ol + α-eudesmol + amorph-4-en-10-ol (6.4%)
preziza-7(15)-en-12-ol + ziza-6(13)-en-12-ol + 7αH-eremophila-1(10),4(15)-dien-2α-ol (33.0%)
4βH-*cis*-eudesma-6,11-dien-3β-ol + pogostol + intermedeol (1.8%)
eudesm-7(11)-en-4β-ol (0.3%)
7αH-eremophila-1(10),11-dien-2α-ol (1.7%)
eremophila-1(10),7(11)-dien-2α-ol (0.9%)
(E)-isovalencenol (6.7%)
spirovetiva-3,7(11)-dien-12-ol + 6,12,7,11-di-epoxy-eudesm-4-ene (0.9%)
epi-6,12:7,11-di-epoxy-eudesm-4-ene + 7,11:8,12-di-epoxy-eudesm-9-ene (0.4%)
7,11:8,12-di-epoxy-eudesm-9-ene (0.2%)

Analysis of the neutral fraction of the Haitian vetiver oil by Weyerstahl et al. (2000) revealed that it contained the following components:

α-cubebene (< 0.1%)
α-ylangene (0.2%)
α-funebrene (0.2%)
3-isopropyl-2-(3-methylcyclopent-2-enyltetrahydrofuran (< 0.1%)
α-cedrene (0.2%)
cascarilladiene (0.3%)
acora-2,4-diene (0.3%)
10-epi-acora-2,4-diene (0.2%)
11,12,13-tri-nor-eremophil-1(10)-en-7-one (0.2%)
preziza-7(15)-ene (0.7%)
ziza-6(13)-ene (1.3%)
α-amorphene + ar-curcumene (1.6%)
4,7-epoxy-spirovetiva-2,11-diene + 3-isopropyl-6-methyl-2-(3-methylcyclopent-2-enyl)-3,4-dihydro-2H-pyran + 12,3-di-nor-eremophil-1(10)-en-7-one (0.3%)
cis-eudesma-6,11-diene + spirovetiva-1,7(11),10(14)-triene + eudesma-4,6-diene + 8α-methyl-11,12,13-tri-nor-eremophil-1(10)-en-7-one (2.2%)
5,11-epoxy-eudesmane (0.5%)
δ-amorphene + β-bisabolene + 7,10-epoxy-eremophila-1,11-diene (1.0%)
sesquicinede + 13-nor-opposit-4(15)-en-11-one (0.5%)
γ-cadinene (0.6%)
δ-cadinene + 11,12,13-tri-nor-*cis*-eudesm-5-en-7-one + 3,10-epoxy-muurol-4-ene + γ-vetivenene + 6-epi-shyobunol (1.5%)
13-nor-*cis*-eudesm-6-en-8-one + 11,12,13-nor-*trans*-eudesm-5-en-7-one + 10,11-epoxy-eremophil-1-ene + furopelargone A + kessane (0.4%)
eudesma-4(15),7(11)-diene + 7-epi-*cis*-dracunculifoliol (0.6%)
eudesma-3,7(11)-diene + elemol + α-agarofuran + 11,12,13-tri-nor-*cis*-eudesma-5,8-dien-7-one + 15-nor-prezizaan-7-one + 13-nor-eudesm-5-en-11-ol (0.5%)
6,12-epoxy-elema-1,3-diene + epi-13-nor-eudesm-5-en-11-ol + β-vetivenene (1.8%)
β-calacorene + cascarilladienol + elema-1,11-dien-15-al (2.7%)
epi-elema-1,11-dien-15-al + cyclocopacamphan-12-ol + epi-cyclocopacamphan-12-ol + 15-nor-funebran-3-one (0.9%)
12-nor-preziza-7(15)-en-2-one + 1,10-epoxy-amorph-4-ene + *cis*-eudesm-6-en-11-ol (0.9%)
khusimone + 6,12-epoxy-spiroax-4-ene + *cis*-guai-6-en-10-ol (2.0%)
trans-dracunculifoliol (0.5%)
13-nor-*cis*-eudesm-6-en-11-one + *cis*-eudesm-6-en-12-al + epi-*cis*-eudesm-6-en-12-al (0.6%)
13-nor-eremophil-1(10)-en-11-one + amorph-4-en-10-ol + 10-epi-cubenol + 12-nor-ziza-6(13)-en-2β-ol (0.8%)
junenol + eudesm-4(15)-en-5β-ol + 12-nor-ziza-6(13)-en-2α-ol (2.2%)
eudesm-6-en-4β-ol (3.1%)
10-epi-γ-eudesmol + 1-epi-cubenol (1.8%)
methyl cyclocopacamphanoate (0.6%)
13-nor-eremophila-1(10),6-dien-11-one + khusian-2-one (1.0%)
α-funebren-15-al + eremophila-1(10),6-dien-12-al + epi-eremophila-1(10),6-dien-12-al (0.9%)
allo-khusiol + 7,15-epoxy-prezizaane (0.4%)
β-eudesmol + valerianol + eudesma-4(15),7-dien-3β-ol (4.6%)
cyclocopacamphan-12-ol + bisabola-3(15),10-dien-7-ol + α-eudesmol + 7,10-epoxy-10-hydroxy-salvialane (2.0%)
epi-cyclocamphan-12-ol + 13-nor-*trans*-eudesma-4(15),7-dien-11-one + epi-amorph-4-en-10-ol + 10-hydroxy-calamenene (2.0%)
ziza-6(13)-en-3-one + ziza-6(13)-en-12-al + 10-epi-acor-3-en-5-one (1.7%)
pogostol + intermedeol + epi-10-hydroxy-calamenene (0.8%)
β-bisabolol + porosadienone + 2-epi-ziza-

6(13)-en-3-one + 4,7-epoxy-spirovetiv-2-en-11-ol + guaia-1(5)11-dien-3α-ol + helifol-1-en-14-ol (1.8%)
ziza-6(13)-en-3α-ol + prezizaan-15-al + 2-epi-ziza-6(13)-en-12-al + β-funebren-14-ol + preziza-7(15)-en-3α-ol (1.1%)
α-bisabolol + epi-α-bisabolol + khusian-2-ol (2.1%)
cyclogermacra-1(10),4-dien-15-al + eremophil-7(11)-en-10β-ol + juniper camphor + (E)-opposita-4(15),7(11)-dien-12-al + eudesma-4(15),7-dien-2β-ol (2.9%)
ziza-6(13)-en-3β-ol + (E)-opposita-4(15),7(11)-dien-12-ol (1.1%)
13-nor-eudesma-4,6-dien-11-one (0.8%)
methyl ziza-6(13)-en-12-oate (0.4%)
isovetiselinenol + epi-*trans*-eudesma-4(15),7-dien-12-ol + 5,6-seco-6,7-eudesman-5-one (4.0%)
eudesma-3,5-dien-α-ol (1.2%)
preziza-7(15)-en-12-ol + eremophila-1(10),4(15)-dien-2α-ol (1.5%)
khusimol + 10-epi-acora-3,11-dien-15-al + methyl 2-epi-ziza-6(13)-en-12-oate + *cis*-eudesma-6,11-dien-3β-ol + eremophila-1(10),11-dien-2α-ol (14.7%)
6,12,7,11-di-epoxy-eudesm-4-ene (0.8%)
β-cyperone + *trans*-eudesma-4(15),7-dien-12-yl formate (0.6%)
ziza-6(13)-en-12-yl formate (0.3%)
eremophila-1(10),7(11)-dien-2α-ol + (E)-isovalencenol + spirovetiva-3,7(11)-dien-12-ol + (Z)-isovalencenal (12.2%)
nootkatone (0.8%)
β-vetivone (2.9%)
(E)-isovalencenal + methyl (E)-eremophila-1(10),7(11)-dien-12-oate + (E)-eremophila-1(10),7(11)-dien-12-yl formate (1.0%)
isonootkatone (3.1%)
ziza-6(13)-en-12-yl acetate (0.2%)
pre-ziza-7(15)-en-12-yl acetate (0.1%)
(E)-eremophila-1(10),7(11)-dien-12-yl acetate (0.1%)

Because of the complexity of the sesquiterpenes characterized by Weyerstahl et al. in their various studies (1996–2000) a list of the derivatives of acorane (5), amorphane (5), cadinane (5), muurolane (2), bisabolane (5), cyclocopacamphane (7), cyclogermacrane (2), elemane (7), eremophilane (27), eudesmane (45), funebrane (8), guaiane (4), helifolane (4), oppositane (6), axane (2), prezizaane (12), spirovetivane (8) and zizane (17) along with their parent structures is included.

An oil produced from vetiver roots (*Vetiveria zizanioides*) collected near Kanpur (Uttar Pradesh, India) was examined by Chowdhury et al. (2002). Using GC/MS as their only method of analysis, the authors reported that the oil possessed the following compositions:

8-methyl heptadecane† (0.7%)
2,6,10-triphenyldodecane† (0.6%)
α-longipinene† (4.9%)
isolongifolene† (0.8%)
longifolene† (0.4%)
4,5-dehydro-isolongifolene† (0.5%)
α-amorphene (1.5%)
aromadendrene† (1.2%)
β-bisabolene† (1.5%)
isocaryophyllene† (1.6%)
β-caryophyllene (0.8%)
clovene† (2.2%)
curcumene* (2.0%)
δ-guaiene† (1.0%)
dehydro-aromadendrane† (0.5%)
farnesene* (1.3%)
γ-cedrene† (3.2%)
β-guaiene* (1.0%)
α-humulene (0.9%)
β-himachalene† (1.5%)
longifolene† (1.9%)
azulene† (0.9%)
p-cymene† (0.6%)
α-muurolol (1.8%)
β-eudesmol (0.9%)
epi-globulol† (4.0%)
isokhusimol[b] (2.0%)
khusimol[d] (9.1%)
spathulenol† (6.0%)
khusinol[a] (4.3%)
viridiflorol† (2.5%)
α-cyperone† (0.7%)
1-cyclopentenone† (0.8%)
khusinone[e] (11.1%)
khusimone[e] (2.1%)
vanillin† (1.0%)
khusinol acetate† (6.1%)
eugenol (1.1%)
isoeugenol* (0.5%)

*correct isomer not identified; †incorrect identification; [a] = also known as cadina-4,10(14) dien-2β-ol; [b] = also known as ziza-2(12)-en-13-ol-prisotricyclovetivenol; [c] = also known as 12-nor-ziza-6(13)-en-2-one; [d] = also known as ziza-6(13)en-12-ol, khusenol or tricyclovetivenol; [e] = also known as cadina-4,10(14)-dien-2-one

Unfortunately, the authors did not present their data in an elution order from a capillary GC column nor did they record any retention indices so the accuracy of their study could not be evaluated except that many of the compounds characterized have never been found as vetiver oil constituents.

Narayanan (2003) published GC profiles of Indian vetiver oil (known as khus oil in India). Unfortunately,

Comparative percentage composition of vetiver oils **T-6**

Compound	Brazilian oil A	Brazilian oil B	Haitian oil	Bourbon oil	Java oil
α-ylangene	–	0.1	–	–	–
pre-zizaene	1.0	0.6	0.4	0.4	0.8
khusimene	1.7	0.5	0.9	–	3.0
α-amorphene	1.6	0.4	1.8	2.1	4.2
cis-eudesma-6,11-diene	1.2	–	1.4	0.8	2.4
cis-β-guaiene	–	0.8	–	–	–
δ-amorphene	1.4	0.2	1.1	1.8	3.5
β-vetispirene	1.0	0.2	1.1	1.0	2.7
γ-cadinene	0.6	0.3	–	0.3	0.7
γ-vetivenene	1.3	–	–	0.8	5.1
β-vetivenene	2.0	0.4	1.6	1.7	5.2
α-calacorene	0.9	–	0.8	–	0.7
cis-eudesm-6-en-11-ol	1.9	1.7	2.4	2.1	1.1
khusimone	3.6	2.6	3.5	3.9	2.6
ziza-6(13)-en-3-one	2.5	2.0	1.4	2.8	2.1
khusinol	3.4	2.2	1.9	1.7	2.4
khusian-2-ol	3.4	2.4	3.4	2.8	1.3
vetiselinenol	1.7	1.3	2.3	1.8	1.0
cyclocopacamphan-12-ol	1.0	0.8	1.7	1.3	0.3
2-epi-ziza-6(13)-3α-ol	1.9	1.9	1.6	1.2	1.1
isovalencenal	1.6	1.5	2.5	2.1	1.0
β-vetivone	1.5	1.9	5.6	3.9	8.0
khusimol	7.2	9.5	13.3	6.4	9.7
nootkatone	1.1	1.1	0.4	0.4	–
α-vetivone	5.4	4.9	4.8	3.3	4.0
isovalencenol	3.0	8.3	15.3	8.9	4.4
bicyclovetivenol	0.5	0.2	1.1	0.8	–
zizanoic acid	11.8	24.0	0.5	0.9	3.3

Brazilian oil A = commercial oil; Brazilian oil B = lab hydrodistilled oil

the quality of the publication was so poor that this reviewer could not read many of the constituents listed on the chromatograms. The compounds whose names were readable were zizaene, germacrene D, α-muurolol, elemol, 10-epi-γ-eudesmol, α-cadinol, khisimol, β-vetivone and α-vetivone. Narayanan also showed that an Indian market sample of vetiver oil was adulterated with diethyl phthalate.

Adams et al. (2003) collected over 20 different vetiver roots from different sources around the world. In addition to performing DNA-finger printing of each cultivar, oils which were produced by water distillation, were found to contain the following range in major constituents:

veliselinenol (2.6–11.0%)
khusimol (14.5–31.4%)
(E)-isovalencenol (9.8–16.5%)
β-vetivone (1.3–7.1%)
vetevenic acid (0–8.4%)
α-vetivone (2.3–5.7%)

Based on the DNA-analyses 19 cultivars clustered around the 'Sunshine' (a sterile cultivar), whereas the other three cultivars were not closely related to 'Sunshine.'

As part of a study of the chemical composition of Brazilian vetiver oil Martinez et al. (2004) compared the composition of a commercially available oil (EO), a supercritical fluid CO_2 extract (SFE), a hydrodistilled oil from the SFE, neutral fraction of EO, a hydrodistilled oil and three commercial oils from Haiti, Reunion (Bourbon) and Java (Indonesia), respectively. The results of this GC (FID), GC/MS study of the oils are shown in **T-6**. The composition of the hydrodistilled oil from the vetiver SFE was found to be:

α-ylangene (0.1%)
pre-zizaene (0.4%)
khusimene (0.7%)
α-amorphene (0.5%)
cis-β-guaiene (0.5%)
δ-amorphene (0.4%)
β-vetispirene (0.1%)
γ-cadinene (0.4%)
cis-eudesm-6-en-11-ol (2.1%)
khusimone (4.5%)
ziz-6(13)en-3-one (2.9%)
khusinol (2.7%)
khusian-2-ol (2.7%)
vetiselinenol (1.8%)
cyclocopacamphan-2-ol (1.0%)
2-epi-ziz-6(13)-3α-ol (2.8%)
isovalencenal (2.5%)
β-vetivone (4.8%)
khusimol (8.3%)
nootkatone (1.7%)
α-vetivone (10.4%)
isovalencenol (10.2%)
bicyclovetivenol (0.6%)
zizanoic acid (6.7%)

Comparative percentage composition of vetiver oils

T-7

Compound	B	C	H	I	J	M-I	M-2	R	S
α-cubebene	–	–	–	–	–	0.1	–	–	–
cyclosativene	–	–	0.2	–	–	–	–	–	0.2
α-ylangene	–	–	0.3	0.3	0.4	0.6	0.4	0.3	–
α-copaene	–	–	–	–	–	0.1	–	–	–
acoradiene*	0.1	0.2	0.2	0.2	0.2	0.2	0.4	0.2	0.2
α-funebrene	0.1	0.7	0.1	0.1	0.2	0.2	0.3	0.2	0.2
trans-2-nor-zizaene	0.1	0.2	0.2	0.2	0.2	–	1.1	0.3	0.1
β-cubebene	0.1	–	0.1	0.1	0.1	–	0.1	0.1	0.1
cyperene	–	–	–	–	0.1	0.1	–	–	–
β-funebrene	0.2	0.2	0.3	0.2	0.2	0.3	0.4	0.3	0.3
cascarilladiene	0.1	–	0.1	–	0.1	0.3	0.3	0.1	0.1
β-caryophyllene	–	–	–	0.3	–	–	–	–	–
β-cedrene	–	–	0.3	0.2	0.3	0.4	0.6	0.4	–
β-copaene	0.2	–	0.2	–	0.3	0.4	–	–	0.2
β-gurjunene	0.4	–	0.3	0.3	0.3	–	0.8	0.3	0.2
α-guaiene	–	–	0.2	0.3	–	0.3	0.6	0.1	0.2
guaia-6,9-diene	–	–	0.1	0.1	–	–	–	0.2	–
acora-3,9-diene	–	0.2	0.1	0.1	0.1	0.1	–	0.1	0.1
isoeugenol*	0.4	1.3	–	–	0.8	–	0.8	–	–
preziza-7(15)-ene	0.7	1.0	0.8	0.6	0.8	0.8	1.4	0.9	0.9
ziza-6(13)-ene[a]	1.2	1.7	1.3	1.1	1.3	1.5	2.3	1.6	1.2
selina-4(15),7-diene	0.8	0.7	0.5	0.5	0.6	0.3	0.8	0.3	0.6
dimethyl-6,7-bicyclo-[4.4.0]-dec-10-en-4-one	–	2.0	0.7	–	1.0	–	1.6	1.1	0.2
selina-4,7(11)-diene	0.1	–	0.1	–	0.1	–	0.2	–	–
β-acoradiene	0.1	0.4	0.2	–	0.3	–	–	–	0.3
α-gurjunene	–	0.5	–	–	–	–	–	–	–
amorpha-4,7(11)-diene	–	–	–	0.3	–	–	–	–	–
α-amorphene	2.4	4.1	1.9	1.9	2.4	2.8	2.8	1.8	1.5
α-vetispirene	–	–	–	1.2	1.5	1.8	2.2	0.9	–
β-selinene	–	–	1.0	–	2.0	2.9	3.1	1.0	–
β-vetispirene	3.1	3.1	2.8	4.5	2.8	1.5	2.7	1.6	1.9
cis-eudesma-6,11-diene	1.2	2.9	0.9	–	–	–	–	–	0.6
γ-amorphene	0.7	0.7	0.8	1.3	–	1.0	3.3	0.6	0.7
eudesma-4,6-diene[b]	–	–	0.1	–	–	–	–	–	0.1
eudesma-2,4,11-diene	–	–	–	–	–	–	–	0.5	–
valencene	–	0.5	–	–	–	–	–	–	–
δ-amorphene	2.5	1.3	1.4	–	1.4	–	–	–	0.3
γ-cadinene	–	0.6	0.3	–	–	3.4	–	–	0.3
7β,10β-epoxy-4β-erimophila-1,11(12)-diene	–	–	0.1	0.1	–	–	–	0.1	–
nootkatene	–	–	–	–	–	0.9	–	–	–
isocalamenene	–	0.3	0.1	–	0.2	–	–	–	0.1
spirovetiva-1(10),7(11)-diene	0.8	0.4	0.8	1.5	0.8	–	1.2	0.7	0.4
eremophylla-1(10),7(11)-diene	1.2	1.3	1.2	0.9	1.3	1.6	2.1	1.4	1.4
γ-vetivenene	2.0	4.3	1.0	0.9	1.8	2.3	3.4	0.7	0.2
α-calacorene	1.0	1.7	0.7	0.8	0.9	0.9	0.8	0.6	0.4
selina-4(15)7(11)-diene	–	–	–	–	0.4	0.4	–	–	–
selina-3,7(11)-diene	–	0.2	0.1	–	0.2	–	–	–	0.1
elemol	0.7	0.3	0.5	0.7	0.6	1.2	0.8	0.5	0.3
β-vetivenene	3.7	5.5	2.6	5.3	3.7	–	5.7	0.2	1.2
13-nor-eremophila-1(10),6-dien-11-one	–	0.2	–	–	–	–	–	–	–
cis-eudesm-6-en-11-ol	2.7	1.1	1.9	1.4	2.0	3.0	3.3	1.4	2.2
β-calacorene	–	–	0.1	–	–	3.5	–	–	0.1
13-nor-eudesm-5-en-11-one (epimer A)	–	–	0.2	–	–	–	–	0.2	–
cis-eudesma-6-en-12-al	–	–	1.0	1.0	–	–	0.8	–	–
cis-eudesma-6,11-dien-3β-ol	0.8	–	0.4	–	0.7	1.3	1.4	0.1	0.5
12-nor-preziza-7(15)-en-2-one	–	0.2	0.7	–	0.5	–	–	–	0.7
cis-guai-6-en-10-ol	–	0.4	–	–	–	–	–	–	–
15-nor-funbran-3-one	–	–	–	–	–	–	–	–	0.2
6,12-epoxy-spiroax-4-ene	0.2	–	0.3	0.3	–	–	–	0.2	–

continued from previous page

T-7

Compound	B	C	H	I	J	M-I	M-2	R	S
13-nor-eudesm-5-en-11-one (epimer B)	0.2	–	0.3	0.3	–	–	0.3	0.3	–
khusimone[c]	0.7	0.8	0.9	0.8	0.9	0.9	0.5	0.9	1.1
12-nor-ziza-6(13)-en-2α-ol	0.3	0.4	0.7	0.7	0.6	0.4	0.3	0.8	0.9
salvial-4(14)-en-1-one	0.9	–	–	1.8	–	2.9	2.3	1.1	–
selin-6-en-4-ol	–	–	–	2.7	–	–	1.4	2.3	1.9
12-nor-ziza-6(13)-en-2β-ol	2.2	–	–	1.3	1.7	1.5	1.1	0.9	–
13-nor-eremophil-1(10)-en-11-one	–	0.2	0.2	–	0.2	–	–	–	0.2
funebran-15-al	0.6	1.0	0.6	–	–	–	0.5	–	0.6
1-epi-cubenol	1.3	–	1.1	–	1.2	2.4	0.5	1.7	0.2
10-epi-γ-eudesmol	1.8	0.3	1.2	0.6	1.0	–	0.4	–	–
eremophila-1(10),6-dien-12-al	–	–	–	1.2	–	–	–	–	–
cedren-15-al	–	–	–	0.9	0.9	0.9	–	0.8	–
prezizaan-7β-ol[d]	–	0.9	1.1	–	–	–	–	–	1.1
β-eudesmol	5.2	2.3	2.2	1.5	–	–	0.9	1.2	0.6
intermedeol[e]	–	–	–	–	1.3	1.3	–	–	–
α-cadinol	–	–	–	6.5	–	1.6	3.2	4.0	–
cyclocopacamphan-12-ol (epimer A)	1.7	1.0	2.0	–	2.7	6.7	1.1	2.8	1.9
cyclocopacamphan-12-ol (epimer B)	1.7	1.9	1.9	1.3	1.9	1.4	1.1	1.1	2.7
β-bisabolol	–	–	0.7	–	–	–	–	–	0.7
khusinol[f]	–	–	2.8	–	–	–	–	–	–
ziza-6(13)en-3-one	2.3	1.0	1.9	2.3	–	–	1.6	1.9	0.9
2-epi-ziza-6(13)-en-3α-ol	1.7	1.0	2.1	2.7	1.8	1.4	1.4	2.2	1.8
prezizaan-15-al	0.4	–	–	0.5	0.4	–	–	–	–
2-epi-ziza-6(13)-en-12-al	1.1	–	0.9	0.6	1.0	1.5	1.3	1.0	–
helifolan-2-ol	2.3	1.5	2.1	1.8	2.0	1.6	1.5	1.9	2.6
ziza-6(13)-en-12-al	–	–	0.4	–	0.4	–	–	–	0.4
ziza-6(13)-en-12-yl methyl ether	–	–	–	–	–	0.4	–	–	–
eudesm-7(11)-en-4α-ol[g]	–	0.2	1.0	1.2	0.8	–	–	–	0.8
ziza-6(13)-en-3β-ol	2.3	0.4	1.6	1.3	1.4	–	0.6	1.3	1.5
eremophila-1(10),4(15)-dien-2α-ol	–	–	–	–	0.9	1.1	–	–	0.8
(E)-opposita-4(15),7(11)-dien-12-al	–	–	0.5	–	–	1.7	–	–	0.5
13-nor-eudesma-4,6-dien-11-one	1.0	1.1	1.1	1.5	1.1	1.1	0.6	0.9	0.9
ziza-5-en-12-ol	0.7	3.3	–	0.7	1.6	–	3.2	0.6	–
2-epi-ziza-6(13)-en-3β-ol	–	0.4	–	–	–	–	–	–	–
1,7-cyclogermacran-1(10),4-dien-15-al	0.4	–	0.4	–	–	–	–	–	–
trans-eudesma-4(15),7-dien-12-ol	2.8	1.7	3.1	3.7	2.9	3.2	1.8	3.0	3.0
helifolan-2-one	–	–	–	–	–	–	–	–	0.8
eremophila-1(10),7(11)-dien-2β-ol	0.3	–	0.7	–	–	–	–	–	1.1
(E)-opposita-4(15),7(11)-dien-12-ol	1.5	–	1.0	–	–	–	–	–	0.4
khusimol[h]	6.6	3.4	11.4	11.9	8.7	5.3	6.5	13.3	13.7
preziza-7(15)-en-12-ol	0.4	0.6	0.6	0.3	0.5	0.3	0.3	0.7	0.8
(E)-eremophila-1(10),7(11)-dien-12-ol[i]	0.4	–	0.8	1.5	0.8	0.9	0.7	1.0	0.4
isokhusenic acid	–	1.3	–	–	–	–	–	–	–
vetiselinol[j]	3.5	1.9	6.2	6.0	5.0	4.6	1.3	7.8	7.5
nootkatone[k]	–	–	0.8	0.7	0.8	–	0.4	0.9	–
(Z)-isovalencenal[l]	0.7	–	0.7	1.0	0.8	1.1	0.6	0.9	0.2
β-vetivone	2.8	3.6	3.5	2.0	3.2	2.3	2.5	4.2	4.9
khusenic acid	4.8	2.1	–	–	3.4	–	0.3	–	3.2
(E)-isovalencenal	1.1	1.1	1.3	1.3	1.1	0.7	0.8	1.4	1.2
(E)-eremophila-1(10),7(11)-dien-12-yl methyl ether	–	–	–	0.3	1.1	0.3	0.1	0.7	–
α-vetivone[m]	6.2	2.6	4.6	2.5	3.7	3.3	3.5	6.4	3.1
ziza-6(13)-en-12-yl acetate	–	0.2	0.2	0.2	0.2	–	0.5	0.9	0.1
(E)-eremophila-1(10),7(11)-dien-12-yl acetate	–	–	–	–	0.2	0.2	–	0.2	–
prekhusenic acid	1.6	–	–	–	–	0.2	–	–	–

B = Brazil; C = China; H = Haiti; I = India; J = Java; M-I = Madagascar; M-2 = Mexico; R = Reunion; S = Salvador; *correct isomer not identified; [a] = also known as khusimene; [b] = also known as δ-selinene; [c] = also known as 12-nor-ziza-6(13)-en-2-one; [d] = also known as allo-khusiol; [e] = also known as eudesm-11-en-4-ol; [f] = also known as cadina-4,10(14)-dien-2β-ol; [g] = also known as juniper camphor; [h] = also known as ziza-6(13)-en-12-ol; [i] = also known as isovalencenol; [j] = also known as eremophila-1(10),7,(11)-dien-2α-ol; [k] = also known as eremophila-1(10),11-dien-2-one; [l] = also known as (Z)-eremophila-1(10),7(11)-dien-12-al; [m] = also known as eremophila-1(10),7(11)-dien-2-one

Kim et al. (2005) examined the antioxidant activity of a commercial sample of vetiver oil. In addition to showing that the oil possessed a strong free radical scavenging activity it was found to contain the following major components:

khisimol (16.2%)
bicyclovetivenol (21.3%)
α-vetivone (6.6%)
β-vetivone (5.2%)
β-vetivene (1.2%)

Starting with 3 kg of vetiver oil Clery et al. (2005) analyzed the base fraction of the oil using GC-FID/NPD to reveal that it contained the following nitrogen heterocyclic compounds:

methylpyrazine (0.3 ppm)
4-methylpyridine (1.3 ppm)
2,5-dimethylpyrazine (0.3 ppm)
2,6-dimethylpyrazine (0.3 ppm)
ethylpyrazine (0.3 ppm)
2,3-dimethylpyrazine (0.3 ppm)
2-ethyl-6-methylpyrazine (0.6 ppm)
2-acetylpyridine (0.3 ppm)
3-ethyl-2,5-dimethylpyrazine (0.9 ppm)
2-ethyl-3,5-dimethylpyrazine (0.3 ppm)
2-isopropyl-3-methoxypyrazine (0.6 ppm)
2-butylpyridine (0.3 ppm)
1-pyridin-2-yl-1-propanone (0.3 ppm)
isocyeanato-methylbenzene (0.9 ppm)
methyl indoline (0.6 ppm)
2-pentylpyridine (0.6 ppm)
3,5-dimethyl-2-(1-propenyl)-pyrazine (0.6 ppm)
quinoline (0.6 ppm)
2-aminoacetophenone (0.6 ppm)
2,5-dimethyl-3-(isoamyl)-pyrazine (0.6 ppm)
methyl anthranilate (0.3 ppm)
trimethylindoline (0.3 ppm)
2,5-dimethyl-3-pentylpyrazine (0.3 ppm)
methylquinoline* (2.7 ppm)
dimethylanthranilate (0.3 ppm)
dimethylquinoline* (0.6 ppm)
2-phenylpyridine (0.3 ppm)
3-phenylpyridine (0.3 ppm)

*correct isomer not identified

Trace amounts (< 0.1 ppm) of 2,3,5-trimethylpyrazine, 2-ethyl-3-methylpyrazine, 1,3-benzothiazole and 2,5-dimethyl-3-(1-propenyl)-pyrazine were also found in this same base fraction.

Twenty-seven commercial samples of vetiver oil were obtained from nine different countries. They were four from Brazil, two from China, four from Haiti, two from India, four from Java (Indonesia), three from Madagascar, two from Mexico, four from Reunion and two from El Salvador. The oils were analyzed by Champagnat et al. (2006) using GC-FID and GC/MS. The comparative results of these analyses can be found in **T-7**. The average data presented in the table revealed that 89.1% of the Brazilian oils, 73.6% of the Chinese oils, 89.3% of the Haitian oils, 89.4% of the Indian oils, 86.2% of the Javan oils, 85.2% of the Madagascar oils, 87.3% of the Mexican oils, 88.2% of the Reunion oils and 83.6% of the El Salvadoran oils were characterized.