

## Physical properties of some spice essential oils and flavourants

Spice	Specific gravity (20°C)	Refractive index (20°C)	Optical rotation (°) (20°C)	Solubility characteristics	Other remarks
Asafoetida	0.906-0.973	1.493-1.518	-9°0' to +9°18'	Soluble in 1-2 vols and more of 70% alcohol, occasionally with opalescence to turbidity on dilution	Sulphur content, 15.3-29%
Allspice (Pimenta) berry oil	1.024-1.055 <sup>a</sup>	1.525-1.536	0°32' to -5°0'		Phenol content, 65-89%
Pimenta leaf oil	1.026-1.065	1.530-1.540	inactive to 5°30'	Soluble in 1-2 vols of 70% alcohol	Phenol content, 65-96%
Bay oil	0.960-0.985 <sup>a</sup> ; in oils of lower quality as low as 0.951	1.506-1.520	laevorotatory up to -2°, seldom up to -3°	Freshly distilled oils are soluble usually in 1-2 vols of 70% alcohol; solubility decreases rapidly on storage	Phenol content 57-60%; in oils of poor quality, as low as 40%
Terpeneless bay oil	1.029-1.050'	1.527-1.536	-0°10' to -1°20'	Soluble in 2-2.5 vols of 60% alcohol, sometimes even in 6-6.5 vols of 50% alcohol	Phenol content, 82-95.5%
Cardamom	0.923-0.941 <sup>a</sup>	1.462-1.467	+24°0' to +41°	Soluble in 2-5 vols of 70% alcohol	Acid number, up to 4; Ester number, 92-150
Cardamom, wild	0.909'	1.474	+16°30'	Soluble in 1-2.5 vols of 70% alcohol	Acid number, 1.1; Ester number, 12
Cinnamon bark. oil	1.020-1.030'	1.568-1.535	-1°0' to -2°10'	Soluble in 1-2.5 vols of 70% alcohol occasionally opalescent to hazy	Aldehyde (cinnamaldehyde), 51.8-56% Phenol (Eugenol), 14-18%
Cinnamon leaf oil	1.037-1.055''	1.529-1.535	1°36' to 0°40'	Soluble in 1.5 vols or more of 70% alcohol. sometimes with opalescence or paraffin separation	Aldehyde, up to 4% Phenol. 77.3-90.5%

Cassia oil	1.055-1.070 <sup>a</sup>	1.600-1.606	-10 <sup>0</sup> ' to +6 <sup>0</sup> '	Readily soluble in 1-2 vols of 80% alcohol, 2-3 vols of 70% alcohol	Aldehyde. 75-90%
Clove bud oil	1.043-1.068 <sup>a</sup>	1.529-1.537	up to -1 <sup>0</sup> 35'	1-2 vols or more of 70% alcohol with slight turbidity: freshly distilled in 2.5-3.0 vols of 60% alcohol	Eugenol. 78-95% seldom up to 98%
Clove stem oil	1.040-1.067 <sup>a</sup>	1.531-1.538	up to -1 <sup>0</sup> 30'	1-2 vols or more of 70% alcohol and 2.5-3 vols of 60% alcohol	Eugenol. 83-95%, in exceptional cases higher
Clove leaf oil	1.032-1.067 <sup>a</sup>	1.533-1.539	-0 <sup>0</sup> 50' to — 1 <sup>0</sup> 53'	0.9 vols or more of 70% alcohol	Eugenol. 78-93%
Ginger	0.877-0.886 <sup>a</sup> oils with lower and higher specific gravity have been observed	1.489-1.494	- 26 <sup>0</sup> ' to - 50 <sup>0</sup> ' lower values observed for oil distilled from old roots stored for a 'long time	Only sparingly soluble in alcohol. Up to 7 vols of 95% alcohol reqd. for solution which is not always clear. In 90% alcohol. the oils are generally, but not always completely soluble.	Acid number. up to 2: Ester number. up to 15: Ester number after acetylation. 24-50
Mustard	1.014-1.030	1.527-1.529	Inactive	Soluble in 160 to 300 parts of water. 7-10 parts of 70% alcohol. 2.5-3.0 vols of 80% ethanol, in 0.5 vols of 90% ethanol, clearly miscible with ether. amyl alcohol. benzene and petroleum ether	Allyl isothiocyanate. 94%; boiling range at 760 nm. 148-154°C
Nutmeg	0.859-0.868	1.469-1.472	+40 <sup>0</sup> 48' to +49 <sup>0</sup> 48'		Acid number. 1.0-1.3: Ester number. 6.8-7.3
Mace	0.860-0.892	1.472-1.479	+21 <sup>0</sup> 42' to +41 <sup>0</sup> 30'		Acid number. 1.5-6.2: Ester number. 2.8-12.8 Ester number. 354-365: Ester content. caled. as methyl salicylate. 96-99%

## Appendix (continued)

Spice	Specific gravity (20°C)	Refractive index (20°C)	Optical rotation (°) (20°C)	Solubility characteristics	Other remarks
Pepper oil	0.873-0.916	1.480-1.499	-10 <sup>0</sup> 01 +3 <sup>0</sup>	Not readily soluble in alcohol, usually soluble in 10-15 vols of alc; soluble in 3-10 vols of 95% alcohol	Acid number, up to 1.1 Ester number, 0.5 to 6.5 Ester number after acetylation, 12-22.4; Phellandrene test, usually strongly positive
Star anise	0.98-0.00	1.553-1.557	up to -2 <sup>0</sup> ;  sometimes up to  0 <sup>0</sup> 36'	Soluble in 1.5-3.0 vols of 90% alcohol	Congealing point, +14-+18 <sup>0</sup>
Ajowan oil	0.910-0.930 <sup>a</sup>	1.498-1.504	up to 5 <sup>0</sup> 0'	Soluble in 1-2 vols and more of 80% alcohol  Soluble in 2-3 vols of 70% alcohol	Phenols, 45.0-57.0%  Acid number, up to 5.0; Ester number, 3.0-22.7
Coriander	0.870-0.885 <sup>a</sup>	1.463-1.471	+8 <sup>0</sup> 0' to +13 <sup>0</sup> 0'	Soluble in 4-9 vols of 80% alcohol	Carvone content, 40-60%
Dill	0.895-0.915 <sup>a</sup>	1.481-1.491	+70 <sup>0</sup> 0' to +82 <sup>0</sup> 0'	Soluble in 1.5-3.0 vols of 90% alcohol	
Anise oil	0.980-0.990	1.52-1.559	up to -1 <sup>0</sup> 50'		
Fennel seed oil	0.965-0.977 <sup>a</sup>	1.528-1.539	+11 <sup>0</sup> 0' to +24 <sup>0</sup> 0'	Soluble in 5-8 vols of 80% alcohol and in 0.5 vols of 90% alcohol	Congealing point, not below 5 <sup>0</sup> , and as high as 10 <sup>0</sup> in good oi Is
celery seed oil	0.872-0.891 <sup>a</sup>	1.480-1.484	+65 <sup>0</sup> 53' to 76 <sup>0</sup> 51'	Turbid in 90% alcohol	Saponification number, 25.1-47.6

Caraway seed oil	0.907-0.919 <sup>a</sup>	1.484-1.488	+70 <sup>0</sup> 0' to +81 <sup>0</sup> 0'	Seldom soluble in 70% alcohol, soluble in 2-10 vols of 80% alc., clearly soluble in equal vols of 90% alcohol.	Carvone content, 50.0 -60%
Parsley seed oil	1.043-1.110 <sup>a</sup>	1.512-1.528	-4 <sup>0</sup> 0' to -10 <sup>0</sup> 8'	4-8 vols and more of 80% alcohol	Acid number. up to 6: Ester number, I to 11, Ester number after acetylation. 4 to 20
Parsley herb oil	0.902-1.016 <sup>a</sup>	1.509-1.526	+1 <sup>0</sup> 16' to +4 <sup>0</sup> 30'	Soluble in 95% alcohol	Acid number, up to I. Ester number. 5 to 14, Ester number after acetylation, 19-68

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**a - at 15<sup>0</sup>C**

### Major essential oils - their production and adulterants

Essential oil	Origin	Major Countries	Adulterants employed
Cassia oil	Cinnamomum Cassia (Lauraceae)	China, Indonesia, Vietnam, Taiwan	Cinnamaldehyde
Cinnamon oil	Cinnamomum Zeylanicum (Lauraceae)	Sri Lanka, India	Leaf oil to bark oil and cinnamaldehyde
Clove leaf oil	Syzygium aromaticum (Myrtaceae)	Madagascar, Indonesia, Tanzania, Brazil, Sri Lanka	Clove stem oil
Clove bud oil	Syzygium aromaticum (Myrtaceae)	Indonesia, Madagascar	Clove stem oil, leaf oil, eugenol, and stem oil terpenes
Coriander oil	Coriandrum sativum (Umbelliferae)	Russia	Synthetic linalool
Mint oil	Mentha arvensis (Labiatae)	China, Brazil, India, Paraguay, Taiwan, Thailand, North Korea, Japan	Not a commercially attractive proposition
Dill oil	Anethum graveolens (Umbelliferae)	US, Hungary, Bulgaria, Russia, Egypt	Distilled orange terpenes
Garlic oil	Allium sativum (Liliaceae)	Mexico, Italy, Egypt	Nature identical raw materials
Ginger oil	Zingiber officinale (Zingiberaceae)	China, India	Not often adulterated