**Biosynthetic pathways and** **metabolic engineering of aroma and pungent compounds from spice plants**

**Supporting Information**

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**Table S1**

The literature information of volatile compounds profiling on spice plants surveyed in the present study. The composition of each aroma compound was collected and normalized into the percentage of the concentration from volatile compounds or essential oils.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Name | Part | Species name | Family | Sampling | GC/MS Column | References |
| Leek | white part of the leek stem | *Allium ampeloprasum* Var. Bulga | *Allioideae* | Dynamic Headspace Collection | DB Wax | (Nielsen & Poll, 2004) |
| Rakkyo | leaves | *Allium chinense G. Don* | *Allioideae* | simultaneous steam distillation | DB-1 fused silica capillary column | (Pino, Fuentes, & Correa, 2001) |
| Chive | leaves | *Allium tuberosum Rottl. ex Sprengel* | *Allioideae* |
| Garlic | bulbs | *Allium sativum L.* | *Allioideae* | SPME | DB-5ms | (Kim, Park, Jang, & Lee, 2011) |
| Cilantro | leaves | *Coriandrum sativum L.* | *Apiaceae* | Distillation | HP-5 fused silica capillary column | (Potter, 1996) |
| Cerely | seed | *Apium graveolens L. (cv.* | *Apiaceae* | SPME | HP-5 capillary column (30 | (Organica et al., 2004) |
| Caraway | seed | *Carum carvi L.* | *Apiaceae* | Microwave assistant | DB-1 | (Chemat, Aït-Amar, Lagha, & Esveld, 2005) |
| Anise | seed | *Pimpinella anisum L.* | *Apiaceae* | Hydrodistillation | Perkin Elmer Elite-5MS capillary column | (G. Singh, Kapoor, Singh, Heluani, & Catalan, 2008) |
| Fennel | seed | *Foeniculum vulgare Mill.* | *Apiaceae* | Simultaneous distillation-extraction (SDE) | SPB-1 (Supelco) methyl silicone column  | (Idalgo, 2005) |
| Bunium persicum | seed | *Bunium persicum* | *Apiaceae* | Hydrodistillation | DB-5 | (Oroojalian, Kasra-Kermanshahi, Azizi, & Bassami, 2010) |
| Cumin | seed | *Cuminum cyminum* | *Apiaceae* |
| Carum copticum | seed | *Carum copticum* | *Apiaceae* |
| Dill  | seed | *Anethum graveolens L.* | *Apiaceae* | Water distillation | FSOT-RSL-200 or FS-HYDRODEX-β-PM fused silica column | (Jirovetz, Buchbauer, Stoyanova, Georgiev, & Damianova, 2003) |
| Coriander  | seed | *Coriandrum sativum L.* | *Apiaceae* | Hydrodistillation | DB-5 | (Bhuiyan, Begum, & Sultana, 2009) |
| Basil | leaves | *Ocimum basilicum L.* | *Lamiaceae* | Hydrodistillation | HP-20M column | (Politeo, Jukic, & Milos, 2006) |
| Thyme | leaves | *Thymus vulgaris L.* | *Lamiaceae* | Simultaneous distillation-extraction (SDE) | SPB-1 (Supelco) methyl silicone column  | (Idalgo, 2005) |
| Savory | Aeiral | *Satureja montana L.* | *Lamiaceae* | Hydrodistillation | CP Sil 8 CB capillary column | (Bezić, Šamanić, Dunkić, Besendorfer, & Puizina, 2009) |
| Majoran | Fresh flower | *Origanum majorana L.* | *Lamiaceae* | Hydrodistillation | BP-1fused silica capillary colum | (Vera & Chane-Ming, 1999) |
| Rosemary | Plants | *Rosmarinus officinalis L.* | *Lamiaceae* | Hydrodistillation | TRACE TR-5 | (Szumny, Figiel, Gutiérrez-Ortíz, & Carbonell-Barrachina, 2010) |
| Oregano | Plants | *Origanum vulgare* | *Lamiaceae* | Hydrodistillation | TRACE TR-5 | (Figiel, Szumny, Gutiérrez-Ortíz, & Carbonell-Barrachina, 2010) |
| Sage | aerial | *Salvia officinalis L.* | *Lamiaceae* | Hydrodistillation | DB-5MS | (Bouaziz, Yangui, Sayadi, & Dhouib, 2009) |
| Cinnamon  | bark | *Cinnamomum altissimum Kosterm* | *Lauraceae* | Hydrodistillation  | HP-5MS UI fused-silica capillary column | (Abdelwahab et al., 2017) |
| Bay | leaves | *Laurus nobilis L. leaves* | *Lauraceae* | Hydrodistillation | HP-5MS capillary column | (Sellami et al., 2011) |
| Allspice | fruit | *Pimenta dioica Lindl* | *Myrtaceae* | Hydrodistillation | VF-1 ms column | (Monteiro et al., 2011) |
| Clove | bud | *Eugenia caryophyllata Thun.* | *Myrtaceae* | Supercritical fluid extraction | DB-5 | (Della Porta, Taddeo, D’Urso, & Reverchon, 1998) |
| White pepper | berry | *Piper nigrum* L. | *Piperaceae* | Hydrodistillation  | Perkins Elmer Elite-5MS capillary column | (S. Singh et al., 2013) |
| Black pepper | seed | *Piper nigrum* L. | *Piperaceae* | Hydrodistillation, SPME | RSL-200 or HP-5MS | (Jirovetz, Buchbauer, Ngassoum, & Geissler, 2002) |
| Ashanti pepper (black) | seed | *Piper guineense* | *Piperaceae* | Hydrodistillation, SPME |
| Ashanti pepper (white). | seed | *Piper guineense* | *Piperaceae* | Hydrodistillation, SPME |
| Orange | juice | *Citrus sinensis* | *Ruteceae* | Hydrodistillation | DB-wax | (Högnadóttir & Rouseff, 2003) |
| Japenese peper | fruit | *Xanthoxylum piperitum DC.* | *Ruteceae* | Methanol extraction | DB-wax | (Jiang & Kubota, 2004) |
| Sichuan pepper | seed | *Zanthoxylum bungeanum Maxim* | *Ruteceae* | Hydrodistillation | DB-5 | (X. Yang, 2008) |
| Star anise | fruit | *Illicium verum Hooker fil* | *Schisandraceae*  | Supercritical fluid extraction | DB-5 | (Della Porta et al., 1998) |
| Turmeric | rhizome | *Curcuma longa Linn.* | *Zingiberaceae* | Hydro distillation | Elite-1 fused silica column | (Kutti Gounder & Lingamallu, 2012) |
| Cardamom  | fruit | *Elettaria cardamomum (L.)* | *Zingiberaceae* | Hydrodistilled | a fused silica column Ulbon HR-1 | (Husain & Ali, 2014) |
| Ginger | rhizome | *Zingiber officinale Rosc. (Zingiberaceae),* | *Zingiberaceae* | HS-SPME: | DB - 5 | (Z. Yang et al., 2009) |

**Table S2**

Enzymes or genes involved in the metabolic engineering biosynthesis of spice flavor compounds.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Compound type | Flavor compound | Enzyme  | Gene | Reference |
| Terpene |  (+)-Valencene  | Terpene synthase CsTPS1 | *CitAP2.10* | Chang et al. 2007 |
| *S*-Linalool | *S*-linaloolsynthase (*LIS*)  | *S-linalool**synthase (LIS) gene* | Lewinsohn et al. 2001 |
| Linalool | Linalool synthases | *CuSTS3-1, CuSTS3-2* | Shimada et al. 2014 |
| Nerolidol/linaloolsynthase | *CuSTS4* |
| Bisabolene | Bisabolene synthases | *ZoTps1* | Fujisawa et al. 2010 |
| Phenylpropanoid | Eugenol | Eugenol synthase |  | Ferrer et al. 2008 |
| Estragole, methyl eugenol | *O*-methyltransferase |  | Lewinsohn et al. 2000 |
| Eugenol, isoeugenol | Eugenol/isoeugenol synthase | *EGS1, IGS1* | Koeduka et al. 2006 |
| Cinnamic acid,p-coumaric acid, caffeic acid, and ferulicacid | Phenylalanine ammonia-lyase, tyrosine ammonia-lyase, 4-coumarate: CoA ligase, stilbene synthase, 4-coumarate 3-hydroxylase, caffeic acid 3-O-methyltrans-ferase, and aflavin-dependent halogenase  | *PAL, TAL, 4CL, STS, C3H, COMT, Rdc2* | Wang et al. 2015 |
| Sulfocompound | Cysteine | Cysteine synthase |  | Urano et al. 2000 |
| *O*-Acetylserine | Serine acetyltransferase |  |
| γ-Glutamyl peptide | γ-Glutamyl transpeptidase |  | Shaw et al. 2005 |
| Allicin | Alliinase |  | Thomson et al. 2013 |
| trans-S-1-propenyl-L-cysteinesulfoxide | Lachrymatory factor synthase |  | Oa et al. 2008 |
| Pungent compounds | Curcuminoids | Curcuminoid synthase |  | Ramirez-Ahumada et al. 2006 |
| Gingerol | Hydroxycinnamoyl-CoA thioesterases |  |
| Capsaicin | Capsaicin synthase | *Csy1* | Narasimha Prasad et al. 2006 |

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