Supporting information

**Optimized Hop Extracts Method Effectively Inhibits *Paenibacillus larvae,* the Causative Agent of American Foulbrood, Without Toxic Effects on Honey Bees**

Fuentes Gisellea,b; Iglesias Azucenaa,b; Mitton Giuliaa,b; Orallo Dalilac; Chaparro Mauroe; Ramos Facundoa,b; Maggi Matiasa,b; Ramirez Cristinac; Fuselli Sandraa,d,.

Corresponding autor: Fuentes Giselle. gisellefuentes07@gmail.com

Table I: List of volatile organic compounds found for each variety of hops in the extracts obtained with the different solvents, the area percentages and Kovats indices are indicated.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Extraction solvent | Compound | Bullion | Nugget | Victoria | Cascade | Theoretical Kovats |
| **% Área** | **KI** | **% Área** | **KI** | **% Área** | **KI** | **% Área** | **KI** |
| Hexane | β myrcene | 6.212 | 993.990 | 4.652 | 993.730 | 3.755 | 993.990 | 6.226 | 993.544 | **992** |
| perillen |  |  |  |  |  |  | 1.913 | 1107.700 | **1099** |
| β-linalool | 4.175 | 1103.757 |  |  | 2.457 | 1103.823 | 3.215 | 1100.725 | **1099** |
| 3-methoxymethoxy-butyric acid |  |  | 9.360 | 1118.089 | 4.843 | 1118.124 | 9.907 | 1118.003 | **1118.1** |
| octanoic acid |  |  |  |  | 1.901 | 1165.985 |  |  | **1165** |
| diethyl succinate | 1.659 | 1180.374 | 9.686 | 1180.297 | 1.498 | 1180.415 | 2.958 | 1180.272 | **1179** |
| 2.3-dimethyl-2-hexanol | 12.243 | 1183.639 |  |  | 13.248 | 1183.790 | 19.500 | 1183.740 | **1183.4** |
| β- geraniol | 2.376 | 1249.250 |  |  |  |  |  |  | **1255** |
| 2-decenal. (Z) |  |  |  |  | 2.368 | 1263.998 |  |  | **1263** |
| α-citral |  |  |  |  |  |  | 1.789 | 1267.213 | **1268** |
| methyl 4-decenoate | 4.119 | 1290.004 |  |  |  |  | 4.378 | 1290.994 | **1290** |
| 2.4-decadienal. (E.E) |  |  |  |  | 2.588 | 1292.947 |  |  | **1293** |
| perillalkohol | 0.658 | 1297.087 |  |  |  |  | 1.211 | 1297.099 | **1297** |
| methyl geranate | 1.237 | 1322.561 |  |  |  |  | 1.304 | 1323.086 | **1323** |
| methyl decanoate | 0.611 | 1324.974 |  |  |  |  |  |  | **1324** |
| geranil acetate | 2.915 | 1384.254 | 6.552 | 1383.433 |  |  | 1.336 | 1384.776 | **1383** |
| 2-dodecanone | 0.645 | 1383.043 |  |  |  |  |  |  | **1384** |
| β-caryophyllene |  |  |  |  | 2.535 | 1437.500 |  |  | **1428** |
| geranil propanoate | 0.689 | 1479.281 | 0.731 | 1478.767 |  |  | 0.659 | 1479.538 | **1478** |
| germacrene A | 1.768 | 1503.780 |  |  | 0.096 | 1503.912 |  |  | **1503** |
| germacrene B | 1.982 | 1557.214 |  |  |  |  | 5.801 | 1557.532 | **1556** |
| nerolidol | 1.474 | 1565.235 | 10.494 | 1564.681 |  |  | 0.925 | 1565.928 | **1565** |
| β-caryophyllene epoxide | 0.340 | 1584.929 | 0.702 | 1585.106 |  |  |  |  | **1569** |
| humulene oxide | 0.187 | 1613.121 | 0.972 | 1613.121 | 6.511 | 1613.121 | 0.277 | 1613.995 | **1609** |
| δ-cadinoL | 1.301 | 1639.621 | 1.701 | 1638.671 | 0.724 | 1639.461 | 0.409 | 164.035 | **1639** |
| No Identificado | 1.339 | 1699.054 |  |  | 0.391 | 1696.576 | 0.405 | 1698.734 |  |
| neophytadiene | 1.422 | 1827.561 | 3.319 | 1827.016 |  |  | 1.004 | 1831.127 | **1830** |
| hulupulone | 0.285 |  | 1.061 |  | 0.487 |  |  |  | **ST** |
| 2.6-farnesol | 3.226 | 1730.843 | 15.585 | 1730.249 | 1.134 | 1730.843 | 3.523 | 1730.972 | **1730** |
| palmitic acid | 1.650 | 1962.249 | 3.318 | 1961.847 | 1.370 | 1962.450 | 1.953 | 1962.450 | **1970** |
| dehydrohumulinic acid | 0.323 | 1980.667 | 1.223 | 1980.912 | 0.616 | 1980.912 | 0.649 | 1980.891 | **1980** |
| linoleic acid | 5.448 | 2164.072 | 2.059 | 2162.874 | 4.999 | 2164.471 | 3.425 | 2164.671 | **2152** |
| stearic acid |  |  |  |  | 0.602 | 2164.471 | 0.435 | 2164.072 | **2172** |
| 1-docosanol | 2.144 | 2475.138 | 1.718 | 2475.587 | 30.462 | 2476.589 | 8.274 | 2475.890 | **2476** |
| cis- isohumulone | 18.324 | 2712.852 | 18.347 | 2707.173 | 11.959 | 2712.947 | 8.400 | 2714.060 | **2715** |
| humulone | 6.068 | 2355.110 |  |  | 1.697 | 2355.110 | 4.164 | 2355.110 | **ST** |
| colupulone | 9.820 | 2426.369 | 5.997 | 2426.369 | 0.554 | 2426.369 | 3.756 | 2426.369 | **ST** |
| n-adlupulone | 5.361 | 2505.144 | 2.522 | 2505.144 | 0.495 | 2505.144 | 2.205 | 2505.144 | **ST** |
| 1-palmitoylglycerol |  |  |  |  | 2.709 | 2745.268 |  |  | **2745** |
| Dicloromethane | β myrcene | 19.313 | 993.028 | 13.673 | 993.157 | 19.993 | 993.544 | 19.695 | 992.447 | **992** |
| 1-hexanol. 2-ethyl |  |  |  |  | 2.394 | 1028.885 |  |  | **1029** |
| perillen |  |  |  |  |  |  | 0.682 | 1105.767 | **1099** |
| β-linalool |  |  |  |  | 1.829 | 1101.055 | 1.005 | 1101.055 | **1099** |
| linalool oxide | 2.173 | 1102.084 | 0.496 | 1100.600 |  |  | 0.006 | 1103.847 | **1107** |
| Isopulegol |  |  | 1.174 | 1147.832 |  |  |  |  | **1146** |
| 6-methylL-1.6-heptanediol | 5.927 | 1149.613 |  |  |  |  |  |  | **1151** |
| lavandulol |  |  |  |  |  |  | 0.486 | 1149.560 | **1152** |
| diethyl succinate |  |  | 1.055 | 1178.560 | 0.697 | 1178.15 | 1.466 | 1178.020 | **1179** |
| β- geraniol |  |  |  |  | 0.393 | 1249.880 | 0.664 | 1249.05 | **1255** |
| 2-decenal. (Z) |  |  |  |  | 0.731 | 1263.450 |  |  | **1263** |
| α-citral |  |  |  |  |  |  | 0.367 | 1267.540 | **1268** |
| methyl 4-decenoate | 2.234 | 1289.716 | 1.173 | 1289.716 | 1.593 | 1289.642 |  |  | **1290** |
| 2.4-decadienal. (E.E) |  |  |  |  | 0.493 | 1292.567 |  |  | **1293** |
| perillalkohol | 1.040 | 1296.760 |  |  |  |  |  |  | **1297** |
| methyl geranate | 0.435 | 1322.470 |  |  |  |  | 0.553 | 132.206 | **1323** |
| methyl decanoate | 0.199 | 1323.875 |  |  |  |  |  |  | **1324** |
| α-copaene | 0.434 | 1377.057 |  |  | 0.357 | 1376.890 |  |  | **1377** |
| geranil acetate | 2.026 | 1383.507 | 1.784 | 1383.209 |  |  | 0.589 | 1383.507 | **1383** |
| 2-dodecanone |  |  |  |  | 0.308 | 1384.367 |  |  | **1384** |
| β-caryophyllene | 0.972 | 1437.072 | 4.875 | 1436.558 | 1.766 | 1437.158 | 0.483 | 1436.901 | **1428** |
| trans α- bergamotene |  |  | 0.449 | 1437.798 |  |  | 0.472 | 1437.872 | **1438** |
| alloaromadendrene |  |  |  |  | 0.100 | 1451.940 |  |  | **1452** |
| α-caryophyllene | 2.664 | 1470.548 | 0.220 | 1470.548 | 7.649 | 1470.805 | 2.640 | 1471.747 | **1463** |
| γ-gurjunene |  |  |  |  | 2.774 | 1474.951 |  |  | **1473** |
| geranil propanoate | 4.659 | 1479.366 | 2.208 | 1478.938 |  |  | 0.312 | 1478.767 | **1478** |
| germacrene D | 1.140 | 1480.051 | 0.560 | 1479.709 | 0.852 | 1479.880 |  |  | **1480** |
| germacrene A | 2.714 | 1502.982 | 1.904 | 1502.003 | 0.170 | 1502.982 | 0.117 | 1502.003 | **1503** |
| germacrene B |  |  |  |  | 0.393 | 1556.243 | 0.270 | 1556.768 | **1556** |
| nerolidol | 1.071 | 1564.958 | 2.684 | 1564.820 |  |  | 0.542 | 1564.681 | **1565** |
| β-caryophyllene epoxide | 0.967 | 1572.218 | 2.975 | 1571.798 | 1.877 | 1572.008 | 0.205 | 1572.008 | **1569** |
| 3-thujanol | 1.918 | 1573.998 |  |  |  |  | 0.805 | 1773.298 | **1573** |
| guaiol | 3.346 | 1587.943 |  |  |  |  |  |  | **1588** |
| humulene oxide | 1.194 | 1613.121 | 5.421 | 1612.943 | 0.275 | 1613.121 | 0.379 | 1613.121 | **1609** |
| δ-cadinoL | 4.394 | 1638.671 |  |  |  |  |  |  | **1639** |
| humuladienone | 4.531 |  |  |  |  |  | 0.390 |  | **ST** |
| hulupulone | 0.670 |  | 0.381 |  | 0.480 |  | 0.442 |  | **ST** |
| 2.6-farnesol | 3.006 | 1730.395 |  |  |  |  | 1.285 | 1730.395 | **1730** |
| palmitic acid | 3.006 | 1961.647 | 0.644 | 1962.048 | 0.385 | 1962.048 | 0.367 | 1961.647 | **1970** |
| dehydrohumulinic acid | 0.687 | 1976.832 |  |  |  |  | 0.332 | 1976.645 | **1980** |
| linoleic acid |  |  |  |  |  |  | 0.406 | 2162.874 | **2152** |
| stearic acid |  |  |  |  | 0.201 | 2164.471 |  |  | **2172** |
| 1-docosanol |  |  | 0.678 | 2475.860 |  |  |  |  | **2476** |
| cis- isohumulone | 16.689 | 2707.173 | 16.286 | 2710.439 | 16.300 | 2706.981 | 20.547 | 2712.852 | **2715** |
| humulone |  |  | 2.183 | 2355.110 |  |  |  |  | **ST** |
| colupulone | 7.885 | 2426.369 | 21.531 | 2426.369 | 17.039 | 2426.369 | 25.318 | 2426.369 | **ST** |
| n-adlupulone | 4.705 | 2505.144 | 17.649 | 2505.144 | 20.950 | 2505.144 | 19.175 | 2505.144 | **ST** |
| Ethyl acetate | β myrcene | 19.687 | 993.057 |  |  | 20.503 | 993.508 | 7.152 | 993.990 | **992** |
| β-linalool | 1.896 | 1100.600 |  |  | 1.156 | 1101.055 | 0.435 | 1101.384 | **1107** |
| 3-methoxymethoxy-butyric acid |  |  |  |  |  |  | 2.503 | 1117.999 | **1118.1** |
| octanoic acid |  |  |  |  |  |  | 0.641 | 1165.985 | **1165** |
| 2.3-dimethyl-2-hexanol | 4.069 | 1182.261 |  |  |  |  | 3.210 | 1182.739 | **1183.4** |
| β- geraniol |  |  |  |  |  |  | 0.232 | 1255.728 | **1255** |
| 2-decenal. (Z) |  |  |  |  | 0.546 | 1263.958 | 0.367 | 1263.009 | **1263** |
| methyl 4-decenoate | 0.212 | 1290.642 |  |  | 0.133 | 1290.004 | 2.162 | 1290.616 | **1290** |
| methyl geranate |  |  |  |  |  |  | 0.596 | 1323.047 | **1323** |
| α-copaene | 0.289 | 1376.998 |  |  | 0.318 | 1377.023 |  |  | **1377** |
| geranil acetate | 1.563 | 1384.328 |  |  |  |  | 0.671 | 1384.701 | **1383** |
| β-caryophyllene | 0.712 | 1437.414 |  |  | 1.425 | 1437.586 | 0.635 | 1437.928 | **1428** |
| trans α- bergamotene |  |  |  |  |  |  | 0.562 | 1450.873 | **1451** |
| α-caryophyllene | 2.000 | 1470.805 |  |  | 6.160 | 1470.976 | 3.307 | 1471.318 | **1463** |
| geranil propanoate | 0.342 | 1479.110 |  |  |  |  | 0.388 | 1479.538 | **1478** |
| germacrene D | 0.625 | 1480.223 |  |  | 0.923 | 1480.394 | 0.561 | 1480.137 | **1480** |
| germacrene A |  |  | 18.448 | 1503.322 |  |  | 0.204 | 1503.780 | **1503** |
| germacrene B |  |  |  |  | 0.311 | 1556.235 | 0.301 | 1556.875 | **1556** |
| nerolidol | 0.807 | 1564.958 | 3.972 | 1564.266 |  |  | 4.617 | 1565.928 | **1565** |
| β-caryophyllene epoxide | 0.454 | 1613.121 |  |  | 0.242 | 1612.943 | 0.212 | 1612.234 | **1569** |
| humulene oxide | 0.628 | 1612.998 |  |  | 0.515 | 1613.121 | 0.505 | 1613.898 | **1609** |
| δ-cadinoL |  |  | 33.260 | 1639.621 |  |  |  |  | **1639** |
| no identificado |  |  |  |  |  |  | 0.657 | 1698.659 |  |
| tetradecanoic acid |  |  |  |  | 0.265 | 1768.008 | 0.184 | 1761.303 | **1768** |
| humuladienone | 2.555 |  |  |  |  |  | 0.340 |  | **ST** |
| neophytadiene |  |  | 32.240 | 1827.324 |  |  |  |  | **1830** |
| hulupulone | 0.237 |  |  |  | 0.179 |  | 0.308 |  | **ST** |
| palmitic acid | 0.858 | 1961.446 | 9.508 | 1961.847 |  |  | 1.141 | 1963.253 | **1970** |
| dehydrohumulinic acid |  |  |  |  |  |  | 0.441 | 1976.645 | **1980** |
| stearic acid | 0.335 | 2164.072 | 2.573 | 2164.072 | 0.197 | 2163.473 |  |  | **2172** |
| 1-docosanol | 0.852 | 2475.348 |  |  | 0.446 | 2475.348 | 1.099 | 2475.860 | **2501** |
| cis- isohumulone | 30.227 | 2707.173 |  |  | 38.877 | 2712.852 | 15.389 | 2713.354 | **2715** |
| humulone |  |  |  |  | 3.982 | 2355.110 | 4.807 | 2355.110 | **ST** |
| colupulone | 19.296 | 2426.369 |  |  | 10.687 | 2426.369 | 25.444 | 2426.369 | **ST** |
| n-adlupulone | 12.358 | 2505.144 |  |  | 13.133 | 2505.144 | 20.246 | 2505.144 | **ST** |
| squalene |  |  |  |  |  |  | 0.684 | 2832.978 | **2833** |
| Ethanol | 3-methyl-2-cyclopenten-1-one |  |  |  |  |  |  | 1.210 | 843.612 | **843** |
| 2.3-dimethyl-2-butenoic acid |  |  |  |  | 1.781 | 936.735 |  |  | **936** |
| β myrcene |  |  | 8.230 | 992.511 | 9.685 | 991.620 | 0.681 | 992.380 | **992** |
| β-linalool | 9.994 | 1101.600 |  |  | 1.322 | 1101.978 | 1.869 | 1104.746 | **1099** |
| 3-methoxymethoxy-butyric acid |  |  | 5.123 | 1118.003 |  |  | 10.415 | 1118.001 | **1118.1** |
| caprylic acid. methyl ester | 3.289 | 1124.133 |  |  |  |  |  |  | **1120** |
| diethyl succinate |  |  | 1.457 | 1179.142 |  |  | 3.116 | 1180.152 | **1179** |
| 2.3-dimethyl-2-hexanol |  |  | 4.116 | 1182.261 | 1.047 | 1182.842 | 6.820 | 1182.501 | **1183.4** |
| nonanoic acid. methyl ester | 11.222 | 1223.568 |  |  |  |  |  |  | **1227** |
| nonanoic acid | 12.710 | 1262.775 |  |  |  |  |  |  | **1280** |
| 4 decenoic acid methyl ester | 0.935 | 1310.373 |  |  |  |  |  |  | **1290** |
| methyl decanoate |  |  | 1.431 | 1326.642 | 1.303 | 1326.642 |  |  | **1324** |
| geranil acetate | 8.838 | 1384.104 | 2.143 | 1383.433 |  |  | 2.357 | 1384.701 | **1383** |
| β-caryophyllene | 2.401 | 1437.329 | 0.512 | 1436.729 | 0.786 | 1437.500 | 0.323 | 1438.014 | **1428** |
| trans α- bergamotene |  |  | 1.122 | 1437.874 |  |  |  |  | **1438** |
| alloaromadendrene |  |  |  |  | 1.324 | 1451.016 |  |  | **1452** |
| β-farnesene | 1.829 | 1466.182 |  |  |  |  |  |  | **1460** |
| α-caryophyllene | 13.845 | 1473.459 | 3.497 | 1470.548 | 4.612 | 1470.976 | 2.016 | 1470.805 | **1463** |
| geranil propanoate | 7.010 | 1479.195 | 0.301 | 1478.767 |  |  | 0.268 | 1479.538 | **1478** |
| germacrene D | 2.557 | 1482.192 | 0.418 | 1479.623 | 0.438 | 1480.137 |  |  | **1480** |
| germacrene A |  |  | 1.835 | 1502.003 | 0.085 | 1503.567 | 1.513 | 1503.780 | **1503** |
| δ-cadinene | 5.205 | 1539.612 |  |  | 0.084 | 1528.532 |  |  | **1530** |
| nerolidol |  |  | 0.543 | 1564.543 |  |  | 3.626 | 1566.066 | **1565** |
| β-caryophyllene epoxide | 10.677 | 1599.468 | 0.253 | 1585.284 | 0.150 | 1598.582 | 0.389 | 1598.936 | **1569** |
| 3-thujanol |  |  |  |  |  |  | 1.374 | 1574.349 | **1573** |
| humulene oxide |  |  | 0.504 | 1613.121 | 0.148 | 1613.038 | 0.746 | 1613.850 | **1609** |
| δ-cadinoL |  |  | 4.186 | 1639.621 | 4.289 | 1639.843 | 12.147 | 1639.975 | **1639** |
| tetradecanoic acid |  |  |  |  | 0.264 | 1761.303 |  |  | **1768** |
| neophytadiene |  |  | 0.480 | 1828.014 |  |  |  |  | **1830** |
| hulupulone |  |  |  |  | 0.625 |  | 0.515 |  | **ST** |
| 2.6-farnesol |  |  | 1.853 | 1730.533 | 0.777 | 1730.761 | 1.182 | 1730.987 | **1730** |
| palmitic acid | 1.912 | 1961.245 | 1.508 | 1961.647 | 1.491 | 1962.048 | 1.503 | 1962.048 | **1970** |
| dehydrohumulinic acid |  |  | 0.609 | 1976.391 | 0.974 | 1976.017 | 2.296 | 1977.214 | **1980** |
| linoleic acid | 7.575 | 2163.473 | 1.657 | 2162.874 | 0.922 | 2163.273 | 4.555 | 2164.471 | **2152** |
| stearic acid |  |  | 0.238 | 2164.072 | 0.371 | 2164.072 | 0.655 | 2164.471 | **2172** |
| 1-docosanol |  |  | 4.089 | 2502.741 | 1.694 | 2502.936 |  |  | **2476** |
| cis- isohumulone |  |  | 11.845 | 2712.852 | 32.882 | 2712.947 |  |  | **2715** |
| humulone |  |  |  |  | 5.676 | 2355.110 |  |  | **ST** |
| colupulone |  |  | 22.286 | 2426.369 | 12.805 | 2426.369 | 21.087 | 2426.369 | **ST** |
| n-adlupulone |  |  | 19.764 | 2505.144 | 16.247 | 2505.144 | 20.550 | 2505.144 | **ST** |
| Methanol | β myrcene |  |  | 3.168 | 991.410 | 6.815 | 991.280 | 6.037 | 991.280 | **992** |
| β-linalool | 1.600 | 1102.109 |  |  |  |  |  |  | **1099** |
| caprylic acid. methyl ester | 0.639 | 1123.665 |  |  |  |  |  |  | **1120** |
| 2.3-dimethyl-2-hexanol | 13.827 | 1183.639 |  |  |  |  |  |  | **1183.4** |
| 2-decenal. (Z) |  |  |  |  |  |  | 0.223 | 1263.009 | **1263** |
| nonanoic acid | 2.602 | 1262.775 |  |  |  |  |  |  | **1280** |
| 4 decenoic acid methyl ester | 4.662 | 1310.448 |  |  |  |  |  |  | **1290** |
| 2.4-decadienal. (E.E) |  |  |  |  |  |  | 0.241 | 1292.995 | **1293** |
| methyl decanoate |  |  |  |  |  |  | 0.808 | 1290.004 | **1324** |
| geranil acetate | 4.683 | 1384.104 | 3.095 | 1385.000 | 0.146 | 1384.000 | 0.282 | 1384.478 | **1383** |
| β-caryophyllene | 1.552 | 1437.414 | 4.606 | 1438.099 | 0.663 | 1437.414 | 0.139 | 1437.671 | **1428** |
| α-caryophyllene | 7.027 | 1473.459 | 2.535 | 1470.805 | 3.718 | 1470.548 | 1.194 | 1470.976 | **1463** |
| geranil propanoate | 5.034 | 1479.538 | 0.334 | 1479.776 |  |  | 0.188 | 1479.538 | **1478** |
| germacrene D |  |  |  |  | 0.401 | 1480.137 |  |  | **1480** |
| germacrene A |  |  |  |  | 0.075 | 1503.567 |  |  | **1503** |
| α- amorphene | 8.003 | 1517.313 |  |  |  |  |  |  | **1506** |
| δ-cadinene | 4.635 | 1528.532 |  |  | 0.180 | 1528.532 |  |  | **1530** |
| No identificado |  |  | 1.086 | 1698.659 |  |  | 0.724 | 1697.172 |  |
| nerolidol |  |  | 4.576 | 1566.205 |  |  | 0.332 | 1565.651 | **1565** |
| β-caryophyllene epoxide |  |  | 0.240 | 1612.790 | 0.909 | 1598.582 | 0.898 | 1599.582 | **1569** |
| humulene oxide | 7.178 | 1599.468 | 0.669 | 1616.667 | 0.162 | 1612.943 | 0.193 | 1615.780 | **1609** |
| δ-cadinoL |  |  |  |  | 0.981 | 1639.845 | 2.098 | 1639.845 | **1639** |
| 2-pentadecanone |  |  |  |  | 0.160 | 1669.736 |  |  | **1671** |
| tetradecanoic acid | 1.128 | 1761.303 |  |  | 0.269 | 1768.008 |  |  | **1768** |
| humuladienone |  |  |  |  | 0.168 |  |  |  | **ST** |
| neophytadiene |  |  | 0.348 | 1828.358 |  |  |  |  | **1830** |
| hulupulone |  |  |  |  | 0.921 |  | 0.311 |  | **ST** |
| di-isobuthyl phthalate | 7.696 | 1878.685 |  |  |  |  |  |  | **1874.3** |
| palmitic acid | 6.449 | 1962.048 | 2.440 | 1962.450 | 1.870 | 1962.048 | 1.820 | 1962.450 | **1970** |
| dehydrohumulinic acid |  |  | 1.489 | 1976.243 | 3.516 | 1976.0o2 | 0.280 | 1976.645 | **1980** |
| linoleic acid | 6.382 | 2163.673 | 2.444 | 2164.671 | 1.109 | 2163.473 | 6.295 | 2164.471 | **2152** |
| stearic acid | 2.867 | 2164.072 | 0.995 | 2164.072 | 0.393 | 2164.072 |  |  | **2172** |
| 1-docosanol |  |  |  |  | 0.817 | 2475.138 | 2.261 | 2475.138 | **2476** |
| cis- isohumulone |  |  |  |  | 36.578 | 2712.947 | 16.607 | 2713.129 | **2715** |
| humulone |  |  |  |  |  |  | 6.103 | 2355.110 | **ST** |
| colupulone | 9.741 | 2426.369 | 39.662 | 2426.369 | 18.437 | 2426.369 | 29.902 | 2426.369 | **ST** |
| n-adlupulone | 4.292 | 2505.144 | 32.313 | 2505.144 | 21.711 | 2505.144 | 23.065 | 2505.144 | **ST** |
| Water | nonanal | 1.663 | 1105.010 | 1.694 | 1104.680 | 2.805 | 1104.680 | 44.220 | 1105.142 | **1104** |
| octanoic acid | 3.914 | 1165.985 | 6.050 | 1165.656 |  |  |  |  | **1179** |
| 2.3-dimethyl-2-hexanol | 30.878 | 1183.789 | 16.162 | 1182.859 |  |  |  |  | **1183.4** |
| nonanoic acid | 11.574 | 1275.775 | 1.581 | 1275.015 | 12.527 | 1269.613 |  |  | **1280** |
| 2-undecenal |  |  | 6.927 | 1375.698 |  |  |  |  | **1376** |
| β-caryophyllene |  |  |  |  | 2.110 | 1437.414 |  |  | **1428** |
| phenol. 2.4-BIS(1.1-dimethylethyl) |  |  |  |  | 16.788 | 1554.987 |  |  | **1555** |
| tetradecanoic acid | 2.045 | 1761.303 | 15.859 | 1761.578 | 5.100 | 1761.790 | 12.112 | 1761.998 | **1768** |
| palmitic acid | 4.422 | 1962.021 | 3.373 | 1962.021 | 7.316 | 1962.048 | 43.668 | 1962.015 | **1970** |
| 8-heptadecenoic acid | 4.990 | 2140.765 | 5.612 | 2140.765 |  |  |  |  | **2140** |
| 1-hexadecanone.1cyclopenyty |  |  | 3.842 |  |  |  |  |  | **2288** |
| adipic acid dictyl ester | 11.423 | 2398.086 | 12.405 | 2398.086 |  |  |  |  | **2398.2** |
| squalene | 24.722 | 2832.876 | 26.496 | 2832.876 | 53.354 | 2832.876 |  |  | **2833** |
| stigmastane-3.6-dione. (5α) | 4.370 | 3601.568 |  |  |  |  |  |  | **3601** |

Table II: MIC and MBC average values for all the extracts with each strain of *P.larvae* tested. Statistical significance between hop varieties for MIC (p value: 0. 0487) and MBC (p value: 0. 1809). Statistical significance between solvents for MIC and and MBC (p value ˂ 0.0001).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Solvent** | **Variety** | **Miramar** | **PL62** | **Pl92** |
|  |   | MIC (µg/ml) | MBC(µg/ml) | MIC(µg/ml) | MBC(µg/ml) | MIC(µg/ml) | MBC(µg/ml) |
| **ethanol** | Bullion | 8.51 | 14.58 | 14.52 | 21.87 | 9.72 | 10.94 |
| Nugget | 10.41 | 20.82 | 14.58 | 31.245 | 7.81 | 10.41 |
| Victoria | 10.49 | 19.36 | 17.75 | 19.36 | 5.65 | 9.68 |
| Cascade | 22.84 | 34.26 | 25.70 | 34.26 | 14.27 | 17.13 |
| **hexane** | Bullion | 5.63 | 18.43 | 26.63 | 36.87 | 9.22 | 19.40 |
| Nugget | 13.95 | 20.93 | 25.58 | 41.87 | 16.28 | 27.90 |
| Victoria | 12.36 | 21.19 | 45.91 | 84.76 | 17.66 | 21.19 |
| Cascade | 15.23 | 28.12 | 35.16 | 56.25 | 25.78 | 42.18 |
| **dichlorometane** | Bullion | 5.78 | 8.67 | 15.90 | 17.34 | 6.50 | 8.67 |
| Nugget | 6.42 | 14.00 | 8.75 | 21.00 | 12.83 | 14.00 |
| Victoria | 4.50 | 6.75 | 10.13 | 13.50 | 7.88 | 10.12 |
| Cascade | 4.07 | 6.99 | 6.41 | 10.47 | 6.99 | 6.99 |
| **ethyl acetate** | Bullion | 4.53 | 14.85 | 14.86 | 19.81 | 6.60 | 9.90 |
| Nugget | 32.45 | 74.16 | 67.98 | 111.24 | 43.26 | 74.16 |
| Victoria | 18.82 | 32.26 | 26.88 | 32.26 | 13.44 | 24.19 |
| Cascade | 28.67 | 34.40 | 31.53 | 34.40 | 12.90 | 25.80 |
| **methanol** | Bullion | 8.01 | 17.18 | 14.31 | 17.18 | 5.72 | 5.72 |
| Nugget | 9.86 | 25.35 | 38.04 | 42.26 | 7.75 | 8.45 |
| Victoria | 9.28 | 15.90 | 26.50 | 23.85 | 5.96 | 11.92 |
| Cascade | 12.44 | 13.70 | 16.40 | 20.35 | 5.09 | 6.78 |
| **water** | Bullion | 654.01 | 1121.16 | 2055.47 | 2242.33 | 420.44 | 840.87 |
| Nugget | 646.25 | 1292.49 | 861.66 | 861.66 | 430.83 | 861.66 |
| Victoria | 216.43 | 432.87 | 396.8 | 649.31 | 234.47 | 541.08 |
|  | Cascade | 59.00 | 118.00 | 236.00 | 354.00 | 78.67 | 118.00 |



Figure 5: Survival curves at 24, 48 and 72 hours of adult bees fed with three increasing concentrations of Bullion (B), Nugget (N), Victoria (V) and Cascade hop extracts; (C) Control without solvent (Control); and solvent control (DMSO Control). The minimum inhibitory concentration of the corresponding variety multiplied by 100 = (100xMIC); multiplied by 500 = (500xMIC) and multiplied by 1000 = (1000xMIC). No significant differences were found between the survival curves corresponding to the Nugget, Victoria and Cascade varieties (p > 0.05). For the Bullion variety the analysis showed evidence of significance p=0.0011. The Dunn's test with multiple comparisons analysis indicated significant difference between (Control Vs B100x MIC), p<0.05, difference: -65.02 and (Control Vs B1000x MIC), p<0.05, difference: -59.44.