

**Supplementary Table S1** Qualitative analysis information of volatile flavor substances in marinated beef. Values represent the mean  $\pm$  S.E. (n = 3). The upper lowercase letters indicate significantly different in the same column ( $P < 0.05$ ). MW: molecular weight; RI: retention index; RT: retention time; DT: drift time; volume (a.u.): peak volume.

No.	Compound	CAS#	Formula	MW	RI	Rt(s)	Dt(a.u.)	volume (a.u.)			
								C1	C2	F1	F2
Ketones											
1	2-Propanone	C67641	C <sub>3</sub> H <sub>6</sub> O	58.1	513.0	113.467	1.12392	4351.12±215.50 <sup>b</sup>	3385.46±118.98 <sup>a</sup>	6054.56±437.92 <sup>c</sup>	7552.66±291.32 <sup>d</sup>
2	2-Butanone-M	C78933	C <sub>4</sub> H <sub>8</sub> O	72.1	575.3	140.698	1.06685	2482.01±129.67 <sup>a</sup>	2396.42±154.02 <sup>a</sup>	2727.76±331.46 <sup>a</sup>	2691.47±71.65 <sup>a</sup>
3	2-Butanone-D	C78933	C <sub>4</sub> H <sub>8</sub> O	72.1	577.7	141.726	1.25239	2296.98±135.00 <sup>a</sup>	1390.78±3.80 <sup>a</sup>	4080.28±908.40 <sup>b</sup>	6063.9±795.73 <sup>c</sup>
4	3-Hydroxy-2-butanone-	C513860	C <sub>4</sub> H <sub>8</sub> O <sub>2</sub>	88.1	705.0	203.633	1.05839	4228.5±265.12 <sup>a</sup>	4230.24±44.43 <sup>a</sup>	3816.85±266.36 <sup>ab</sup>	3663.44±411.55 <sup>a</sup>
5	3-Hydroxy-2-butanone-D	C513860	C <sub>4</sub> H <sub>8</sub> O <sub>2</sub>	88.1	709.4	207.230	1.33182	7132.57±508.94 <sup>ab</sup>	6472.24±161.23 <sup>a</sup>	7574.95±109.87 <sup>ab</sup>	7851.79±1002.29 <sup>b</sup>
6	2-Heptanone	C110430	C <sub>7</sub> H <sub>14</sub> O	114.2	892.9	393.972	1.26498	127.76±22.32 <sup>a</sup>	184.79±3.06 <sup>b</sup>	126.34±19.38 <sup>a</sup>	135.07±4.29 <sup>a</sup>
7	Cyclohexanone	C108941	C <sub>6</sub> H <sub>10</sub> O	98.1	896.9	401.310	1.15173	159.91±20.01 <sup>a</sup>	334.57±13.61 <sup>b</sup>	159.84±19.83 <sup>a</sup>	163.18±5.61 <sup>a</sup>
8	6-Methyl-5-hepten-2-one	C110930	C <sub>8</sub> H <sub>14</sub> O	126.2	991.4	577.665	1.18050	177.07±33.51 <sup>a</sup>	159.39±7.79 <sup>a</sup>	164.44±17.12 <sup>a</sup>	151.38±13.51 <sup>a</sup>
9	Acetophenone	C98862	C <sub>8</sub> H <sub>8</sub> O	120.2	1065.2	714.661	1.18378	122.72±21.42 <sup>b</sup>	94.41±4.59 <sup>a</sup>	80.9±2.42 <sup>a</sup>	84.35±6.15 <sup>a</sup>
10	3-Methylbutanal-M	C590863	C <sub>5</sub> H <sub>10</sub> O	86.1	641.0	169.373	1.17608	1113.96±79.25 <sup>a</sup>	1140.58±151.97 <sup>a</sup>	1809.38±154.23 <sup>b</sup>	1896.01±124.35 <sup>b</sup>
11	3-Methylbutanal-D	C590863	C <sub>5</sub> H <sub>10</sub> O	86.1	643.2	170.346	1.40841	225.72±14.16 <sup>a</sup>	231.29±45.84 <sup>a</sup>	1071.7±529.37 <sup>b</sup>	1933.54±342.21 <sup>c</sup>
12	Pentanal-M	C110623	C <sub>5</sub> H <sub>10</sub> O	86.1	691.6	192.558	1.18273	527.52±36.02 <sup>b</sup>	1049.06±37.32 <sup>c</sup>	488.66±50.21 <sup>ab</sup>	426.73±36.07 <sup>a</sup>
13	Pentanal-D	C110623	C <sub>5</sub> H <sub>10</sub> O	86.1	691.2	192.331	1.42426	56.01±14.73 <sup>a</sup>	464.14±57.18 <sup>b</sup>	65.77±19.03 <sup>a</sup>	61.92±14.24 <sup>a</sup>
14	2-Pentenal-(E)	C1576870	C <sub>5</sub> H <sub>8</sub> O	84.1	745.1	236.461	1.10614	42.71±6.68 <sup>a</sup>	152.65±15.58 <sup>c</sup>	66.09±13.22 <sup>b</sup>	79.09±12.12 <sup>b</sup>
15	Hexana-M	C66251	C <sub>6</sub> H <sub>12</sub> O	100.2	791.0	276.330	1.25434	1013.34±18.93 <sup>a</sup>	1028.37±74.46 <sup>a</sup>	978.56±51.86 <sup>a</sup>	1006.77±82.32 <sup>a</sup>

Supplementary Table S1 (Continued)

No.	Compound	CAS#	Formula	MW	RI	Rt(s)	Dt(a.u.)	Volumn(a.u.)			
								C1	C2	F1	F2
16	Hexanal-D	C66251	C <sub>6</sub> H <sub>12</sub> O	100.2	791.2	276.586	1.56423	1702.81 ± 349.83 <sup>a</sup>	3769.32 ± 139.04 <sup>b</sup>	1525.43 ± 267.45 <sup>a</sup>	1799.96 ± 258.03 <sup>a</sup>
<b>Aldehydes</b>											
17	(E)-2-Hexenal-M	C6728263	C <sub>6</sub> H <sub>10</sub> O	98.1	846.7	340.325	1.18086	200.13 ± 38.50 <sup>a</sup>	333.96 ± 22.04 <sup>c</sup>	225.39 ± 26.13 <sup>ab</sup>	285.12 ± 46.23 <sup>bc</sup>
18	(E)-2-Hexenal-D	C6728263	C <sub>6</sub> H <sub>10</sub> O	98.1	846.7	340.325	1.51962	33.31 ± 9.31 <sup>a</sup>	85.27 ± 8.33 <sup>b</sup>	46.86 ± 9.47 <sup>a</sup>	68.71 ± 14.17 <sup>b</sup>
19	Heptana-M	C111717	C <sub>7</sub> H <sub>14</sub> O	114.2	900.2	407.457	1.33354	938.6 ± 106.10 <sup>b</sup>	1163.07 ± 44.23 <sup>c</sup>	743.39 ± 30.98 <sup>a</sup>	698.11 ± 22.66 <sup>a</sup>
20	Heptanal-D	C111717	C <sub>7</sub> H <sub>14</sub> O	114.2	900.2	407.457	1.69918	700.01 ± 128.70 <sup>b</sup>	2239.8 ± 101.91 <sup>c</sup>	485.4 ± 53.59 <sup>a</sup>	437.49 ± 47.04 <sup>a</sup>
21	Methional-M	C3268493	C <sub>4</sub> H <sub>8</sub> OS	104.2	903.8	414.190	1.09308	1218.84 ± 52.05 <sup>b</sup>	663.13 ± 15.65 <sup>a</sup>	1624.23 ± 25.58 <sup>c</sup>	1792.84 ± 77.33 <sup>d</sup>
22	Methional-D	C3268493	C <sub>4</sub> H <sub>8</sub> OS	104.2	902.8	412.492	1.40093	1208.4 ± 233.64 <sup>b</sup>	616.36 ± 23.70 <sup>a</sup>	3076.61 ± 75.52 <sup>c</sup>	4374.35 ± 231.99 <sup>d</sup>
23	Benzaldehyde-M	C100527	C <sub>7</sub> H <sub>6</sub> O	106.1	953.9	507.675	1.15072	1926.59 ± 157.82 <sup>b</sup>	1646.58 ± 15.66 <sup>a</sup>	1940.35 ± 29.30 <sup>b</sup>	2030.4 ± 113.74 <sup>b</sup>
24	Benzaldehyde-D	C100527	C <sub>7</sub> H <sub>6</sub> O	106.1	955.9	511.590	1.47186	2957.13 ± 292.77 <sup>b</sup>	1912.95 ± 32.66 <sup>a</sup>	3820.89 ± 189.79 <sup>c</sup>	4886.47 ± 133.40 <sup>d</sup>
25	Octanal-M	C124130	C <sub>8</sub> H <sub>16</sub> O	128.2	1011	614.158	1.40222	1705.75 ± 172.47 <sup>bc</sup>	1861.99 ± 19.44 <sup>c</sup>	1453.23 ± 153.13 <sup>a</sup>	1602.13 ± 24.01 <sup>ab</sup>
26	Octanal-D	C124130	C <sub>8</sub> H <sub>16</sub> O	128.2	1008.9	610.243	1.82590	1596.11 ± 207.20 <sup>a</sup>	2469.06 ± 264.26 <sup>b</sup>	1218.38 ± 453.60 <sup>a</sup>	1568.62 ± 129.01 <sup>a</sup>
27	2,4-Heptadienal-(E,E)	C4313035	C <sub>7</sub> H <sub>10</sub> O	110.2	1020.5	631.797	1.18958	138.97 ± 27.11 <sup>a</sup>	181.82 ± 22.45 <sup>b</sup>	141.33 ± 5.86 <sup>a</sup>	156.77 ± 12.81 <sup>ab</sup>
28	Phenylacetaldehyde-M	C122781	C <sub>8</sub> H <sub>8</sub> O	120.2	1045.3	677.761	1.25044	407.67 ± 11.47 <sup>b</sup>	323.1 ± 13.99 <sup>a</sup>	854.06 ± 25.29 <sup>c</sup>	1040.17 ± 17.90 <sup>d</sup>
29	Phenylacetaldehyde-D	C122781	C <sub>8</sub> H <sub>8</sub> O	120.2	1046.0	679.056	1.53882	36.79 ± 1.71 <sup>a</sup>	32.84 ± 2.77 <sup>a</sup>	112.71 ± 8.82 <sup>b</sup>	165.26 ± 0.44 <sup>c</sup>
30	2-Octenal-(E)	C2548870	C <sub>8</sub> H <sub>14</sub> O	126.2	1062.9	710.365	1.33702	164.02 ± 23.62 <sup>a</sup>	312.98 ± 12.53 <sup>c</sup>	188.06 ± 15.26 <sup>a</sup>	241.82 ± 7.51 <sup>b</sup>
31	n-Nonana- M	C124196	C <sub>9</sub> H <sub>18</sub> O	142.2	1106.5	791.308	1.47388	2721.63 ± 323.61 <sup>ab</sup>	2872.05 ± 107.35 <sup>b</sup>	2416.52 ± 42.19 <sup>a</sup>	2653.94 ± 104.10 <sup>ab</sup>
32	n-Nonanal-D	C124196	C <sub>9</sub> H <sub>18</sub> O	142.2	1106.5	791.308	1.94471	1912.17 ± 469.76 <sup>ab</sup>	2353.09 ± 332.55 <sup>b</sup>	1490.17 ± 141.93 <sup>a</sup>	2061.02 ± 350.93 <sup>ab</sup>
33	(E)-2-Nonenal	C18829566	C <sub>9</sub> H <sub>16</sub> O	140.2	1166.3	902.085	1.41436	162.55 ± 44.35 <sup>a</sup>	414.94 ± 46.42 <sup>b</sup>	185.23 ± 15.52 <sup>a</sup>	183.42 ± 12.20 <sup>a</sup>

Supplementary Table S1 (Continued)

No.	Compound	CAS#	Formula	MW	RI	Rt(s)	Dt(a.u.)	Volumn(a.u.)			
								C1	C2	F1	F2
34	Decanal	C112312	C <sub>10</sub> H <sub>20</sub> O	156.3	1222.4	1006.133	1.54092	195.45 ± 34.25 <sup>a</sup>	205.53 ± 11.72 <sup>a</sup>	174.01 ± 10.53 <sup>a</sup>	178.89 ± 2.86 <sup>a</sup>
<b>Alcohols</b>											
35	1-Pentanol-M	C71410	C <sub>5</sub> H <sub>12</sub> O	88.1	761.6	250.073	1.24957	499.79 ± 31.02 <sup>a</sup>	1097.92 ± 56.44 <sup>b</sup>	460.85 ± 81.87 <sup>a</sup>	423.47 ± 64.31 <sup>a</sup>
36	1-Pentanol-D	C71410	C <sub>5</sub> H <sub>12</sub> O	88.1	760.5	249.101	1.51036	77.96 ± 11.16 <sup>a</sup>	393.38 ± 40.17 <sup>b</sup>	68.94 ± 10.13 <sup>a</sup>	64.44 ± 16.15 <sup>a</sup>
37	2,3-Butanediol	C513859	C <sub>4</sub> H <sub>10</sub> O <sub>2</sub>	90.1	777.7	263.199	1.36574	538.02 ± 36.54 <sup>b</sup>	374.05 ± 24.98 <sup>a</sup>	1419.66 ± 72.16 <sup>c</sup>	2282.75 ± 137.60 <sup>d</sup>
38	n-Hexanol-M	C111273	C <sub>6</sub> H <sub>14</sub> O	102.2	871.8	369.192	1.32675	258.59 ± 24.13 <sup>a</sup>	491.93 ± 31.46 <sup>b</sup>	230.18 ± 2.95 <sup>a</sup>	253.83 ± 8.31 <sup>a</sup>
39	n-Hexanol-D	C111273	C <sub>6</sub> H <sub>14</sub> O	102.2	869.6	366.645	1.6383	23.9 ± 2.69 <sup>a</sup>	53.81 ± 7.34 <sup>b</sup>	21.24 ± 3.00 <sup>a</sup>	25.83 ± 4.74 <sup>a</sup>
40	Hheptanol	C53535334	C <sub>7</sub> H <sub>16</sub> O	116.2	976.7	550.349	1.39819	91.37 ± 15.86 <sup>a</sup>	243.9 ± 23.11 <sup>b</sup>	83.81 ± 11.33 <sup>a</sup>	77.95 ± 0.81 <sup>a</sup>
41	1-Octen-3-ol	C3391864	C <sub>8</sub> H <sub>16</sub> O	128.2	984.3	564.471	1.16060	523.64 ± 53.36 <sup>b</sup>	768.41 ± 19.97 <sup>c</sup>	410.92 ± 66.88 <sup>a</sup>	521.42 ± 35.70 <sup>b</sup>
42	3-Octanol	C589980	C <sub>8</sub> H <sub>18</sub> O	130.2	986.3	568.301	1.39959	174.24 ± 19.92 <sup>a</sup>	344.15 ± 12.37 <sup>b</sup>	181.39 ± 42.69 <sup>a</sup>	143.1 ± 22.24 <sup>a</sup>
43	1-Octanol	C111875	C <sub>8</sub> H <sub>18</sub> O	130.2	1081.6	745.048	1.47061	294.76 ± 56.11 <sup>ab</sup>	349.18 ± 40.63 <sup>b</sup>	267.46 ± 36.21 <sup>a</sup>	267.94 ± 9.86 <sup>a</sup>
<b>Esters</b>											
44	Geranyl acetate	C105873	C <sub>12</sub> H <sub>20</sub> O <sub>2</sub>	196.3	1346.5	1236.389	1.22031	856.25 ± 325.32 <sup>a</sup>	669.29 ± 28.28 <sup>a</sup>	654.88 ± 20.04 <sup>a</sup>	708.44 ± 52.94 <sup>a</sup>
<b>Heterocycles</b>											
45	Methylpyrazine	C109080	C <sub>5</sub> H <sub>6</sub> N <sub>2</sub>	94.1	779.4	264.658	1.08954	1693.35 ± 83.86 <sup>a</sup>	2005.23 ± 39.22 <sup>b</sup>	2275.66 ± 119.53 <sup>c</sup>	2531.98 ± 180.90 <sup>d</sup>
46	2,6-Dimethylpyrazine	C108509	C <sub>6</sub> H <sub>8</sub> N <sub>2</sub>	108.1	900.1	407.362	1.53854	576.55 ± 14.31 <sup>b</sup>	461.07 ± 25.18 <sup>a</sup>	876.1 ± 37.99 <sup>c</sup>	1017.18 ± 86.01 <sup>d</sup>
47	2-Acetylthiazole	C24295032	C <sub>5</sub> H <sub>5</sub> NOS	127.2	1023	636.356	1.13140	1068.84 ± 78.50 <sup>a</sup>	1490.49 ± 18.87 <sup>b</sup>	1342.62 ± 106.15 <sup>b</sup>	1436.01 ± 111.66 <sup>b</sup>