**Zeitschrift:** Mitteilungen aus dem Gebiete der Lebensmitteluntersuchung und Hygiene = Travaux de chimie alimentaire et d'hygiène

**Herausgeber:** Bundesamt für Gesundheit

**Band:** 89 (1998)

**Heft:** 5

**Artikel:** Volatile compounds of Swiss processed cheeses

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**DOI:** https://doi.org/10.5169/seals-983158

Mitt. Gebiete Lebensm. Hyg. **89**, 625–638 (1998)
Received 16 June 1998. Accepted 25 June 1998

# Volatile Compounds of Swiss Processed Cheeses

*Key words*: Volatile compounds, Processed cheese,
Dynamic headspace analysis, GC-MS analysis

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## Introduction

Processed cheese is manufactured by heating a mixture of cheese, water, emulsifying salts and optional other ingredients. Mix constituents and processing conditions are chosen to give the desired structure, flavour, colour and storage stability at an acceptable cost. Typical emulsifying salts include sodium citrates, sodium orthophosphates and sodium polyphosphates (1). The mix is heated in a batch cooker or in a continuous process to 70–145 °C. Typically the hot processed cheese is filled into the desired packages such as slices or wedges. Thereafter the packages are sealed and the products are cooled down.

In the United States, processed cheese is one of the most popular cheese products. However, its flavour is one of the less studied subjects (2–4). Only pyrazines as «volatiles» or «aroma compounds» seem to have been reported in processed American cheese (5).

The first aim of this work is to list the volatile compounds identified in 11 commercial Swiss processed cheese varieties and to determine their relative distribution. Since their «matrices» are similar, a direct comparison of these different processed cheese types can be made using dynamic headspace analysis. The second aim of this work is to determine the influence of the heat treatment on the occurrence and stability of these volatile compounds.

## Experimental part

### *Sampling*

Eleven commercial processed cheese types were supplied by Tiger Käse AG (CH-3550 Langnau i.E.): Toast extra, Fettine Emmental, ¼ fett mild, Glarissa (with herbs), Gruyère with ham (medium fat), Salami, Emmental, Gruyère, Appenzell, Tartine extra-fin and Fondicrem. The first 3 products were supplied in slices (approximately 18 g), the others as wedges (approximately 30 g) packaged in an aluminium foil.

In order to study the thermal behaviour of volatiles in different processed cheeses, samples were taken from the line before and after the heat treatment of the cheese mix. The heat treatment was a continuous direct UHT processing (2–4 s at 140 °C). The coding of the samples was the following: E1 = Emmental, G1 = Gruyère, T1 = Tilsiter, S1 = Schabziger (= Glarissa) and a mixture of them (E1+T1+S1) before heat processing, and E2 = Emmental, G2 = Gruyère, T2 = Tilsiter, S2 = Schabziger and a mixture of them (E2+T2+S2) after heat processing.

### *Sample preparation*

Before analysis, samples were manually grated in a deep frozen state using a domestic rasp (i.e. Bircher rasp or equivalent), in a refrigerated room at 7–8 °C. A representative sample of approximately 10 g was weighed and introduced into a 25 ml sparger before extraction of the volatiles.

### *Extraction of volatiles*

The Purge and Trap system LSC 2000 (Tekmar, Cincinnati, OH, USA) included a 25 ml non-fritted sparger (Schmidlin Co, part no. 14-2333-4SL, CH-6345 Neuheim), a trap (no. 8, containing a mixture of Carbosieve SIII (0.05 g) and Carbopack B60/80 (0.2 g) as well as a cryofocusing unit. The moisture control module was not used. Operating conditions were as follows: room temperature; purge gas: nitrogen; purge flow (vent): 30 ml/min; prepurge: 1 min; purge: 10 min; dry purge: 10 min; cap cool-down: –125 °C; desorb preheat to 210 °C; desorb: 4 min at 220 °C; inject: within 1.5 min from –125 to 200 °C; bake: 5 min at 260 °C; 6-port valve: 150 °C; line: 150 °C; capillary union heater (= transfer line from purge and trap to gas chromatograph): 150 °C.

### *Gas chromatography*

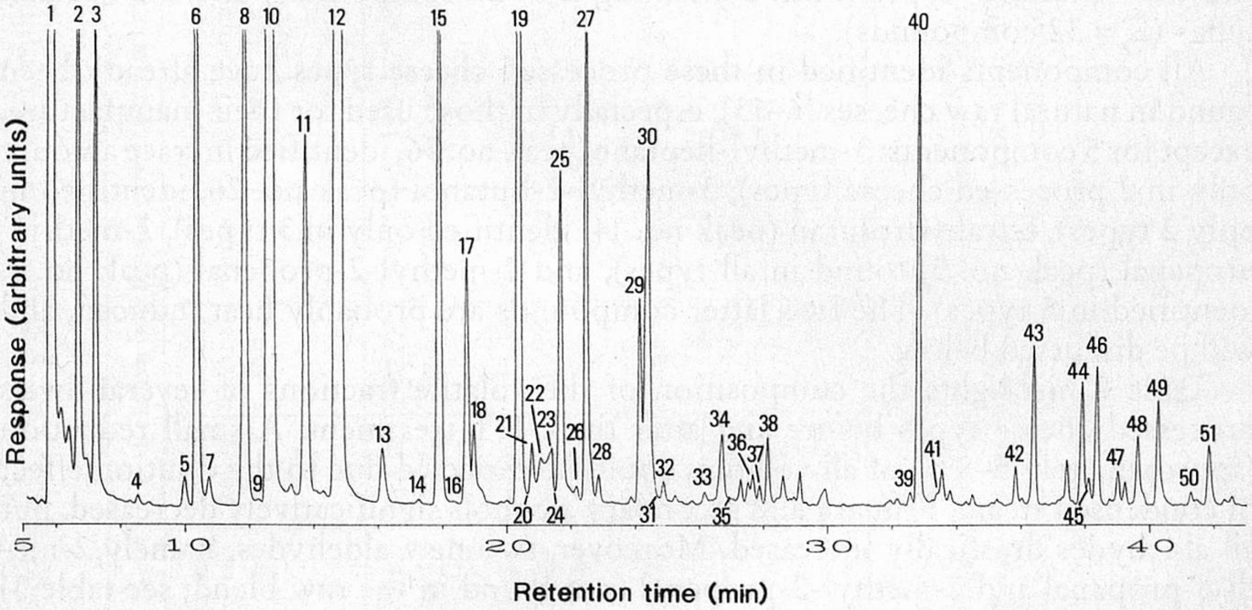
A Hewlett-Packard (HP) 5890, Series II was used. Operating conditions were as follows: carrier gas: helium; inlet pressure 40 kPa; flow: approx. 1.6 ml/min, injection at 45 °C; transfer line (from GC to MS): 280 °C; interface: direct inlet;

temperature program: 13 min at 45 °C, heating rate: 5 °C/min to 240 °C, and 5 min at 240 °C; capillary column: SPB1 (Supelco), 30 m × 0.32 mm id., film thickness: 4 µm.

*Detection*

Two detectors were mounted in parallel by splitting the flow at the end of the capillary column (split ratio: approx. 1:1 at 45 °C), i.e. a Hewlett-Packard flame ionisation detector (FID) and a mass-sensitive detector (MSD model HP 5972), operating in the scan mode (TIC) from 19 to 250 amu at 2.9 scan/s, ionisation by EI at 70 eV by autotuning; MS-Scan after 3.5 min. The MSD was used for the identification of the volatile (flavour) compounds (signal/noise ratio = 3), the FID for determination of their relative quantities (6). All determinations were performed twice.

Figure 1 shows a typical GC/FID chromatogram of a processed cheese.




Caption: The peak numbering is indicated in table 1–7. Some peaks, visible on the GC/FID chromatogram, were not considered: they were below the detection limit for identification in the corresponding GC/MSD chromatogram. Others, identified in other processed cheese types but not visible on this figure, are nevertheless indicated as retention time (i.e. peaks no. 20, 24, 31 and 35). Further peaks, due to contaminants present in the blank, were not considered

*Fig. 1.* Typical GC/FID chromatogram of volatile compounds found in the Salami-type processed cheese

## Results and Discussion

Using the MSD, 51 volatile compounds were identified from the 11 commercial Swiss processed cheeses studied. These compounds are grouped into alcohols (table

1), ketones (table 2), aldehydes (table 3), esters (table 4), hydrocarbons (table 5), terpenes (table 6) and miscellaneous components (table 7) according to their chemical functionality.

Each table indicates the frequency $\Sigma_i$ ($1 \le i \le 11$) of occurrence of a given volatile component i in the various processed cheese types investigated. Most volatiles occur in most cheese varieties but at different concentrations (the detection limit, defined by a signal/noise ration of 3, corresponds to 500 arbitrary units for the FID). Several components such as 2-methyl-propanal, 2-methyl- and 3-methyl-butanal, ethanol, 2-propanol, 2-propanone, 2,3-butanedione, 2-butanone, 2-pentanone, 2-heptanone occurred in all the 11 cheese varieties. Many others occurred frequently.

Table 7 also shows the total number of volatiles $\Sigma_j$ contained in a given processed cheese type j. The cheese variety with the least number of volatiles was the «¼ Fett» ($\Sigma_j$ = 18 compounds identified) followed by the «Fondicream» cheese type ($\Sigma_j$ = 19 compounds). The cheeses with the highest number of volatiles were the «Gruyère» and the «Glarissa» types (both containing $\Sigma_j$ = 29 compounds) and the «Salami type» ($\Sigma_j$ = 32 compounds).

All components identified in these processed cheese types have already been found in natural raw cheeses (6–13), especially in those used for their manufacture, except for 5 components: 3-methyl-heptane (peak no. 36, identified in trace amount only in 2 processed cheese types), 3-methyl-2-butanol (peak no. 26, identified in only 2 types), tetrahydrofuran (peak no. 14, identified only in 3 types), 2-methyl-propanal (peak no. 5, found in all types), and 2-methyl-2-propenal (peak no. 7, identified in 5 types). The two latter compounds are probably heat induced, and will be discussed below.

Table 8 highlights the composition of the volatile fractions of several Swiss processed cheese types before and after the UHT treatment. A small reduction (approximately 5–8%) of all volatiles could be expected due to the dilution effect of condensed steam. Primary and secondary alcohols significatively decreased, but all aldehydes drastically increased. Moreover, two new aldehydes, namely 2-methyl-propanal and 2-methyl-2-propenal (not found in the raw blend; see table 3) occurred in most processed cheeses. This general trend could be related to the β-oxidation of the unsaturated fatty acids or originate from the corresponding amino acids. Any new compounds could also be originally present as conjugates, sulphates or glucuronidates, from which they are liberated by heat. Many ketones decreased in concentration, but some others increased. All esters decreased. This behaviour was also observed with the aromatic hydrocarbons and terpenes. These various losses could be explained by the volatility of these compounds.

A small amount of α-pinene occurred in the «Glarissa» processed cheese which contains alpine herbs («Ziegerklee») (14). Nine further terpenes were identified, mostly in trace amounts below the detection limit in the Total Ion Current mode (TIC) in the Salami type using the MSD in Selected Ion Monitoring (SIM) mode and the retention indices of these terpenes. They originate from the added spices and not from the cheese base used.

*Table 1.* Alcohols identified (with MSD) and whose relative quantities were determined with FID in various Swiss processed cheese types

| Peak No | Compounds | $\Sigma_i$ | Relative height measured in different cheeses (arbitrary units**) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Emmentaler | Gruyère | Appenzeller | Tartine (extra-fin) | Fondicrem | Toast extra (Slices) | fettine Emmentaler (Slices) | ¼ fett mild (Slices) | Glarissa (with alpine herbs) | Gruyère with ham | Salami | Reference number related to other cheese varieties |
| 1 | ethanol | 11 | 36888 | 54057 | 81421 | 33128 | 18451 | 60352 | 27422 | 51512 | 335552 | 70041 | 98150 | (7,9,11) |
| 6 | 1-propanol* | 10 | 3606 | 3623 | 4456 | 2651 | 729 | 4111 | 3071 | | 107042 | 3333 | 4397 | (7,9,11) |
| 13 | 2-methyl-1-propanol* | 5 | | 579 | 771 | | | | | | 978 | 4816 | 608 | (7,9,11) |
| 18 | 1-butanol* | 7 | 611 | 1080 | 1056 | | | 1021 | | | 177218 | 727 | 502 | (7,9,11) |
| 29 | 3-methyl-1-butanol* | 10 | 3262 | 3704 | 4504 | 1058 | 909 | 2230 | 2024 | | 2355 | 3348 | 3039 | (7,9,11) |
| 31 | 2-methyl-1-butanol* | 4 | 1912 | 2246 | 2150 | | | | 1596 | | | | | (7) |
| 33 | 1-pentanol* | 2 | | | | | | | | 1749 | 2387 | | | (7,9,11) |
| 3 | 2-propanol* | 11 | 5752 | 5877 | 9735 | 1865 | 1313 | 3516 | 2973 | 755 | 4409 | 4656 | 7652 | (7,9,11) |
| 4 | 2-methyl-2-propanol | 3 | | | | 782 | | | | | | 1145 | 510 | (7,9,11) |
| 11 | 2-butanol* | 8 | 652 | 775 | 2984 | 781 | | 5416 | | | 2827 | 1159 | 2814 | (7,9,11) |
| 25 | 2-pentanol | 7 | 3156 | 2587 | 5568 | 783 | | 1911 | | | | 2156 | 2921 | (7,9,11) |
| 26 | 3-methyl-2-butanol | 2 | | | | | | | 4298 | | 1367 | | | |

Caption: blank = not detected (detection limit: 500 arbitrary units).
trace = trace amount (below the detection limit, found with MSD in SIM mode).
* = confirmed by comparison of retention times and MS spectra of authentic substances.
** = the extraction rate of the different compounds using the dynamic headspace analysis is unknown.
$\Sigma_i$ = number of cheese varieties containing a given component i.

*Table 2.* Ketones identified (with MSD) and whose relative quantities were determined with FID in various Swiss processed cheese types

| Peak No | Compounds | $\Sigma_i$ | Relative height measured in different cheeses (arbitrary units**) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Emmentaler | Gruyère | Appenzeller | Tartine (extra-fin) | Fondicrem | Toast extra (Slices) | fettine Emmentaler (Slices) | ¼ fett mild (Slices) | Glarissa (with alpine herbs) | Gruyère with ham | Salami | Reference number related to other cheese varieties |
| 2 | 2-propanone* | 11 | 18136 | 20805 | 16776 | 4546 | 6281 | 20631 | 12948 | 5541 | 18313 | 10871 | 9099 | (7,8,9) |
| 8 | 2,3-butanedione* | 11 | 4839 | 5925 | 6289 | 19114 | 13236 | 7161 | 8504 | 31874 | 7515 | 5684 | 5210 | (7,8,12) |
| 10 | 2-butanone* | 11 | 25164 | 22549 | 33801 | 46637 | 73201 | 8136 | 1557 | 1750 | 56020 | 64953 | 95748 | (7,10,11) |
| 16 | 3-methyl-2-butanone | 1 | | | | | | 712 | | | | | | (4,5) |
| 19 | 2-pentanone* | 11 | 20933 | 21179 | 28854 | 6884 | 6491 | 17832 | 12539 | 2715 | 19561 | 1371 | 12427 | (7,10,11) |
| 20 | 3-methyl-2-pentanone* | 1 | | | | | | | | | 1420 | | | (7,9,10) |
| 21 | 2,3-pentadienone | 7 | | 1250 | 2010 | | 707 | 1207 | 1450 | | | 17298 | 1045 | (7) |
| 24 | 3-hydroxy-2-butanone | 2 | | | | 508 | | | | 1022 | | | | (7,8) |
| 30 | 4-methyl-2-pentanone* | 6 | | | | 4945 | 3281 | 1893 | | | 5203 | 5813 | 3749 | (7,11) |
| 40 | 2-heptanone | 11 | 13540 | 1233 | 14412 | 5408 | 4594 | 9094 | 12327 | 2798 | 10824 | 10934 | 7486 | (7,8,11) |
| 51 | 2-nonanone | 10 | 1987 | 9865 | 1499 | 1014 | 851 | 1342 | 2785 | | 677 | 1010 | 938 | (7,8,11) |

Caption: See table 1

*Table 3.* Aldehydes identified (with MSD) and whose relative quantities were determined with FID in various Swiss processed cheese types

| Peak No | Compounds | Relative height measured in different cheeses (arbitrary units**) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $\Sigma_i$ | Emmentaler | Gruyère | Appenzeller | Tartine (extra-fin) | Fondicrem | Toast extra (Slices) | fettine Emmentaler (Slices) | ¼ fett mild (Slices) | Glarissa (with alpine herbs) | Gruyère with ham | Salami | Reference number related to other cheese varieties |
| 5 | 2-methyl-propanal | 11 | 2495 | 2182 | 1444 | 470 | 533 | 2974 | 941 | 4016 | 918 | 656 | 644 | |
| 7 | 2-methyl-2-propenal | 5 | 848 | 802 | | 559 | | 1008 | | 870 | | | | |
| 9 | butanal | 1 | | | | | | trace | | | 1742 | | | (7,10) |
| 15 | 3-methyl-butanal* | 11 | 11092 | 14190 | 14511 | 9834 | 7126 | 13096 | 5577 | 16338 | 19590 | 4949 | 9096 | (7,8,12) |
| 17 | 2-methyl-butanal* | 11 | 5212 | 5212 | 4715 | 2481 | 1884 | 6575 | 2200 | 9168 | 7605 | 1990 | 2042 | (7,8,12) |
| 22 | pentanal | 10 | 987 | 807 | 1189 | 957 | 882 | 1284 | 1315 | 8613 | 2404 | 1079 | | (7,9,10) |
| 37 | hexanal | 3 | 531 | 531 | | | | | | 1028 | | | | (7,9,10) |

Caption: See table 1

*Table 4.* Esters identified (with MSD) and whose relative quantities were determined with FID in various Swiss processed cheese types

| Peak No | Compounds | Relative height measured in different cheeses (arbitrary units**) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $\Sigma_i$ | Emmentaler | Gruyère | Appenzeller | Tartine (extra-fin) | Fondicrem | Toast extra (Slices) | fettine Emmentaler (Slices) | ¼ fett mild (Slices) | Glarissa (with alpine herbs) | Gruyère with ham | Salami | Reference number related to other cheese varieties |
| 12 | ethyl acetate* | 10 | 3785 | 3942 | 4898 | 65043 | 48424 | 2930 | 2455 | | 48426 | 73116 | 81941 | (7,9,10) |
| 27 | ethyl propionate | 10 | 7961 | 6906 | 8745 | 2628 | 1421 | 6965 | 6560 | | 2785 | 7063 | 6138 | (7,9,10) |
| 38 | ethyl butanoate* | 8 | 750 | 580 | 751 | | | 651 | 671 | | 2241 | 686 | 806 | (7,9,11) |
| 41 | propyl butanoate | 1 | | | | | | | | | 1231 | | | (7,9,10) |

Caption: See table 1

*Table 5.* Hydrocarbons identified (with MSD) and whose relative quantities were determined with FID in various Swiss processed cheese types

| Peak No | Compounds | | Relative height measured in different cheeses (arbitrary units**) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $\Sigma_i$ | Emmentaler | Gruyère | Appenzeller | Tartine (extra-fin) | Fondicrem | Toast extra (Slices) | fettine Emmentaler (Slices) | ¼ fett mild (Slices) | Glarissa (with alpine herbs) | Gruyère with ham | Salami | Reference number related to other cheese varieties |
| 28 | heptane | 2 | | 714 | | | | | | | | | 620 | (7) |
| 34 | methyl benzene* | 10 | 788 | 951 | 1114 | 737 | | 6708 | 1863 | 10179 | 2210 | 1885 | 2045 | (7) |
| 36 | 3-methyl-heptane | 2 | | | | | | | | | | 1096 | 734 | |
| 39 | 1,3-dimethyl-benzene | 1 | 760 | | | | | | | | | | | (7,9,10) |

Caption: See table 1

*Table 6.* Terpenes identified (with MSD) and whose relative quantities were determined with FID in various Swiss processed cheese types

| Peak No | Compounds | | Relative height measured in different cheeses (arbitrary units**) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $\Sigma_i$ | Emmentaler | Gruyère | Appenzeller | Tartine (extra-fin) | Fondicrem | Toast extra (Slices) | fettine Emmentaler (Slices) | ¼ fett mild (Slices) | Glarissa (with alpine herbs) | Gruyère with ham | Salami | Reference number related to other cheese varieties |
| 42 | α-thujene* | 1 | | | | | | | | | | | 605 | (13) |
| 43 | α-pinene* | 1 | | | | | | | | | trace | | 2083 | (13) |
| 44 | sabinene* | 1 | | | | | | | | | | | 2015 | (13) |
| 45 | β-myrcene* | 0 | | | | | | | | | | | trace | (13) |
| 46 | β-pinene* | 1 | | | | | | | | | | | 1951 | (13) |
| 47 | α-phellandrene* | 0 | | | | | | | | | | | trace | (13) |
| 48 | δ-3-carene* | 1 | | | | | | | | | | trace | 739 | (13) |
| 49 | dl-limonene* | 1 | | | | | | | | | | | 1498 | (13) |
| 50 | γ-terpinene* | 0 | | | | | | | | | | | trace | (13) |

*Table 7.* Miscellaneous compounds identified (with MSD) and whose relative quantities were determined with FID in various Swiss processed cheese types

| Peak No | Compounds | $\Sigma_i$ | Relative height measured in different cheeses (arbitrary units**) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $\Sigma_i$ | Emmentaler | Gruyère | Appenzeller | Tartine (extra-fin) | Fondicrem | Toast extra (Slices) | fettine Emmentaler (Slices) | ¼ fett mild (Slices) | Glarissa (with alpine herbs) | Gruyère with ham | Salami | Reference number related to other cheese varieties |
| 14 | tetrahydrofuran | 3 | | | | | | 1754 | 675 | 2013 | | | | |
| 23 | propanoic acid | 6 | 767 | 1051 | | 826 | 952 | | 2834 | | 1716 | | | (7,8,12) |
| 32 | dimethyl disulfide* | 7 | 789 | 4004 | 14816 | | | 10802 | 847 | 1604 | trace | 541 | | (7,11) |
| 35 | butanoic acid | 1 | | | | | | | | | 4047 | | | (7,8,12) |
| | Total number of components contained in a given cheese variety j (Σ j) | Σ j | 27 | 29 | 25 | 24 | 19 | 27 | 24 | 18 | 29 | 27 | 32 | |

Caption: See table 1

*Table 8.* Distribution of volatiles in various processed cheese varieties before and after heat treatment

| Compounds | Relative peak height (arbitrary unit) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Emmentaler E1 | Emmentaler E2 | Greyerzer G1 | Greyerzer G2 | Tilsiter T1 | Schabziger S1 | Schabziger Mixture S1+T1+E1 | Schabziger Mixture S2+T2+E2 |
| ethanol | 154 046 | 84 197 | 149 259 | 56 574 | 219 202 | 1 086 234 | 1 133 168 | 775 986 |
| 1-propanol | 13 718 | 4 796 | 7 460 | 5 580 | – | 113 870 | 223 173 | 123 702 |
| 2-methyl-1-propanol | 1 446 | 590 | – | – | 1 200 | – | 1 719 | 1 455 |
| 1-butanol | 1 792 | 623 | 6 079 | 1 896 | – | 496 176 | 491 340 | 311 740 |
| 2-methyl-1-butanol | 4 546 | 2 518 | 1 203 | 665 | – | – | 2 530 | 1 637 |
| 3-methyl-1-butanol | 7 862 | 3 987 | 1 915 | 906 | – | 10 577 | 7 483 | 5 988 |
| 1-pentanol | – | – | – | – | – | 27 627 | 12 219 | 8 535 |
| 2-propanol | 13 065 | 4 194 | 4 278 | 2 697 | 4 568 | – | 17 524 | 4 421 |
| 2-butanol | 1 500 | 1 419 | 1 719 | 512 | – | – | 31 061 | 29 484 |
| 3-methyl-2-butanol | – | – | 1 990 | 653 | 3 065 | – | 5 089 | – |
| 2-pentanol | 7 468 | 4 534 | – | – | – | – | 4 288 | – |
| 3-penten-2-ol | – | – | – | – | – | 14 752 | – | – |
| 2-heptanol | 679 | 452 | – | – | – | – | – | – |
| 2-methyl-propanal | – | 2 864 | 547 | 2 456 | – | – | – | 1 056 |
| 2-methyl-propenal | – | 1 427 | – | 1 298 | – | – | – | – |
| butanal | – | – | – | – | – | – | 6 712 | 2 833 |
| 3-methyl-butanal | 1 162 | 17 046 | 2 475 | 11 848 | 1 409 | – | 1 287 | 20 376 |
| 2-methyl-butanal | 2 808 | 5 988 | 1 524 | 5 188 | – | – | 746 | 7 399 |
| pentanal | – | 2 215 | – | – | – | – | – | 2 246 |
| hexanal | 345 | 1 880 | – | – | – | – | – | – |

| Compounds | Relative peak height (arbitrary unit) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Emmentaler E1 | Emmentaler E2 | Greyerzer G1 | Greyerzer G2 | Tilsiter T1 | Schabziger S1 | Schabziger Mixture S1+T1+E1 | Schabziger Mixture S2+T2+E2 |
| 2-propanone | 31 971 | 16 139 | 20 245 | 22 980 | 88 440 | – | 36 546 | 16 852 |
| 2,3-butanedione | 13 872 | 8 952 | 13 133 | 6 823 | 75 520 | – | 48 088 | 17 084 |
| 3-hydroxy-2-butanone | – | – | – | – | 17 370 | – | – | – |
| 2-butanone | 5 126 | 7 591 | 3 480 | 2 787 | – | – | 19 956 | 16 807 |
| 2,3-pentadienone | – | – | 1 450 | 972 | – | – | – | – |
| 2-pentanone | 46 656 | 22 951 | 13 973 | 12 492 | – | – | 18 184 | 10 807 |
| 4-methyl-2-pentanone | 2 308 | 2 484 | – | – | – | – | – | – |
| 2-hexanone | 895 | 549 | – | – | – | – | – | – |
| 2-heptanone | 16 479 | 13 864 | 6 307 | 6 932 | 3 065 | – | 7 924 | 9 219 |
| 2-nonanone | 3 306 | 3 062 | 1 094 | 268 | – | 21 806 | 872 | 1 456 |
| ethyl acetate | 7 620 | 5 355 | 2 381 | 7 787 | 1 111 | – | 6 196 | 3 599 |
| butyl acetate | – | – | – | – | – | 68 267 | 10 514 | 4 706 |
| propyl acetate | – | – | – | – | – | – | 10 068 | ? |
| ethyl propionate | 23 742 | 13 678 | 4 086 | 2 298 | – | – | 21 014 | 4 669 |
| propyl propanoate | 560 | 388 | – | – | – | – | – | – |
| butyl propionate | – | – | – | – | – | 146 273 | 8 684 | 2 291 |
| ethyl butanoate | 1 317 | 991 | 761 | 539 | – | 118 330 | 36 971 | 23 776 |
| propyl butanoate | – | – | – | – | – | 56 358 | 6 165 | 3 920 |
| butyl butanoate | – | – | – | – | – | – | 8 684 | 6 559 |
| methyl benzene | 5 013 | 3 858 | 2 001 | 2 737 | 3 205 | – | 2 764 | 3 454 |
| 1,3-dimethylbenzene | – | – | – | – | – | – | – | 691 |
| decane | – | – | – | – | 768 | – | 1 088 | – |
| β-myrcene | 1 304 | – | – | – | – | – | – | – |
| β-pinene | 740 | – | – | – | – | – | – | – |
| γ-terpinene | 2 311 | – | – | – | – | – | – | – |
| dimethyl disulfide | – | – | 3 923 | 3 276 | – | – | 2 065 | 1 171 |

Caption: E1: Swiss Emmentaler before heat treatment
E2: Swiss Emmentaler after heat treatment
G1: Greyerzer before heat treatment
G2: Greyerzer after heat treatment
T1: Tilsiter before heat treatment
S1: Schabziger before heat treatment
S1+T1+E1: Schabziger mixture before heat treatment
S2+T2+E2: Schabziger mixture after heat treatment
blank = not detected (detection limit: 500 arbitrary units)
? = peak overlapping

### *Acknowledgements*

We are grateful to Mrs. *Gerda Urbach* (CSIRO, Food Science Australia, Melbourne Laboratory) and Dr. *Robert Sieber* (FAM) for careful reviewing of the manuscript.

### *Summary*

The present study identifies and gives relative quantities for 51 volatiles found in 11 Swiss commercial processed cheese varieties using a dynamic headspace GC-MSD & FID analysis. Most of the volatiles are present in all processed cheese types but in different ratios. Most components are already preformed in the raw material before heat processing. The thermal treatment of the various processed cheese varieties generally produced a decrease in the concentration of most alcohols, ketones (with a few exceptions), esters, as well as terpenoids, due to their relatively high volatility. On the other hand, the significant increase in the concentration of all aldehydes seems to be related to the heat processing. The presence of the terpenes can be explained by the presence of herbs (Glarissa processed cheese) or spices (Salami processed cheese).

### *Zusammenfassung*

In 11 verschiedenen schweizerischen Schmelzkäsesorten wurden 51 flüchtige Verbindungen mittels einer dynamischen Dampfraum- und GC/MSD & FID-Analysenmethode nachgewiesen. Die meisten Verbindungen wurden in sämtlichen Käsesorten gefunden, aber in sehr unterschiedlichen Konzentrationen. Im allgemeinen war die Mehrheit der Komponenten bereits im Rohmaterial (vor der thermischen Behandlung) vorhanden. Nach dem Schmelzen der Käsemasse beobachtete man normalerweise eine Gehaltsabnahme der meisten flüchtigen Stoffe wie Alkohole und Ketone (mit einigen Ausnahmen), Ester und Terpenoide, was auf deren hohe Flüchtigkeit zurückzuführen ist. Im Gegensatz dazu scheint die deutliche Konzentrationszunahme sämtlicher Aldehyde von der thermischen Behandlung verursacht zu sein. Das Vorkommen einiger Terpene in Spuren kann durch die Verwendung von Kräutern (im Glarissa-Schmelzkäse) oder Gewürzen (im Salamischmelzkäse) erklärt werden.

## *Résumé*

Le présent travail a permis d'identifier et de quantifier de façon relative 51 composés volatils dans 11 sortes de fromages fondus suisses du commerce en utilisant une technique d'analyse d'effluves dynamique par GC/MSD & FID. La plupart de ces composants sont présents dans la majorité des sortes de fromages fondus analysés, mais dans des proportions très variables. Maints composés ont d'ailleurs déjà été trouvés dans la matière première avant la fonte. Après celle-ci, la teneur en volatils tels que alcools, cétones (à quelques exceptions près), en esters et en hydrocarbures aromatiques tendait en général à décroître en raison de leur volatilité relativement élevée. Inversement, l'augmentation significative de la teneur en aldéhydes semble clairement indiquer que ces substances sont générées par le traitement thermique appliqué. La présence de quelques composés terpéniques s'explique par l'emploi de plantes (dans la sorte «Glarissa» aux herbes) ou d'épices (dans la sorte «au salami»).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