

Chapter 14

Synthesis and Sensorial Description of New Sulfur-Containing Odorants

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Various sulfur-containing odorants, such as 2-thioalcanes, 3-acetylthio-2-alkyl alkanals, and trialkylated 1,3,5-dithiazines were prepared by conventional, parallel, and split-mix synthesis approaches. 2-Heptanethiol, newly identified in bell peppers, and 3-acetylthio-2-methylpentanal showed relatively low odor thresholds of 10 and 5 µg/kg water, respectively. Several odorants were found to develop interesting notes, which are compatible with both savory and sweet flavors.

Introduction

Volatile organic sulfur compounds contribute to the aroma of many vegetables, fruits, and food products (1, 2). In general, thiols belong to the most intense and characteristic aroma substances with sulfury, vegetable-like, fruity notes perceived at low concentrations. In bell peppers, we have recently identified 2-heptanethiol as an odor-active compound (3). However, the identification of thiols is generally a challenging task due to their instability and the low concentration. The sensory relevance of such odorants can be explained by their low threshold values. For example, (2*R*,3*S*)-3-mercapto-2-methyl-1-pentanol, a character-impact constituent of fresh onions, shows an odor threshold of 0.03 µg/kg water (4).

Identification of sensory relevant compounds can be achieved by applying a

combinatorial approach. Vermeulen and coworkers (5-8) have prepared a series of sulfur-containing odorants by reacting various precursors in one reaction vessel. Odor-active compounds were screened by gas chromatography-sniffing techniques for identification experiments, which are facilitated due to higher concentrations as compared to natural extracts.

An alternative approach is to run several reactions in parallel in different reactors, a method called parallel synthesis (9). In general, combinatorial approaches are easy to run and could be applied for the identification of unknown compounds. However, the analysis is more complex since mixtures of many products are obtained. The parallel approach has the advantage of simple automation leading to several isolated compounds.

This article deals with the combinatorial synthesis of various sulfur-containing odorants. We used this approach for the identification of natural aroma components in different ingredients such as fried onion or bell peppers.

Experimental

Materials

The following chemicals were commercially available and of highest purity: piperidine, 2-hexanol, 2-heptanol, 2-octanol, 2-nonanol, ethanal, isobutanal, *p*-toluenesulfonyl chloride, sodium hydrogensulfide monohydrate (NaSH·H₂O), ammonium sulfide, deuteriochloroform (C²HCl₃) (Fluka/Aldrich, Buchs, Switzerland); hydrochloric acid (HCl, 37%), magnesium sulfate (MgSO₄), silica gel 60 (Merck, Darmstadt, Germany); citric acid monohydrate (Citrique Belge, Belgium). The solvents pentane, dimethylformamide (DMF), ethyl acetate (EtOAc), toluene, and diethyl ether (Et₂O) were from Merck and freshly distilled prior to use. Solvents were distilled on sodium/benzophenone (Fluka/Aldrich) for air-sensitive reactions, which were carried out under nitrogen atmosphere. Purification by column chromatography was carried out on silica gel 60 (Fluka).

Synthesis of 2-Thioalcanes

The aliphatic 2-thioalcanes were synthesized from the corresponding 2-alcanols as starting material using classical approaches (10), i.e. by tosylation of the alcohol and nucleophilic substitution of the intermediary tosylate with sodium hydrogensulfide into the target thiol.

General Procedure for the Synthesis of 2-(p-Toluenesulfonyl)alcanes. These were obtained from the corresponding 2-alcanols **1a-d** (200 mmol, 1.0 equiv) dissolved in pyridine (135 mL) and cooled to 0 °C. *p*-Toluenesulfonyl chloride (41.8 g, 220 mmol, 1.1 equiv) was slowly added and the mixture was stirred at room temperature overnight. Toluene was added (200 mL), the reaction mixture filtered, and the filtrate washed with toluene (200 mL). The mother liquor was washed twice with an aqueous HCl solution (5 N, 200 mL). The organic layer was dried over MgSO₄ and concentrated under reduced pressure. After dry chromatography on silica gel (pentane/EtOAc, 9:1, v/v), the 2-(*p*-toluenesulfonyl)alcanes **2a-d** were obtained as colorless oils in 60-80% yields.

2-(p-Toluenesulfonyl)hexane 2a. Yield: 73%. ¹H NMR (360 MHz, C²HCl₃, δ/ppm): 0.74 (t, 3H, CH₃, ³J = 7.1 Hz), 1.05-1.34 (m, 4H, 2 CH₂), 1.19 (d, 3H, CH₃, ³J = 6.1 Hz), 1.38-1.52 (m, 2H, CH₂), 2.37 (s, 3H, CH₃), 4.58 (qt, 1H, CH, ³J = 6.1 Hz, ³J = 6.35 Hz), 7.28 (d, 2H, ³J = 8.3 Hz), 7.73 (d, 2H, ³J = 8.3 Hz); ¹³C NMR (90 MHz, C²HCl₃, δ/ppm): 14.2 (CH₃), 21.2 (CH₃), 22.0 (CH₃), 21.9 (CH₃), 22.6 (CH₂), 27.3 (CH₂), 36.5 (CH₂), 81.0 (O-CH), 128.0 (C=CH), 130.1 (C=CH), 134.9 (C=C), 144.8 (C=C).

2-(p-Toluenesulfonyl)heptane 2b. Yield: 76%. ¹H NMR (360 MHz, C²HCl₃, δ/ppm): 0.82 (t, 3H, CH₃, ³J = 7.2 Hz), 1.12-1.23 (m, 6H, 3 CH₂), 1.26 (d, 3H, CH₃, ³J = 6.3 Hz), 1.42-1.63 (m, 2H, CH₂), 2.44 (s, 3H, CH₃), 4.59 (qt, 1H, CH, ³J = 6.1 Hz, ³J = 6.35 Hz), 7.33 (d, 2H, ³J = 8.3 Hz), 7.79 (d, 2H, ³J = 8.3 Hz). ¹³C NMR (90 MHz, C²HCl₃, δ/ppm): 14.3 (CH₃), 21.3 (CH₃), 22.1 (CH₃), 22.8 (CH₂), 24.9 (CH₂), 31.7 (CH₂), 36.8 (CH₂), 81.1 (O-CH), 128.1 (C=CH), 130.1 (C=CH), 135.0 (C=C), 144.8 (C=C).

2-(p-Toluenesulfonyl)octane 2c. Yield: 75%. ¹H NMR (360 MHz, C²HCl₃, δ/ppm): 0.90 (t, 3H, CH₃, ³J = 7.0 Hz), 1.20-1.36 (m, 8H, 4 CH₂), 1.31 (d, 3H, CH₃, ³J = 6.35 Hz), 1.47-1.70 (m, 2H, CH₂), 2.49 (s, 3H, CH₃), 4.65 (qt, 1H, CH, ³J = 6.1 Hz, ³J = 6.35 Hz), 7.38 (d, 2H, ³J = 8.1 Hz), 7.85 (d, 2H, ³J = 8.1 Hz). ¹³C NMR (90 MHz, C²HCl₃, δ/ppm): 14.4 (CH₃), 21.3 (CH₃), 22.0 (CH₃), 22.9 (CH₂), 25.2 (CH₂), 29.2 (CH₂), 31.9 (CH₂), 36.9 (CH₂), 81.1 (O-CH); 128.1 (C=CH), 130.1 (C=CH), 135.0 (C=C), 144.8 (C=C).

2-(p-Toluenesulfonyl)nonane 2d. Yield: 62%. ¹H NMR (360 MHz, C²HCl₃, δ/ppm): 0.83 (t, 3H, CH₃, ³J = 6.8 Hz), 1.05-1.34 (m, 10H, 5 CH₂), 1.27 (d, 3H, CH₃, ³J = 6.2 Hz), 1.35-1.60 (m, 2H, CH₂), 2.39 (s, 3H, CH₃), 4.54 (qt, 1H, CH, ³J = 6.2 Hz, ³J = 6.35 Hz), 7.28 (d, 2H, ³J = 8.3 Hz), 7.74 (d, 2H, ³J = 8.3 Hz). ¹³C NMR (90 MHz, C²HCl₃, δ/ppm): 14.5 (CH₃), 21.3 (CH₃), 22.0 (CH₃), 23.0 (CH₂), 25.3 (CH₂), 29.4 (CH₂), 29.5 (CH₂), 32.1 (CH₂), 36.9 (CH₂), 81.1 (O-CH), 128.1 (C=CH), 130.1 (C=CH), 135.0 (C=C), 144.8 (C=C).

General Procedure for the Synthesis of 2-Thioalcanes. 2-(*p*-Toluenesulfonyl)alcanes **2a-d** (37 mmol, 1.0 equiv) and NaSH·H₂O (7.0 g, 94 mmol, 2.5 equiv) were stirred in DMF (25 mL) at 80 °C for 2 h. The reaction mixture was diluted in brine (200 mL) and the aqueous layer was extracted with

Et₂O (3 x 200 mL). The organic layers were combined and washed with brine (5 x 200 mL), dried over MgSO₄ and concentrated under reduced pressure. The racemic target compounds **3a-d** was obtained after distillation under reduced pressure in 20-40% yield.

2-Hexanethiol 3a. ¹H NMR (360 MHz, C²HCl₃, δ/ppm): 0.89 (t, 3H, CH₃, ³J = 7.2 Hz), 1.27-1.36 (m, 6H, 3 CH₂), 1.36 (d, 3H, CH₃, ³J = 6.7 Hz), 1.49-1.62 (m, 2H, CH₂), 2.96 (tq, 1H, ³J = 6.5 Hz, ³J = 6.1 Hz). ¹³C NMR (90 MHz, C²HCl₃, δ/ppm): 14.4 (CH₃), 22.8 (CH₂), 26.0 (CH₃), 30.0 (CH₂), 36.0 (CH₃), 41.1 (CH). MS (EI, *m/z*, rel-%): 118 (M⁺, 35), 85 (26), 84 (26), 69 (33), 61 (65), 56 (42), 55 (40), 41 (100). GC: RI(PONA) = 850, RI(DB-Wax) = 1063. Yield: 20%, boiling point: 34°C (14 mbar).

2-Heptanethiol 3b. ¹H NMR (360 MHz, C²HCl₃, δ/ppm): 0.82 (t, 3H, CH₃, ³J = 7.2 Hz), 1.27-1.38 (m, 6H, 3 CH₂), 1.36 (d, 3H, CH₃, ³J = 6.7 Hz), 1.49-1.62 (m, 2H, CH₂), 2.96 (tq, 1H, ³J = 6.5 Hz, ³J = 6.1 Hz). ¹³C NMR (90 MHz, C²HCl₃, δ/ppm): 14.5 (CH₃), 23.0 (CH₂), 26.0 (CH₃), 27.5 (CH₂), 31.9 (CH₂), 36.0 (CH₃), 41.3 (CH). MS (EI, *m/z*, rel-%): 132 (M⁺, 32), 98 (31), 70 (32), 69 (26), 61 (60), 57 (100), 56 (74), 55 (40), 43 (41), 41 (76). GC: RI(PONA) = 953, RI(DB-Wax) = 1170. Yield: 40%, boiling point: 120°C (143 mbar).

2-Octanethiol 3c. ¹H NMR (360 MHz, C²HCl₃, δ/ppm): 0.90 (t, 3H, CH₃, ³J = 7.2 Hz), 1.29-1.60 (m, 13H, 1 CH₃, 5 CH₂), 2.94 (tq, 1H, ³J = 7.0 Hz, ³J = 6.1 Hz). ¹³C NMR (90 MHz, C²HCl₃, δ/ppm): 14.5 (CH₃), 23.0 (CH₂), 26.0 (CH₃), 27.8 (CH₂), 29.4 (CH₂), 32.2 (CH₂), 36.0 (CH₃), 41.3 (CH₂). MS (EI, *m/z*, rel-%): 146 (M⁺, 16), 112 (27), 84 (22), 83 (34), 71 (45), 70 (58), 61 (64), 57 (64), 56 (48), 55 (68), 43 (62), 41 (100). GC: RI(PONA) = 1057, RI(DB-Wax) = 1271. Yield: 24%, boiling point: 44°C (13 mbar).

2-Nonanethiol 3d. ¹H NMR (360 MHz, C²HCl₃, δ/ppm): 0.82 (t, 3H, CH₃, ³J = 7.2 Hz), 1.27-1.38 (m, 15H, CH₃, 6 CH₂), 2.96 (tq, 1H, ³J = 7.0 Hz, ³J = 6.1 Hz). ¹³C NMR (90 MHz, C²HCl₃, δ/ppm): 14.5 (CH₃), 23.0 (CH₂), 26.0 (CH₃), 27.9 (CH₂), 29.6 (CH₂), 29.7 (CH₂), 32.2 (CH₂), 36.0 (CH₃), 41.3 (CH). MS (EI, *m/z*, rel-%): 160 (M⁺, 17), 126 (31), 97 (31), 85 (22), 84 (28), 70 (40), 69 (42), 61 (58), 56 (62), 55 (76), 43 (77), 41 (100). GC: RI(PONA) = 1160, RI(DB-Wax) = 1377. Yield: 34%, boiling point: 28°C (0.03 mbar).

Parallel Synthesis of 3-Acetylthio-2-alkyl Alkanals

This was achieved using the Quest 205 apparatus from Argonaut Technologies (Basel, Switzerland). Combination of parallel synthesis with on-line work-up and sample collection allows synthesis procedures using one single instrument. Each reaction vessel has a port at the top, a drain valve at the bottom and inert gas to control draining time. This gives a number of options for on-line work-up such as liquid-liquid extraction or solvent evaporation.

Synthesis of 3-Acetylthio-2-alkyl Alkanals. Piperidine (100 μ L) was added to alkenals **5a-f** (34 mmol) under nitrogen at 10 °C in separated cylinders of the Quest 205 apparatus. Thioacetic acid (3.68 mL, 51.6 mmol) was then added drop-wise at 10 °C. Thereafter, the reaction mixture was stirred for another 18 h at room temperature. The mixture was diluted with Et₂O (10 mL), washed first with HCl (10 mL, 1 N) and then twice with a saturated NaHCO₃ solution (10 mL). The organic phases were dried over Na₂SO₄. All these steps were carried out at the same time in the Quest 205. Then, the solvent was evaporated for each sample. The GC purity of the crude products was 50-90%, depending on the starting alkenal. In each case, a mixture of the two diastereomers was obtained. The detailed analytical description of the 3-acetylthio-2-alkyl-alkanals **6a-f** has been reported elsewhere (11).

Split-mix Synthesis of Trialkylated 1,3,5-Dithiazines

In a glass reactor containing an aqueous acid solution of pH 3-4, isobutanal (7.10 mL) was added slowly followed by ethanal (8.65 mL). Then, an ammonium sulfide solution (44.6 mL, 21%) was added dropwise, keeping the temperature in the reactor at about 2-3 °C. After the addition, the reaction mixture was stirred for 30 min at 2-3°C before warming up to 20°C. The sample was stirred for additional 12 h at 20°C. The aqueous phase was removed and the organic phase filtered to obtain a yellow oil (11.8 g), which was stirred under vacuum (30 mbar) at 60°C for 3 h. Distillation of the clear yellow oil (10.7 g) under reduced pressure (1 mbar) at 70-120°C led to a yellow oil (8.74 g, 60% yield) with strong odor.

Gas Chromatography - Mass Spectrometry / Olfactometry (GC-MS/O)

Mass spectra of the synthesized compounds and their retention indices were acquired using a gas chromatograph GC 5890 (Agilent, Geneva, Switzerland) equipped with 2 splitless injectors heated at 260 °C and coupled with a quadrupole mass spectrometer MS 5970 (Agilent, Geneva, Switzerland) operating in the electron impact ionization mode at 70 eV. Acquisitions were carried out over a mass range of 10 to 350 Da. Separations were performed on a 100% dimethyl polysiloxane apolar stationary phase (Ultra-1 PONA, 50 m x 0.20 mm i.d., 0.5 μ m film thickness, Agilent) and on a polyethylene glycol polar stationary phase (DB-Wax, 60 m x 0.25 mm i.d., 0.5 μ m film thickness, J&W, Folsom, CA). Helium was used as the carrier gas with a constant flow rate of 0.6 mL/min and 1.0 mL/min, respectively. The oven was programmed as follows: 20 °C (0.5 min), 70 °C/min to 60 °C, 4 °C/min to 240 °C. The temperature of the

transfer line was held at 280 °C during the chromatographic run. Sniffing detection was performed on both stationary phases.

Nuclear Magnetic Resonance (NMR) Spectroscopy

The samples for NMR spectroscopy were prepared in Wilmad 528-PP 5 mm Pyrex NMR tubes using deuteriochloroform as solvent (0.7 mL). The NMR spectra (¹H-NMR, ¹³C-NMR, DEPT-135) were acquired on a Bruker AM-360 spectrometer equipped with a quadrinuclear 5 mm probe head, at 360.13 MHz for ¹H and at 90.03 MHz for ¹³C under standard conditions (12). All chemical shifts are cited in ppm relative to the solvent signal.

Threshold Determination

Orthonasal detection thresholds were determined in water (Vittel) with seven panelists. Eight samples were presented in order of decreasing concentrations (factor 10 between samples) to estimate the range of threshold concentration. Threshold values were determined by triangular test using a series of four concentrations (factor 2.5 between samples). Threshold values correspond to ≥70% of correct answers.

Results and Discussion

2-Thioalcanes

Synthesis. In the frame of our work on the identification of impact odorants found in bell peppers and onions (3), we synthesized various secondary thiols using the pathway described in Figure 1. The alcohols 1a-d were activated with *p*-toluenesulfonyl chloride as a good leaving group. This reaction was performed with 2-hexanol 1a, 2-heptanol 1b, 2-octanol 1c, and 2-nonanol 1d. The different tosyl derivatives were obtained in good 73%, 76%, 75% and 62% yield, respectively. The tosylate group was then substituted with sodium hydrogen sulfide as nucleophile. The conversion yields were excellent, however the isolated yields were moderate (20-40%), mainly due to the instability of the thiols, which were easily oxidized to the corresponding disulfide during the distillation procedure, as indicated by GC analysis (data not shown).

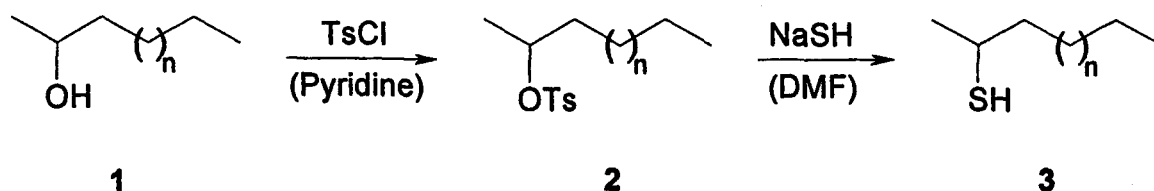


Figure 1. Synthesis pathway to 2-thioalcanes

Sensory Properties. The odor properties of the 2-thioalcanes synthesized are summarized in Table 1. The odor thresholds determined in water were between 10 to 90 $\mu\text{g/L}$. 2-Heptanethiol showed the lowest orthonasal detection threshold value (10 $\mu\text{g/L}$ in water). This threshold is similar to hydrogen sulfide having a sulfury, egg-like note (2). In high dilution, *i.e.* about 10-times the threshold, 2-heptanethiol was mainly described as bell pepper-like, fruity, and vegetable-like. At higher concentrations (100-1000 times the threshold), the odor description was completely different: sulfury, onion-like, with some mushroom note. In the literature, the odor of 2-heptanethiol has been described as sweet, fruity, tropical (sulfury), and floral, however without indicating the threshold value (13).

Table I. Sensorial Properties of 2-Thioalcanes.

<i>Compound</i>	<i>Odor description^a</i>	<i>Odor threshold^b</i>
2-Hexanethiol 3a	Sulfury, leek	60
2-Heptanethiol 3b	Bell pepper, green vegetables, sulfury ^a , onion ^a , mushroom ^a	10
2-Octanethiol 3c	Mushroom, slightly fruity, bell pepper	50
2-Nonanethiol 3d	Herbaceous, mushroom, woody	90

^a Odor description at a higher concentration (about 1 mg/L). ^b Detection threshold in water ($\mu\text{g/L}$) was obtained by orthonasal measurements performed by 7 panelists.

2-Hexanethiol 3a was described as more leek-like. On the contrary, the higher molecular weight odorants, 2-octanethiol 3c and 2-nonanethiol 3d, were reminiscent of mushroom and herbaceous sensory characteristics, which is close to sensory properties of the corresponding C8 and C9 alcohols known to elicit mushroom notes (14). The descriptors of the 2-thioalcanes are in accordance

with those reported by Sakoda and coworkers (13) who studied the relationship of odor and chemical structure comparing 1- and 2-alkyl alcohols and their corresponding thiols. To our knowledge, none of the thioalcanes studied have been found in natural products or reported as constituents of food.

3-Acetylthio-2-alkyl Alkanals

Parallel synthesis. Several 3-acetylthio-2-alkyl alkanals with different chain length were prepared by parallel synthesis. As shown in Figure 2, the first step was an aldol-type condensation of an *n*-alkanal, which results in the corresponding 2-alkyl- α,β -unsaturated aldehyde. Depending on the starting aldehyde, the yields varied between 40 and 70%. The alkenals were then mixed with thioacetic acid under alkaline condition to introduce regioselectively the acetylthio function in the aldehyde backbone. Structure characterization and purity control was carried out on the basis of GC, GC-MS, and NMR data. The purity (GC) of the crude products was between 50 and 90% and conversion yields were between 55 and 98%, depending on the starting alkenal. The analytical data are reported elsewhere (11).

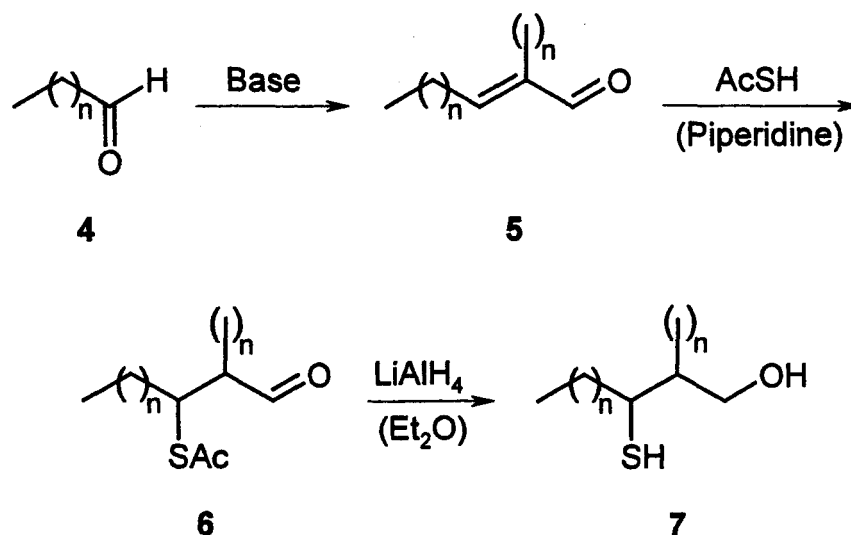


Figure 2. Synthesis pathway to 2-alkyl-3-mercapto alcohols

To obtain the corresponding mercaptoalcohols, both the acetylthio and aldehyde functions can be reduced with lithium aluminum hydride under inert conditions (7, Figure 1). Also the mercaptoalcohols were obtained as a mixture of diastereomers. In general, conversion yields were about 80 % in all cases as

indicated by GC. Only 3-mercapto-2-methyl-1-pentanol was isolated and characterized by GC-MS and NMR. The data were in good agreement with those reported in the literature (4).

Sensory Properties. The sensory properties of the acetylthio aldehydes are shown in Table 2. They are predominantly characterized by fruity notes, such as tropical and grapefruit-like, in particular odorants 6b-e. On the contrary, the lower and higher homologues, i.e. 3-acetylthio-2-methyl pentanal 6a and 3-acetylthio-2-hexyl decanal 6f, showed savory characters such as onion-like and fatty, chicken-like, respectively. Surprisingly, 3-acetylthio-2-butyl octanal 6d was described as fresh, green, vegetable-like, reminiscent of crude cauliflower, when it is smelt neat. From a structural point of view, these data are in good agreement with the tropical/vegetable "odorophore" recently proposed by Rowe and Tangel (15). Following our results, the "olfactophore" model based on a 1,3-oxygen-sulfur structure can further be generalized by adding the acetyl group for substituent A in Figure 3 (16). Interestingly, the threshold concentration of the 3-acetylthio-2-alkyl alkanals 6a-e increased exponentially with the carbon chain length (11).

Table 2. Sensorial Properties of 3-Acetylthio-2-alkyl Alkanals

<i>Compound</i>	<i>Odor description^a</i>	<i>Odor threshold^b</i>
3-Acetylthio-2-methyl pentanal 6a	Leek, onion, bouillon	5
3-Acetylthio-2-ethyl hexanal 6b	Fruity, tropical, grapefruit	15
3-Acetylthio-2-propyl heptanal 6c	Fruity, tropical, grapefruit	50
3-Acetylthio-2-butyl octanal 6d	Fruity, grapefruit, green vegetables, cauliflower	200
3-Acetylthio-2-pentyl nonanal 6e	green, fruity, citrus	500
3-Acetylthio-2-hexyl decanal 6f	Fatty, chicken	n.d.

^a Odor description was performed at a concentration of about 0.5-5 mg/L. ^b Detection threshold in µg/L water was obtained by orthonasal measurements performed by 7 panelists (n.d., not determined).

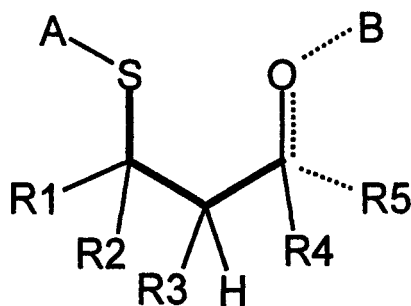


Figure 3. The "olfactophore" for tropical/vegetable notes with A: H, SCH₃, ring; B: H, CH₃, acyl, absent if carbonyl; R1, R2: H, alkyl; R3: H, alkyl, ring; R4: H, CH₃, ring, OR; R5: H, absent if carbonyl. Adapted from ref. 16.

Dihydro-2,4,6-trialkyl-4H-1,3,5-dithiazines

Synthesis (split-mix). Trialkylated dihydro-4H-1,3,5-dithiazines **10** were obtained by mixing aldehydes **8** and ammonium sulfide **9** in aqueous solution under acidic conditions (Figure 4). When using several aldehydes a mixture of dithiazines was obtained representing the different combinations between the reagents. For example, when using isobutanal and ethanal as starting aldehydes the six following 1,3,5-dithiazine derivatives can theoretically be obtained: 2,4,6-trimethyl, 2-isopropyl-4,6-dimethyl, 4-isopropyl-2,6-dimethyl, 2,4-diisopropyl-6-methyl, 4,6-diisopropyl-2-methyl, 2,4,6-triisopropyl with a statistical distribution of 1/1/2/2/1/1. In practice, steric hindrance and electronic differences modified the statistical distribution leading to a 4/2/3/0.2/0.4/0.1 ratio of the above-mentioned dithiazine derivatives. In more general terms, *n* aldehydes should theoretically provide $n^2(n+1)/2$ dithiazines in the same reaction.

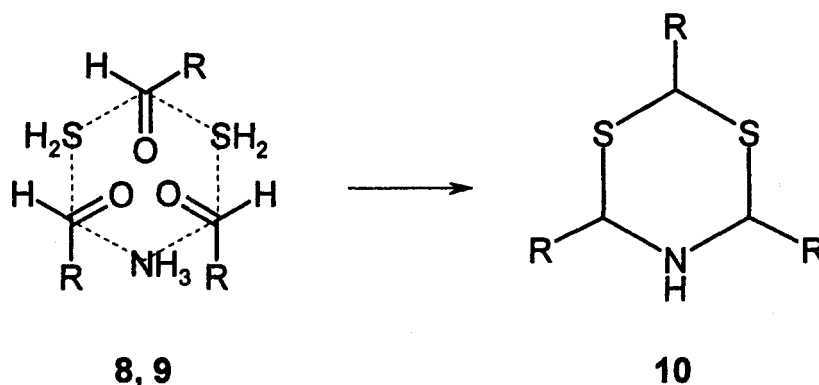


Figure 4. Synthesis pathway to trialkylated 1,3,5-dithiazines

Sensory Properties. This mixture showed a very strong onion and leek-like aroma. All components can be sensorially characterized by GC-O. The sensory characteristics of the 1,3,5-dithiazines from isobutanal and ethanal used as starting aldehydes have already been reported earlier (17).

In conclusion, parallel synthesis and more generally, combinatorial chemistry, seems to be an attractive approach in aroma research to help identifying new odorants with interesting sensory properties. It allows rapid synthesis of a large number of components in a reasonable time. The reference compounds can be very useful for structure elucidation of unknown odorants.

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