

The role of lipids in aroma/food matrix interactions in complex liquid model systems

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ABSTRACT

The release of nine aroma compounds was investigated in complex liquid bouillon-type model systems containing various non-volatile constituents. The relative release was determined by static headspace GC-MS as a function of the bulk composition. Among the non-volatile food constituents studied, fat appeared to be very efficient in binding volatile aroma molecules. This retention by the fat was directly correlated with the intrinsic physical properties of the aroma compounds, such as the water/octanol partition coefficient. The individual effect of the major fat constituents was studied as well, indicating that, for example, even small amounts of phospholipids may effectively retain volatile compounds.

1. INTRODUCTION

The phenomena related to aroma release and retention have become a widely studied research field [1,2]. Despite the high complexity of food, most of the work published so far is dealing with rather simple systems studying the release of volatile compounds as affected by selected food biopolymers, such as starch [3], xanthan [4], carrageenan [5], pectin [6], and β -lactoglobulin [7]. Also lower molecular weight compounds of different chemical classes were studied, in particular lipids, which notably affect flavour release by lowering the vapour pressure of many odorants and changing the time scale of release with varying concentrations [8]. Reduction of fat content in food results in a drastic shift of the overall flavour profile leading to different odour sensation, even if the changes in the fat content are small [9]. The affinity of flavours to the lipid phase depends on its chemical composition, chain length, degree of saturation, and sequence of fatty acids in the triacylglycerol [10].

As the results obtained from simple model systems hardly allow prediction of the release behaviour in food systems, we studied the release of nine odorants in rather complex liquid models containing various types of macromolecules. The aim of this work was to investigate aroma release under static headspace conditions as a function of the bulk composition and to elucidate the role of different lipid constituents.

2. MATERIALS AND METHODS

Materials. The following compounds were commercially available: 3-methylbutanal, n-hexanal, n-heptanal, n-octanal, 1-hexanol, chitin (from crab cells), triacylglyceride palm oil (Fluka, Buchs, Switzerland); n-nonanal, benzaldehyde (Aldrich, Buchs, Switzerland); α -pinene (Glidco Organics, Jacksonville, USA); 1-octen-3-one (Lancaster, Cardiff, UK); cellulose gum (Aqualon, Düsseldorf, Germany); collagen (Biogel AG, Lucern, Switzerland); cured ham fat (from the local market).

Sample preparation. A stock solution composed of 3-methylbutanal (3 μ l/l), hexanal (30 μ l/l), heptanal (8 μ l/l), octanal (5 μ l/l), 1-hexanol (50 μ l/l), nonanal (1 μ l/l), benzaldehyde (50 μ l/l), α -pinene (1 μ l/l), 1-octen-3-one (2 μ l/l) was prepared in mineral water (Vittel, Nestlé Waters, France) or in deionised water and adjusted to pH 7. The solution was stored at 4 °C prior to analysis. Macromolecules were used at the following concentrations: fat (5.0 g/l), collagen (2.7 g/l), cellulose gum (1.5 g/l), chitin (0.3 g/l). A fat model was composed of triacyl glycerol (85%), diacyl glycerol (3%), monoacyl glycerol (1%), free fatty acids (10%), and phospholipid (1%). Non-volatile molecules were weighted directly into a 20 ml vial and 5 ml of the volatile stock solution was added. If necessary, the samples were readjusted to pH 7 before starting with the equilibrium phase. The vials were closed with caps and equilibrated at 37 °C for 2 h. After achieving equilibration under stirring (300 rpm, 2 h), 2 ml of the headspace sample was injected using an autosampler held at 37 °C. Each sample was prepared in triplicate for GC headspace analysis.

3. RESULTS AND DISCUSSION

Effect of biopolymers. With the exception of the apolar compounds α -pinene and nonanal, of which 60% and 15%, respectively, was retained by cellulose, neither cellulose nor chitin strongly influenced aroma release into the headspace at the concentration applied (Figure 1). Collagen seemed to play a role in the release of aliphatic aldehydes and 1-octen-3-one by retaining about 20% and 70%, respectively. The release of 1-octen-3-one was much more affected suggesting a specific interaction between collagen and this aroma compound. Various chemical reactions of the carbonyl group have been reported in the literature, such as the reaction with amino and sulfhydryl groups of amino acids or proteins leading to Schiff's base formation and cysteine-aldehyde condensation, respectively [11].

Effect of fat. As shown in Figure 1, only fat produced significant differences in aroma release for all volatile components compared to the reference sample, clearly indicating aroma/lipid interactions. Relatively polar aroma compounds such as 1-hexanol and 3-

methylbutanal were readily released into the headspace reaching about 80-90% release. In contrast, lipophilic aroma compounds such as nonanal, α -pinene, and octanal were well retained by the fat (75-99%) leading to only 1-25% release compared to the reference sample. The retention of each aroma compound induced by the addition of fat is well correlated with its intrinsic physico-chemical properties, such as the octanol/water partition coefficient, thus explaining the preferred binding of lipophilic aroma compounds, in particular α -pinene ($\log P = 4.83$), nonanal ($\log P = 3.27$), octanal ($\log P = 2.78$), heptanal ($\log P = 2.29$), and 1-octen-3-one ($\log P = 2.13$). These data confirm earlier work [12] that fat plays an important role in aroma release both by decreasing the overall headspace concentration of aroma compounds and by changing the headspace composition due to a preferred entrapment of hydrophobic volatile compounds.

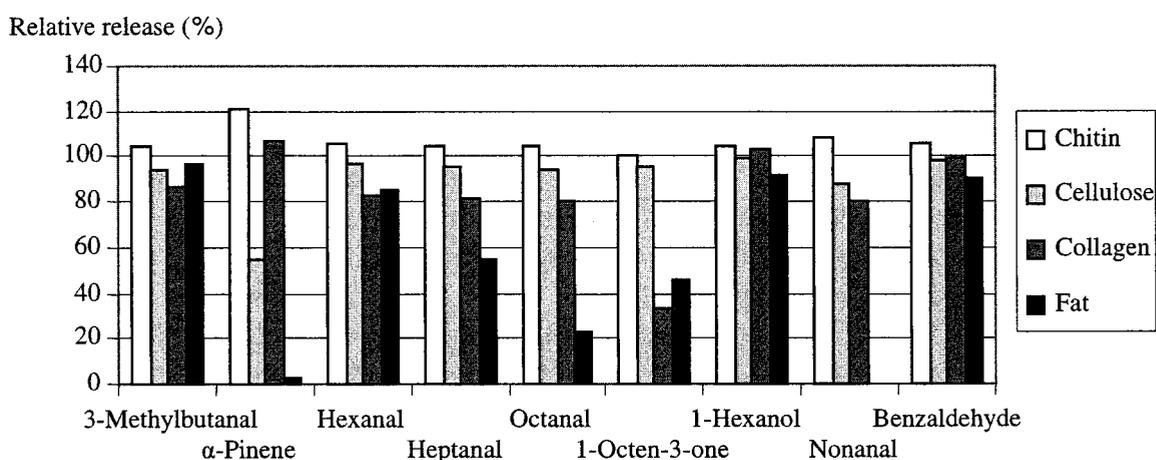


Figure 1. Individual effect of macromolecules on the release of selected volatile compounds.

Effect of the concentration. As mentioned above, neither cellulose nor chitin affected strongly, at the concentration used, the aroma release into the headspace, while collagen and in particular fat markedly modified the aroma release of most of the volatile compounds. When increasing the concentration of polysaccharides, the reduction of release into the headspace observed was clearly correlated with an increase in the viscosity (data not shown). These results confirm that the effect of hydrocolloids or proteins in aroma retention require relatively high concentrations that correspond more to a yoghurt or mayonnaise type of product rather than a bouillon application. A small increase of fat concentration resulted in drastic retention of apolar volatile compounds. On the other hand, the rather polar compounds 3-methylbutanal, 1-hexanol, and benzaldehyde were less affected by higher amounts of lipids.

Effect of lipid constituents. The headspace results obtained with the fat model were practically identical to those obtained with the natural ham fat (Figure 1). As the aroma release behaviours were similar, the simplified lipid model could be used to mimic the original cured ham fat in order to study the role of each constituent. The aroma release patterns obtained with each class of fat at the original concentration and ratio were compared with the complete system. Triacyl glycerol was the most important lipid

constituent with respect to aroma retention, most likely due to its high abundance in the fat. In general, triacyl glycerol influenced the retention of the entire volatile composition. However, apolar compounds were preferably retained (50-90%) compared to 3-methylbutanal, benzaldehyde, and 1-hexanol (10-20%). These results suggest that the interactions are more driven by hydrophobic than dipole-dipole interactions at this concentration and ratio. In agreement with that, the most apolar odorants α -pinene and nonanal were retained by all lipid compounds. Despite their lower concentrations, free fatty acids and phospholipids also influenced the aroma release, in particular of apolar compounds. A possible synergistic effect of lipid constituents was checked by using various binary mixtures in aroma release experiments. None of the combinations studied showed any interaction between lipid constituents, as the measured aroma release corresponded globally to the sum of the effect obtained with each lipid species individually (data not shown).

4. CONCLUSION

As systems mimicking food ingredients are quite complex, it is consequently difficult to discuss and clearly assess the nature of the interactions or the parameters mainly responsible for the effect. However, it appears that aroma release in the headspace is quantitatively and qualitatively modified by molecules responsible for food texture (fat and macromolecules). Not surprisingly, fat appeared in our system as the most important non-volatile constituent affecting aroma retention and release. This study has clearly demonstrated that aroma, taste, and texture are difficult to dissociate due to physico-chemical interactions between the various molecule species, which certainly play a role in the global sensory perception. In addition, there are probably many other factors influencing the sensory perception as well, such as physiological and psychological interactions, which should be taken into consideration.

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