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Tackling obesity: Aeration as a novel approach to fat reduction in dairy products

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ABSTRACT

Obesity is one of the major challenges of modern societies. The food industry is under increasing pressure from government and the consumer side to reformulate foods to reduce the fat, sugar and salt content. However, if fat or sugar is reduced the overall flavor perception of the food is changed. In the case of fat reduction these changes are caused by a different aroma release during in mouth processing. Additionally the texture is perceived as less creamy. It was recently found that aeration can increase aroma release and change texture perception in terms of creaminess. The goal of this work is to study both effects in perspective of fat reduction in fermented dairy products.

Various mathematical models will be used to understand and describe the different effects involved. Since temperature is a critical parameter for aroma release and foam stability, heat transfer into a simplified mouth model for aroma release analysis was studied using the finite element method. In a second step the aroma release during foam collapse will be modelled and validated by aroma analysis data. In the last step the model linking the sensory perception of creaminess to the physical parameters of the foam (friction coefficient, viscosity, bubble size distribution) and the chemical attributes of the aroma substance (hydrophobicity, volatility) will be shown. The findings from this work, both from the effect of aeration and the methodological approach may be transferred to other food categories as well.

1. INTRODUCTION

Both developed and developing countries are currently confronted with a rise in nutrition related diseases, especially obesity, cardiovascular diseases, and diabetes. This development is caused by an excess consumption of fat, salt and sugar. Since a reduction of these food ingredients may contribute to saving lives and reducing healthcare costs the reformulation of foods is in focus of legislation, food industry and scientific community.

Fat reduction in foods causes a significant change in aroma perception due to the different aroma release (Guichard, 2002). Volatile aroma substances are often

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hydrophobic and are bound by fat more then by the more hydrophilic phase of the food. Heilig *et al.* (2016) found that the higher the log P value of an aroma substance (Eq. 1) the lower the partition coefficient K_{mg}, i.e. the stronger the binding to a dairy food matrix. This relationship between static aroma release (Eq. 2), and the log P value is obvious from their definitions with c_o as aroma concentration in octanol, c_w its concentration in water, c_m in the food matrix and c_g in the headspace above the food.

$$log\, P = log\frac{c_o}{c_w} \qquad \text{(Eq. 1)}$$

$$K_{mg} = \frac{c_m}{c_g} \qquad \text{(Eq. 2)}$$

In the attempt to replace fat in foods one must therefore find new ways to bind aroma to the matrix which is then released during oral processing. Recent studies by Hinrichs *et al*. (2014) have found that aeration can increase static aroma release. This finding was verified by sensory studies (triangle test) which showed significant differences in aroma intensity in the headspace over a foamed matrix in comparison to an unfoamed one. Both matrices were flavoured with the same amounts of aroma. These analyses were performed on the equilibrated food system, i.e. the temperature and the concentrations were constant before analysis. During oral processing however the temperature increases and diffusion of aroma substances occurs due to concentration gradient between the headspace of the oral cavity and the food itself. Aroma reaches the olfactory epithelium in the nasal cavity as a result of the simultaneous processes of heat and mass transfer. In a first study Hinrichs *et al*. (2014) simulated the process of dynamic aroma release from a foamed dairy matrix using a model mouth coupled to a PTR-MS (proton transfer reaction-mass spectrometer). A more intense aroma release from the foamed matrix was found in comparison to the unfoamed one (Fig. 1).

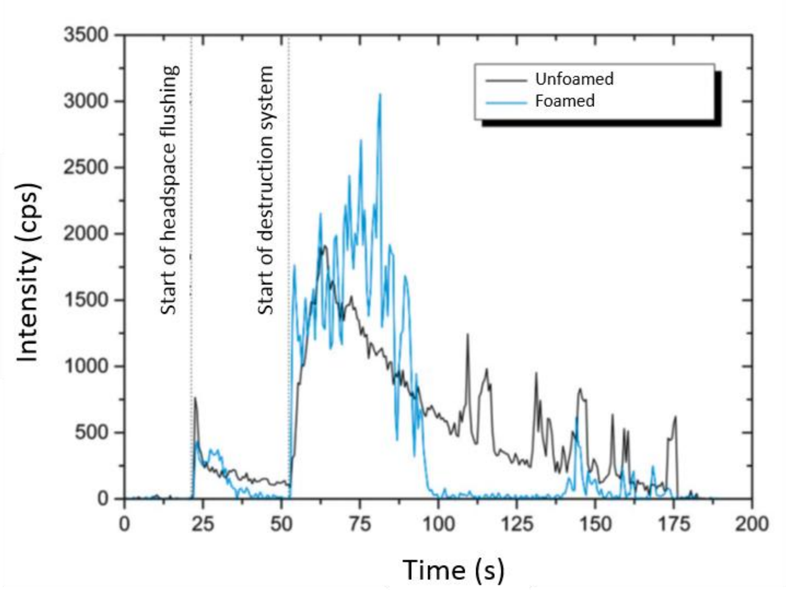

Fig. 1 Proton Transfer Reaction - Mass Spectrometry analysis of a dairy foam (4% protein, 1% alginate) (Hinrichs *et al*., 2014)

These results show the potential of aeration to increase aroma perception in dairy foods. However more research is necessary to understand the effect to be able to create products with lower fat content but similar aroma perception. The overall goal is to understand how the aroma substance volatility, hydrophobicity and chemical group (e.g. carboxylic acid, ester, lactone), and the foam parameters overrun, bubble size distribution and aeration gas influence the dynamic aroma release from a foamed dairy matrix.

Looking at the multi-sensory experience of fat perception, texture also plays an important role in creating creaminess besides aroma (Schiffmann et al., 1998, Frøst & Janhøj, 2007). It is the interplay of viscosity, particle size distribution and lubrication properties which creates creaminess in yoghurt, for example (Sonne *et al.*, 2014). Fat reduction changes all three parameters, so to create creamy products with low fat presents a great challenge. One approach is to use aeration, as it lowers the product hardness. Additionally, aeration introduces a second phase which is separated during oral processing, as the oil or fat phase is from its emulsified form in fatty products. In spite of its potential use the effect of aeration on sensory properties is not well understood yet. A first study by Minor *et al.* (2009) showed that the bubble size distribution and gas volume fraction are important factors in creaminess perception of aerated foods.

Due to the complexity of oral food processing mathematical modeling can be a helpful tool. However, the modelling techniques have to be chosen according to the scientific question. If the physical processes are known physics based models can be used solving the continuum equations. In many cases however the coefficients describing the food properties, e.g. diffusion coefficients, are not available for the materials. Additionally these coefficients are temperature dependent and are thus varying over time and location. This is why observation based models are more often used instead (Datta & Sablani, 2006).

2. METHODS

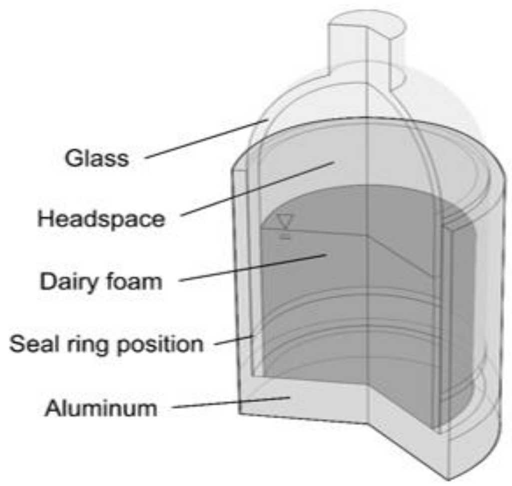

Fig. 2 3D graph of mouth model for *in vitro* studies
of aroma release from dairy foam (Thomas *et al*., under review)

To study the effect of aeration on aroma and texture perception of dairy products firstly a mouth model was designed to simulate oral processing of the foam (Fig. 2). This *in vitro* model enables the generation of data on aroma release from the matrix without the complexity of oral physiology. Saliva composition, breathing rate and mastication strategies for example play an important role in fat perception (Guichard *et al*., 2018). However, these parameters show large inter-individual differences, hence making it difficult to generate representative results in *in vivo* studies.

Several steps have to be studied in order to understand the effect of aroma release from a foamed matrix (Tab. 1, step 1 – 3) and predict the effect of the varied texture and aroma release on sensory perception (step 4 – 6). Physical models are used in the first steps to determine the dominating variables of the processes. In prediction of sensory perception however tools like fuzzy logic are more advantageous. Correlations of several variables, e.g. describing the texture of a food, with several sensory output variables can be achieved by using artificial neuronal networks.

Tab. 1 Steps in understanding (1 – 3) and prediction (4 – 6) of the effect of aeration on fat perception in a dairy matrix;

Step		**Independent variable**	**Dependent variable**	**Model approach**
1	Mouth model temperature	Location, time	Temperature	Physical: finite element
2	Effect of temperature on aroma and texture	Temperature	Viscosity, partition coefficient	Empirical: regression
3	Effect of foam collapse on aroma release	Viscosity, partition coefficient	Aroma concentration in headspace	Physical: finite element
4	Correlation of texture to sensory perception	Viscosity, friction coefficient, bubble size distribution, gas volume fraction	Sensory perception (creaminess)	Empirical: ANN, fuzzy logic
5	Correlation of aroma release to sensory perception	Aroma release rate	Sensory perception (Aroma intensity)	Empirical: ANN, fuzzy logic
6	Prediction of sensory acceptance	Fat content, gas volume fraction, aroma	Sensory perception (overall liking)	Empirical: ANN, fuzzy logic

ANN: artificial neuronal network

Even using powerful computers modelling foam structures and their breakdown is a challenging task. However a two-phase system can also be described accurately by a mean matrix property coefficient, for example its thermal conductivity (Thomas *et al.*, under review). If the calculation of the mean coefficient is challenging, a small section of the foam system can be simulated with both phases and the result can be transferred to the whole foam. This approach facilitates much faster simulation of a complex aerated food system.

3. OUTLOOK

Many foods are foams or can be aerated, so using the effect of aeration to reduce fat in foods is a very straight forward technique. The technology is well-known and compared to other approaches in line with the current customer demand of “clean label” foods. Using the tools of mathematic modelling to understand the underlying effects creates the knowledge foundation for the transfer of the findings from fermented dairy products to other foods (e.g. whipped desserts, carbonated beverages, bakery products). Additionally using modern modelling techniques on practical technological questions could lower barriers to use these tools to tackle other scientific challenges.

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