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Effects of texture and temperature on the kinetic of aroma release from model dairy custards

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ABSTRACT

The structure of a foodstuff, and its perceived texture, are important characteristics involved in the sensory availability of flavour compounds released during the food consumption. This study identifies the effect of texture on the dynamic release of aroma compounds under simulated oral conditions (temperature and shearing). Two custard desserts, with two levels of texture but the same composition, flavoured with four aroma compounds, were analysed. The rheological behaviour of the custards and the release of aroma compounds (SPME analysis) were simultaneously followed, using a mouth simulator. The custard with the lowest texture level showed the highest kinetic release for all aroma compounds studied. With fast increase of temperature (10–25 °C), the decrease in viscosity of the custards and its impact on flavour release seemed to be less important than the heat transfer inside the products and its effect on partition of aroma compounds.

1. Introduction

The structure of a foodstuff and its perceived texture are characteristics which can be involved in the sensory availability of flavour compounds during food consumption. The state of the art methodologies available in this field are effective but conclusions drawn vary, depending on the methods employed: *in vitro* approach and/or *in vivo* approach. The *in vitro* approach is characterised by a kinetic component to the flavour release and mechanical and thermal effects of the sample in the mouth; it is difficult to simulate all these phenomena with in an *in vitro* approach.

The perception of flavour at the level of the olfactory receptors depends partly on the availability of the aroma compounds released from the foodstuff. The retention of the components in the matrix and the kinetics of release modulate the presence of aroma compounds in the vapour phase in the mouth and therefore influence their sensorial perception (Seuvre, Philippe, Rochard, & Voilley, 2007). The intrinsic factors involved in flavour release, such as the physicochemical properties of aroma compounds and food ingredients and rheological behaviour of the matrix, have been well studied (Guichard, 2002).

The impact that the texture of the product has on olfactory perception is generally indirectly examined by studying the effect of factors modifying the rheological properties of a matrix on the relative volatility of aroma compounds. When the impacts of various thickening agents and aroma compounds are studied, it is observed that the response is dependent on the combination of thickener and flavour compounds used together (Lubbers, 2006). Some authors have shown that increasing the quantity of thickener (starch and pectin) used in a model dairy gel, induces effects on both the viscosity and aroma release (Boland, Delahunty, & van Ruth, 2006; Decourcelle, Lubbers, Vallet, Rondeau, & Guichard, 2004). A greater release of hydrophilic compounds occurs from pectin gels; starch gels show a greater release of hydrophobic compounds (Baines & Morris, 1987; Pangborn & Szczesniak, 1974). The retention of the aroma compound in the matrix can be explained by a decrease in the diffusion of the aroma compounds with increase of viscosity and by interactions between thickeners (polysaccharides or proteins) and aroma compounds (Decourcelle et al., 2004; Seuvre, Philippe, Rochard, & Voilley, 2006). Notably, many studies were carried out under equilibrium conditions which is rarely the case in the real process of consumption. Conversely, other reports showed low or no impact of the texture of matrices on *in vivo* flavour release (Cook, Linforth, & Taylor, 2003; Gonzalez-Tomas, Bayarri, Taylor, & Costell, 2007; Hollowood, Linforth, & Taylor, 2002; Lethuaut, Weel, Boelrijk, & Brossard, 2004; Weel et al., 2002).

The kinetic dimension appears to be an important parameter for the diffusivity inside the matrix and for flavour release. Moreover, structure loss of foodstuff during its consumption must be considered. The shearing of a food sample and increase in temperature trigger significant changes in the partition of aroma compounds between the matrix and the air phase (Taylor, Besnard, Puaud, &

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Linforth, 2001). The main effect of shearing is to increase the area of the transferring surface between the product and the gas phase and hence to accelerate the transport of the aroma compounds (Bakker, Boudaud, & Harrison, 1998; Roberts, Elmore, Langley, & Bakker, 1996; Savary, Semon, Meunier, Doublier, & Cayot, 2007). During the consumption of cold foodstuffs, the piece of food is heated in the oral cavity. This increase in temperature causes an increase in flavour release, as well as changes in rheological behaviour, by reducing the rigidity of dairy gels, which is favourable for aroma compound availability (Seuvre, Turci, & Voilley, 2008).

The aim of the present work was to study the effect of texture on the dynamic release of aroma compounds in-mouth simulated conditions. Two custard desserts with the same composition, but with two texture levels were prepared. The mouth simulator used made it possible to simultaneously follow the rheological behaviour of the custard dessert and the release of aroma compounds. To simplify the study, no addition of saliva was made during the flavour release experiments in the mouth simulator. Additionally, two sets of temperature and a constant shear rate were used in the simulator, so as to highlight the importance of these factors on the kinetic of release of aroma compounds.

2. Materials and methods

2.1. Aroma compounds

Four aroma compounds with various physicochemical properties were chosen (Table 1). Pure compounds (Sigma Aldrich, purity 95%, 99%) were mixed in propan-1,2-diol (Sigma Aldrich, purity 99.5%) at 10 mg g^{-1}. The aroma mixture was stored at 4 °C. The samples (water, custards) were flavoured at a concentration of 1 g kg^{-1}. The flavoured products were stored at 4 °C for 48 h before analysis.

2.2. Custard preparation

The custard recipe was composed of 1800 g of skimmed milk (UHT, fat trace), 140 g of commercial sugar (Erstein, France), 60 g of modified tapioca starch Farinex VA 70T (kindly provided by AVEBE) and 4 g of kappa carrageenan WG-95 (kindly provided by GELIMAR).

Skimmed milk was placed in an IKA LR 2000 reactor. The water bath, attached to the double jacket bowl of the reactor, allowed temperature control at 30 °C. The powdered ingredients were slowly added to the milk whilst stirring at 70 rpm. Once all the powder was added, the mixture was left stirring for 20 min to ensure that all of the powder had dispersed. Then the custard mixture was heated and stirred for 30 min until the internal temperature reached 90 °C. When this temperature was reached, the custard was maintained at this temperature for 10 min. After the heating process, the bowl was cooled with cold water circulating in the double jacket. The custard was cooled this way for approximately 1 h until the temperature reached 5 °C. This custard, named T1, was stored at 4 °C for a maximum of 7 days.

To obtain the second level of texture in the custard (T2), extra-shearing was applied. After custard T1 was cooled to 5 °C, an Ultra Turrax® blender was attached to the reactor with the speed of rotation set to 13,500 rpm. The temperature was held at 5 °C to prevent overheating of the product. The custard was mixed under these conditions for 20 min. Once again the custard was stored at 4 °C for a maximum of 7 days.

2.3. Model mouth headspace analysis

2.3.1. Operating conditions in the model mouth

Flavour release measurements from products were performed in a mixing instrument designed to simulate mouth shearing. This model mouth, which was developed for semisolid foodstuffs, is described in Decourcelle (2004). An aliquot of 80 g of product was inserted into a 100 ml closed double jacket vessel. The temperature was regulated, from 10 °C to 40 °C, with a programmable water-bath. The top was closed, using a cap lined with a Teflon seal. A screw-cap valve with Teflon seal allowed the sampling of the headspace vessel. The propeller (diameter 45 mm, hub diameter 8 mm, height of blades 15 mm, number of blades 3) used to shear the product in the tank, was placed 1 cm from the bottom of the tank. The temperature inside the product was recorded online with a digital thermometer with PT100 probe (Fisher Bioblock Scientific, Illkirch, France). A rheometer (RM180 Rheometric Scientific, France) drove the propeller and measured the torque values during the shearing. The data were recorded using the Orchestrator® software (Rheometric Scientific™, France). A shear rate of 100 s^{-1} was applied to the product during headspace sampling of aroma compounds. This shear rate would correspond to shear conditions in the mouth for semisolid foodstuffs (Dickie & Kokini, 1983; Kokini, Kadane, & Cussler, 1977; Roberts et al., 1996).

2.3.2. Operating condition for SPME analysis

Solid phase micro-extraction (SPME) was used to trap the aroma compounds in the headspace vessel during shearing. The fibre (65 µm PDMS/DVB, Supelco, USA) was inserted in the headspace vessel for 5 s at the start of shearing. A second fibre was exposed at time 10 s for a period of 5 s. The previous steps were repeated for the times 20–25 s, 30–35 s, 40–45 s, and 55–60 s. After the first minute, sampling was carried out for the times 5, 10, 15, 20, 30, 40, 60, 90, 120 min.

To perform quantitative analysis of aroma compounds with SPME, aqueous solutions of aroma compounds (10 mg l^{-1}) were poured into a headspace vial (40 ml, Supelco, USA) and equilibrated in a water bath at 25 °C until the equilibrium was reached (2 h).The SPME fibre was then exposed for 5 s in the headspace vial. According to the partition coefficients of aroma compounds available in the literature (expressed in ratios of concentration, vapour/liquid), the relationship between the vapour concentration and the chromatographic peak area was established to form a calibration.

Table 1
Physicochemical properties of aroma compounds.

Aroma compounds	Cas number	Molecular weight	Log *P* (o/w)	*K* air/water 25 °C
Isoamyl acetate	123-92-2	061.08	2.26	12.3×10^{-3} [a]
Octan-2-one	11-13-7	128.22	2.37	12.3×10^{-3} [b]
Ethyl hexanoate	123-66-0	144.21	2.83	33.1×10^{-3} [c]
Allyl hexanoate	123-68-2	156.22	3.12	40.0×10^{-3} [d]

[a] Lubbers, Charpentier, Feuillat, and Voilley (1994).
[b] van Ruth and Villeneuve (2002).
[c] Savary, Guichard, Doublier, and Cayot (2006).
[d] Tournier (2006).