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SCIENCE DIRECT
Food Chemistry 100 (2007) 297–305
Food Chemistry
www.elsevier.com/locate/foodchem

Influence of flavour transfer between different gel phases on perceived aroma

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Received 3 March 2005; received in revised form 16 June 2005; accepted 21 July 2005

Abstract

Multiphasic models of stirred fruit yoghurts made from a bilayer that consisted of a pectin and a dairy gel were developed in order to study the transfer of strawberry flavour compounds between the two phases. Several parameters (i.e., the flavour concentration, the fat content of the dairy gel and the storage temperature) affecting flavour compound transfer, using an experimental design, together with their effect on sensory perception were investigated. Strawberry flavour transfer between the two gels was high enough to affect the sensory perception of the dairy gels. The parameters that modified the partitioning of ethyl esters between the pectin and dairy gel (i.e., fat content of the dairy gel and flavour concentration) also affected the perception of the fruity odour attribute; the storage temperature had no effect on the sensory perception. An increase in the initial flavour concentration in the pectin gel increased the fruity odour intensity of both gels. Conversely, the presence of fat in the dairy gel decreased the odour intensity of both gels by reducing flavour compound volatility in the dairy gel and decreasing the flavour concentration in the pectin gel.

Keywords: Flavour release; Sensory evaluation; Model matrices; Transfer; Physicochemical interactions

1. Introduction

Due to concentration gradients between the two phases of stirred fruit yoghurts (a fruit preparation and a dairy gel), several chemical types (i.e., protons, water, colorants and flavour compounds) can migrate from one phase to the other (Nongonierma et al., 2005; Warin, Gekas, Voirin, & Dejmek, 1997). Among these, flavour compound migration are influenced by many parameters such as the storage temperature and the fat content of the yoghurt (Nongonierma et al., 2005).

Many studies related to the identification of key yoghurt flavour compounds (Imhof, Glättli, & Bosset, 1995; Ott, Fay, & Chaintreau, 1997) and to their quantification (Dumont & Adda, 1973; Ott, Germond, Baumgartner, & Chaintreau, 1999) have been carried out. The effect of the fat content upon flavour release during consumption has also been studied (Brauss, Linforth, Cayeux, Harvey, & Taylor, 1999). Relatively few studies related to the strawberry flavour perception in fruit yoghurts have been reported. Among these, a market analysis using quantitative profiling to determine the drivers of liking for strawberry yoghurts was carried out (Ward, Stampanoni Koeferli, Piccinali Schwegler, Schaeppi, & Plemmons, 1999). Flash profile and conventional profiling methods have been compared to evaluate the sensory characteristics

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doi:10.1016/j.foodchem.2005.07.063

of blended strawberry yoghurts (Delarue & Sieffermann, 2004).

The influence of storage upon the degradations caused by oxidation (Jensen et al., 2004) or Maillard reactions and proteolysis in milk samples (Valero, Villamiel, Miralles, Sanz, & Martínez-Castro, 2001) have been studied. The efficiency of packaging regarding the avoidance of flavour losses has also been evaluated (Lebossé, Ducruet, & Feigenbaum, 1997). Very few studies relating the effect of flavour compound transfer during food storage upon their sensory perception have been carried out. These transfers might nevertheless have a large influence on the organoleptic quality of foods. In particular the contrast between the different phases might play an important role, especially as the perception of flavour has been shown to be driven by variations in the concentration in the nasal cavity rather than by the concentration itself (Baek, Linforth, Blake, & Taylor, 1999).

The aim of this research was to study flavour compound partitioning between the two phases of stirred fruit yoghurts models (i.e., a pectin and a dairy gel) during storage, together with its effect on the odour perception. Different parameters affecting flavour transfer between the pectin and the dairy gels (i.e., the storage temperature, the flavour concentration and the fat content of the dairy gel) were investigated using an experimental design. The fruity odour intensity of both gels was rated by a panel, from which the transfer of flavour compounds was related to their sensory perception.

2. Material and methods

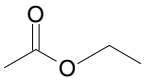
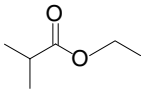
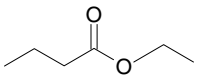
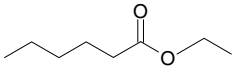
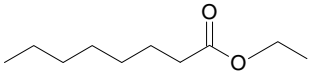
2.1. Flavour compounds

A mix of thirteen key strawberry flavour compounds (ethyl acetate, ethyl butanoate, ethyl isobutanoate, ethyl hexanoate, ethyl octanoate, hexanal, 2-methyl butanoic acid, linalool, furaneol, mesifurane, γ-decalactone, *cis*-3-hexen-1-ol and methyl cinnamate) was studied. These compounds were purchased from Sigma–Aldrich (Steinheim, Germany) except for ethyl acetate, from Prolabo (Paris, France). Their purity was always greater than 98%. As only the fruity attributes have been considered for sensory evaluation (see below), the physicochemical properties and odour description of the ethyl esters responsible for the fruity odour (Ulrich, Hoberg, Rapp, & Kecke, 1997) are given in Table 1.

2.2. Model matrices

The dairy gels were prepared and characterised according to Nongonierma, Springett, Le Quéré, Cayot, and Voilley (2005). The milk was reconstituted by dispersing 14.5% (w/w) skimmed milk powder (Ingredia, Arras, France), corresponding to 4.5% protein content, 0.1% (w/w) potassium sorbate (Aldrich, Steinheim, Germany) in 85.4% (w/w) water (Danone, Volvic, France). Milks with three fat contents (0, 1.5 and 5% fat) were prepared using deodorised anhydrous milk fat (Corman, Goé-Limbourg, Belgium), in order to simulate milk fat but avoid any flavours which may interfere with the subsequent sensory evaluation. Gelation was carried out by adding 2.2% (w/w) glucono-δ-lactone (Prolabo, Paris, France) that hydrolysed during 19 h at 25 °C, causing a slow pH decrease to 4.4 (Cayot, Fairise, Colas, Lorient, & Brule, 2003). Afterwards, the set gels were broken down with a pilot microstirrer. The gel particles had an average diameter of 23 ± 0.9 μm, which is very close to that of a low fat commercial stirred yoghurt (20.3 ± 0.2 μm). To simulate the mixing between the syrup from the fruit preparation

Table 1
Physicochemical characteristics and odour descriptors of the ethyl esters studied

Flavour compound	Structural formula[a]	Boiling temperature (°C)[a]	log *P*[b]	Odour descriptor
Ethyl acetate		75	0.7	Chemical[c] , glue[d]
Ethyl isobutanoate		112	1.6	Fruity[c]
Ethyl butanoate		121	1.7	Cheese[d], fruity, ester, sweet[e]
Ethyl hexanoate		168	2.8	Fruit, ester, green apple[d]
Ethyl octanoate		206	3.8	Fruity, floral[a]

[a] Fenaroli (1975).
[b] Estimation of the hydrophobicity (log *P*) by Hansch and Leo (1979) method.
[c] da Silva and das Neves (1999).
[d] Larsen and Poll (1992).
[e] Ulrich et al. (1997).

and the yoghurt that would occur during the industrial process, the stirred gels were mixed with a syrup in the ratio 1:9 syrup:dairy gel (w/w) (Nongonierma, Springett et al. 2005). This syrup contained 63% (w/w) sucrose (Sucre Union, Paris, France), 35% (w/w) water (Danone, Volvic, France), 0.8% (w/w) low methylated pectin (LM 104 AS, CP Kelco, Lille Skensved, Denmark), 0.2% (w/w) tricalcium diphosphate (Prolabo, Paris, France), 0.1% (w/w) potassium sorbate (Aldrich, Steinheim, Germany) and 0.08% (w/w) citric acid (Prolabo, Paris, France).

The fruit model matrix was prepared according to Nongonierma et al. (2005). It consisted of a pectin gel containing 57% (w/w) water (Volvic, Danone, France), 40% (w/w) sucrose (Sucre Union, Paris, France), 2% (w/w) low amidated pectin (Grinsted™ pectin LA 110, Danisco, France), 0.2% (w/w) citric acid (Prolabo, Paris, France), 0.1% (w/w) potassium sorbate (Aldrich, Steinheim, Germany) and 0.09% (w/w) calcium chloride (Prolabo, Paris, France). This matrix was flavoured with the thirteen flavour compounds, each added at 10, 15 or 20 ppm.

To model the fruit/yoghurt interface, a biphasic system made of 50g dairy gel poured over 50 g pectin gel flavoured with the thirteen flavour compounds was used. The pectin mix was allowed to gel in cylindrical glass flask of 3.5 cm diameter and 10 cm height, for 14 h at 4 °C, and then the dairy gel was poured over it. These bilayer samples were used to determine the concentration of flavour compounds in the pectin gel after 7 days storage at 4, 7 or 10 °C.

For the sensory analysis, the biphasic samples were made up from 5 g of each gel. The dairy gel was poured onto the pectin gel that had been previously allowed to gel (14 h at 4 °C) in a plastic cup of 30mL with lids (Projet, Paris, France). The samples were prepared 7 days before their evaluation and stored at different temperatures (4, 7 and 10 °C). This time was sufficient to establish an equilibrium in the partitioning of flavour compounds between the two gels (Nongonierma et al., 2005).

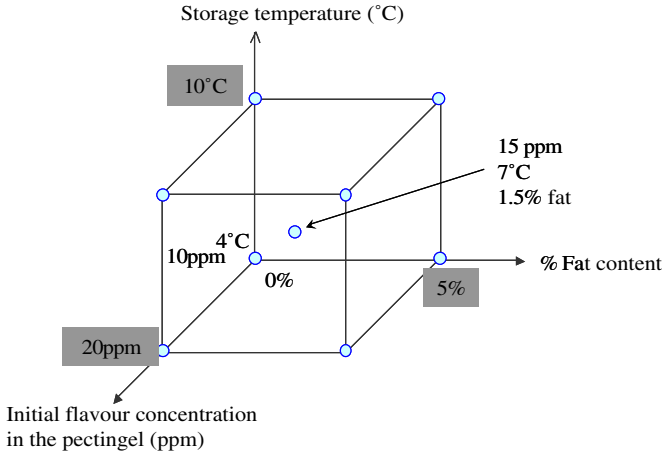


Fig. 1. Experimental design (2^3) used to study flavour compound transfer between the pectin and the dairy gel. Each point represents an experimental condition.

2.3. Experimental design

An experimental design including 3 factors at two levels (Fig. 1) was used to study the effect of different parameters on the flavour transfer between the two gels. These factors were:

- The storage temperature between 4 and 10 °C (equivalent to industrial and domestic refrigerator storage temperatures, respectively).
- The fat content of the dairy gel between 0% and 5%, corresponding to the usual range of fat content found in commercial yoghurts.
- The flavour concentration in the pectin gel between 10 and 20 ppm for each flavour compound.

The central point conditions were: 7 °C, 1.5% fat, and 15 ppm for each flavour compound.

2.4. Determination of flavour partitioning between the two gels and their retention in the matrices

Equilibrium ethyl esters concentration in the pectin gel was determined using a direct immersion-SPME (solid-phase microextraction) method developed by Nongonierma et al. (2005). Extractions were carried out in the pectin gel because proteins and fats from the dairy gels might damage the fibres by irreversible adsorption (Prosen & Zupancic-Kralj, 1999; Souchon, 1994). Before each sampling, the fibre was thermally cleaned (300 °C, for 45 min) and a blank analysis was performed to check its cleanliness and a reference sample made of the pectin gel flavoured at the initial concentration in the samples (10, 15 or 20 ppm) was extracted.

The kinetics of flavour compound transfer from the pectin gel were studied by sampling it at 5 mm from the pectin/dairy gel interface for 30 min. Flavour compounds were extracted with a Carboxen/PDMS fibre (Supelco, Bellefonte, USA) for 30 min, and then thermally desorbed in the injector of a gas chromatograph (CP 3800, Varian Analytical Instruments, Walnut Creek, USA) for 5 min at 250 °C. The gas chromatograph was equipped with a HP FFAP column (30 m × 0.32 mm × 0.25 μm thickness, Agilent Technologies, Karlsruhe, Germany). The oven temperature was set at 50 °C for 4 min, raised to 180 °C at 5 °C min^{-1} and held at this temperature for 17 min. The temperature of the injector (splitless) and the flame ionisation detector (FID) were, respectively, 250 and 200 °C. Helium was used as a carrier gas at a velocity of 42.8 cm s^{-1} at 40 °C.

Sampling was carried out over a period of 28 days (normal use by date for fruit yoghurts) for the central point of the experimental design (at 0, 2, 5, 8, 24, 30, 48, 72, 96, 144, 192, 504 and 672 h) and 14 days for the other conditions of the experimental design. To avoid sampling at the same location several times, the fibre was inserted deeper (horizontally) in the pectin gel at each new extraction. This

was achieved by increasing the position of the SPME holder depth gauge by 1 mm at each new extraction.

After sampling, the fibre was cleaned with water (three times) to remove non-volatile analytes that can undergo Maillard reaction and generate new flavour compounds during the fibre desorption (Verhoeven, Beuerle, & Schwab, 1997). This cleaning procedure consisted of immersing the fibre in a water beaker (Danone, Volvic, France) then drying it on a paper filter (Argos Fogema, Sens, France). The fibre was then desorbed 5 min at 250 °C and was subjected to a subsequent cleaning in the injector of a gas chromatograph HP 5890 (Hewlett Packard, Walbronn, Germany) set at 300 °C, for 45 min.

The immersion-SPME method was suitable for the extraction of the five ethyl esters studied. However, in the case of ethyl octanoate, the peak areas obtained were very small and showed large variations. Quantification was therefore not accurate and only the results obtained for the four other ethyl esters were included in the subsequent data analyses.

Flavour compound retention in the matrices (pectin and dairy gels) corresponded to the percentage of volatility decrease relatively to water (Nongonierma, Springett et al. 2005). The percentage of retention was calculated using the following formula:

$$\% \text{ Retention} = \left(1 - \frac{K_{\text{matrix}}}{K_{\text{water}}}\right) \times 100, \quad (1)$$

where K_{matrix}, the vapour/matrix partition coefficient (expressed in mass fractions) and K_{water}, the vapour/water partition coefficient (expressed in mass fractions).

2.5. Sensory procedure

The panel consisted of 20 assessors (14 females and 6 males), 20–31 years old.

Only the odour evaluated by orthonasal perception was studied in order to avoid a bias due to interactions between the different senses (King et al., 2003; Ott, Hugi, Baumgartner, & Chaintreau, 2000; Paci et al., 2003). During 10 sessions of 30 min each over a period of 4 weeks, the assessors were trained to evaluate the smell of the strawberry flavour added in water, pectin and dairy gels samples. During the first 3 sessions, they were asked to generate freely descriptors related to the sample odour. From this, a consensus session was conducted during which the assessors agreed on the major attributes of the odour and its definition. ''Fruity'' was the major descriptor used to describe the strawberry flavour. In strawberry fruits, the ethyl esters are principally responsible for the fruity odour descriptors (da Silva & das Neves, 1999; Larsen & Poll, 1992; Ulrich et al., 1997). For this reason, the influence of the partitioning of the ethyl esters between the pectin and the dairy gels upon the odour perception was studied.

Finally, six sessions were performed to familiarize the assessors with the samples and with the intensity rating of the odour attribute of strawberry on a 9 cm non-structured scale.

Evaluation of the samples was carried out in separate booths in line with AFNOR (French standardisation organisation) requirements. The panellists randomly evaluated the samples, identified by a three-digit code. Nine samples prepared according to the conditions of the experimental design were evaluated during each session. This was repeated three times. The samples were equilibrated for one hour at room temperature (22 °C) prior to the evaluation.

At the beginning of each session, three reference samples consisting of dairy gels with 0% fat flavoured at 0, 7 and 20 ppm (for each flavour compound) were evaluated to define the limits of the scale corresponding, respectively, to no odour perception (0), intermediate (6) and very intense odour perception (9). The assessors evaluated the fruity odour intensity of both sample layers successively. For this purpose, they were asked to rate first the odour intensity of the dairy gel. Then, they removed the dairy gel with a spoon, rinsed the surface of the pectin gel with water, stirred it with a clean spoon, and rated its odour intensity. Between each rating, the assessor eliminated any odour remaining in the nose by sniffing a pure water sample. For each sample, the odour intensities of both gels were reported on separate scales.

2.6. Statistical analysis

A two-way analysis of variance (ANOVA) was carried out on the intensity ratings of each gel with the samples and assessors as variables. The assessors were treated as a random effect. Following this, a four-way ANOVA was performed on the intensity ratings of each gel with the variables of the experimental design (flavour concentration, fat content and storage temperature) and the assessors. For each gel, a Student–Newman–Keuls multiple comparison test at a significance level of $P \leqslant 0.05$ was performed to identify the differences between the odour intensity ratings of the samples. The correlation between the odour intensity and the variables were determined using a general linear procedure. These different analyses were performed using the Statistical Analysis System (SAS) software version 8 (Sas Institute Inc., Cary, USA).

3. Results and discussion

3.1. Influence of the experimental design variables on the partitioning of ethyl esters between the two gels

The concentrations of ethyl esters at equilibrium (after 7 days storage) in the pectin gel at the different conditions of the experimental design are given in Table 2. The concentrations were generally more than half of the initial concentration, indicating a higher affinity for the pectin gel than for the dairy gel. This result was confirmed by the flavour compound retention in the matrices (Fig. 2). At both

Table 2
Concentration of ethyl esters (ppm) remaining in the pectin gel after 7 days storage as a function of the experimental design variables (temperature, flavour concentration and fat content) (Nongonierma et al., 2005)

Temperature (°C)	Flavour concentration (ppm)	Fat content (%)	Flavour concentration (ppm)			
			Ethyl acetate	Ethyl isobutanoate	Ethyl butanoate	Ethyl hexanoate
7	15	1.5	6.9 ± 0.5^{bcd}	9.6 ± 1.6^{b}	7.1 ± 0.9^{fe}	6.2 ± 1.9^{cd}
10	20	5	13.6 ± 0.8^{a}	16.3 ± 1.4^{a}	11.2 ± 0.9^{bc}	13.7 ± 1.8^{a}
10	20	0	13.6 ± 2.2^{a}	16.3 ± 1.7^{a}	13.5 ± 2.0^{a}	14.6 ± 1.8^{a}
10	10	5	7.9 ± 0.6^{bc}	9.2 ± 0.3^{b}	6.7 ± 0.1^{fe}	9.0 ± 1.8^{bcd}
10	10	0	8.0 ± 0.8^{bc}	9.8 ± 0.1^{b}	7.9 ± 0.4^{de}	10.4 ± 1.0^{b}
4	20	5	9.2 ± 2.3^{b}	11.5 ± 1.9^{b}	9.7 ± 2.6^{cd}	9.5 ± 2.8^{bc}
4	20	0	9.7 ± 2.0^{b}	16.2 ± 0.2^{a}	12.7 ± 1.3^{ab}	17.1 ± 0.5^{a}
4	10	0	4.7 ± 0.3^{d}	5.6 ± 0.3^{c}	4.8 ± 0.2^{f}	6.1 ± 1.4^{cd}
4	10	5	5.5 ± 0.9^{cd}	4.8 ± 0.2^{c}	5.0 ± 0.2^{f}	5.4 ± 1.4^{d}

Values are the mean flavour concentrations remaining in the pectin gel and their confidence intervals determined at $P \leqslant 0.05$. For a given flavour compound, figures with different letters are significantly different at $P \leqslant 0.05$ (Student–Newman–Keuls test).

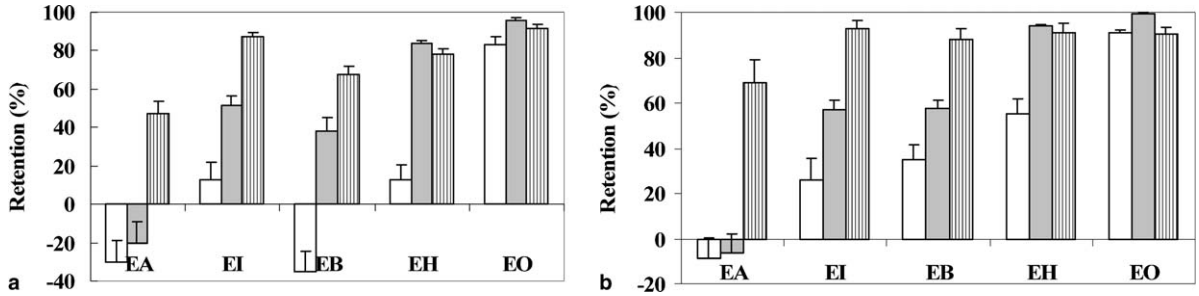


Fig. 2. Retention of the ethyl esters in the dairy gel with 0 (□) and 5% fat (▩) and in the pectin gel (▥) at 4 (a) and 10 °C (b). (EA, ethyl acetate; EB, ethyl butanoate; EI, ethyl isobutanoate; EH, ethyl hexanoate; EO, ethyl octanoate).

temperatures, the pectin gel had the highest retention for many of the compounds except for the most hydrophobic compounds studied, ethyl hexanoate and ethyl octanoate, which had higher retentions in the dairy gel with a 5% fat content. In the dairy gels, flavour retention was attributed to physicochemical interactions with milk proteins (Jouenne & Crouzet, 2000; Landy, Druaux, & Voilley, 1995) and fats (Nongonierma et al., 2005; Roberts, Pollien,

Table 3
Effect of the experimental design variables (temperature, flavour concentration and fat content) on the fruity strawberry odour intensity of the pectin and dairy gels and on the ethyl esters concentration in the pectin gel after 7 days storage

Source of variation	Fruity strawberry odour intensity		Flavour concentration in the pectin gel at equilibrium (after 7 days storage)[a]			
	Pectin gel	Dairy gel	Ethyl acetate	Ethyl isobutanoate	Ethyl butanoate	Ethyl hexanoate
Assessor	***	***				
Sample	***	***				
Assessor*fat	*	n.s.				
Assessor*temperature	n.s.	*				
Flavour concentration	***	***	***	***	***	***
Storage temperature	n.s.	n.s.	***	**	**	**
Fat content of the dairy gel	*	***	n.s.	*	**	**
Concentration*temperature	n.s.	*	n.s.	n.s.	n.s.	n.s.
Temperature*fat	n.s.	n.s.	n.s.	*	n.s.	n.s.
Concentration*fat	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Assessor*fat	*	n.s.				
Assessor*temperature	n.s.	*				
Assessor*concentration	n.s.	n.s.				
Assessor*sample	**	n.s.				

n.s., Not significant at $P \leqslant 0.05$.
*, Significant at $P \leqslant 0.05$.
**, Significant at $P \leqslant 0.01$.
***, Significant at $P \leqslant 0.001$.
[a] Determined using and immersion-SPME method (Nongonierma et al., 2005).

& Watzke, 2003). In the pectin gel, there may be some interactions (for example dipole–dipole and hydrophobic interactions) with the pectin and the sucrose, causing an increase in the retention of the flavour compounds (Braudo et al., 2000; Hansson, Andersson, & Leufvèn, 2001). The particularly high retention in the pectin gel was also attributed to possible capillary forces (Nongonierma et al., 2005) which were involved in the physical entrapment of flavour compounds within the gel structure (Guinard & Marty, 1995; Rega, Guichard, & Voilley, 2002).

Table 3 shows that the different experimental design variables (i.e., flavour concentration, fat content and storage temperature) influenced the flavour partitioning. There was no interaction between the variables, except in the case of ethyl isobutanoate where an increase in the flavour concentration increased the concentration in the pectin gel. Nevertheless, the transfer mechanisms were not affected in the concentration range studied (Voilley & Bettenfeld, 1985) as the initial flavour concentration and that at equilibrium in the pectin gel remained proportional.

The retention of flavour compounds varied with temperature (Fig. 2). The pectin gel structure and therefore the balance between the interactions that maintains this structure depends upon the temperature (Fu & Rao, 1999). These structural changes might have caused a water expulsion from the pectin gel at 4 °C, which favoured flavour release (Nongonierma et al., 2005). This could explain the lower retention of flavour compounds in the pectin gel at 4 °C compared to 10 °C.

Increase in the fat content in the dairy gel significantly lowered the flavour concentration in the pectin gel, except for ethyl acetate, the least hydrophobic ethyl ester studied. Fat generally acts as a solvent of flavour compounds, with an effect more marked on the most hydrophobic ones (Roberts et al., 2003). This effect of fat was responsible for the increased release of flavours from the pectin gel. These results are consistent with those of Brauss et al. (1999) who demonstrated that the presence of fat in yoghurts only modified the release of the most hydrophobic compounds, the least hydrophobic ones being unaffected.

The immersion-SPME method enabled to extract 4 other flavour compounds (2-methyl butyric acid, linalool, hexanal and *cis* 3-hexen-1-ol) in the pectin gel. The influence of the experimental design parameters upon the transfer of these flavour compounds were very similar to that of ethyl esters (Nongonierma et al., 2005). The increase in the storage temperature, or the increase in the flavour concentration resulted in an increase in the equilibrium flavour concentration in the pectin gel. On the contrary to ethyl esters, the fat content of the dairy gel did not modified the partitioning of other flavour compounds between the pectin gel and dairy gel. This was attributed to the preponderant retention of flavour compounds within the pectin gel network, which could have hindered the effect of fat.

3.2. Perception of the fruity odour according to the assessors and the samples

To determine whether the samples were perceived differently from each other, an ANOVA with the variables, assessor, samples and the interaction assessor* sample was carried out (Table 3). Whatever the gel evaluated, the variables, assessor and sample were all significant ($P \leqslant 0.05$). The effect of the sample was due to a difference in the odour perception of the nine samples evaluated. The significant effect of the assessor indicated interindividual differences in the rating of the fruity attribute. A Student–Newman–Keuls test revealed that no assessor rated the samples differently from the rest of the panel, except for the pectin gel where one assessor tended to give higher notes than the rest of the panel. Nevertheless this assessor did not reproduce higher rating for the dairy gels.

The interaction, assessor* sample was significant only for the pectin gel. This interaction suggested that the samples were not ranked in the same order by all the assessors, probably due to different samples showing very similar odour intensities. This probably did not occur with the dairy gel because its composition was changed by the addition of fat which is known to greatly modify flavour perception (Brauss et al., 1999; de Roos, 1997).

The origin of these differences in perception were probably the variation in the composition of the gel matrices and the storage conditions which might have modified the partitioning of flavour compounds in the biphasic samples. The effect of the experimental design variables on the odour perception is presented in the following section.

3.3. Effect of flavour transfer on the odour perception of the different phases of the stirred fruit yoghurt model

The appearance of a fruity odour in the dairy gel was caused by the transfer of flavour compounds from the pectin to the dairy gel during the storage. The effects of the experimental design variables were studied by means of an ANOVA (Table 3). As expected, for both gels, increasing the flavour concentration resulted in an increase in the odour intensity (Fig. 3).

At the highest fat content (5%), the odour intensity was lower, both in the dairy and pectin gels (Fig. 4). In the dairy gels, fat governed flavour release at vapour/matrix interfaces, causing a decrease in their volatility (Druaux et al., 1998; Nongonierma, Springett et al. 2005; Roberts et al., 2003). The lower fruity odour intensity in the presence of fat was then directly linked to the retention of ethyl esters in the dairy gels. Together with the physicochemical interactions, an increase in the fat content from 0% to 5% increased the viscosity of the dairy gels by 30% (Nongonierma, Springett et al. 2005). This increased viscosity reduced the rate of release of flavour compounds into the gas phase, causing a lowering in their odour perception. Similarly, Brauss et al. (1999), showed a decrease in the maximum flavour intensity perceived when the fat content

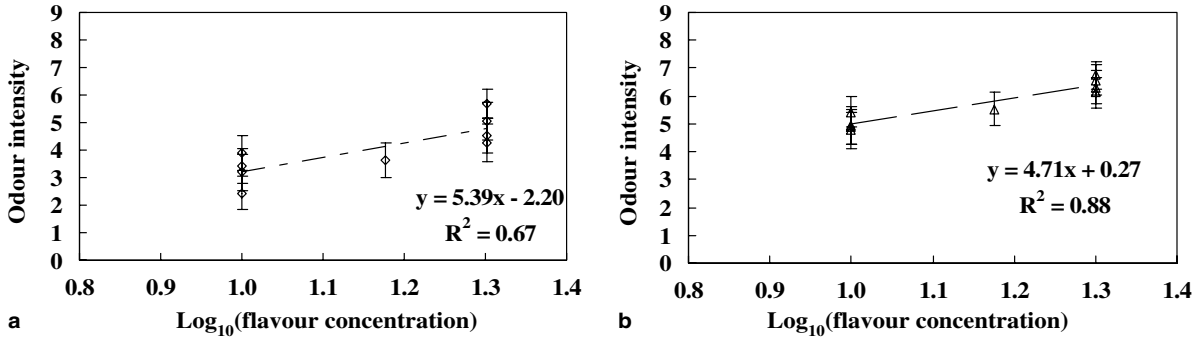


Fig. 3. Effect of the flavour concentration upon the fruity odour intensity of the dairy (a) and pectin (b) gels.

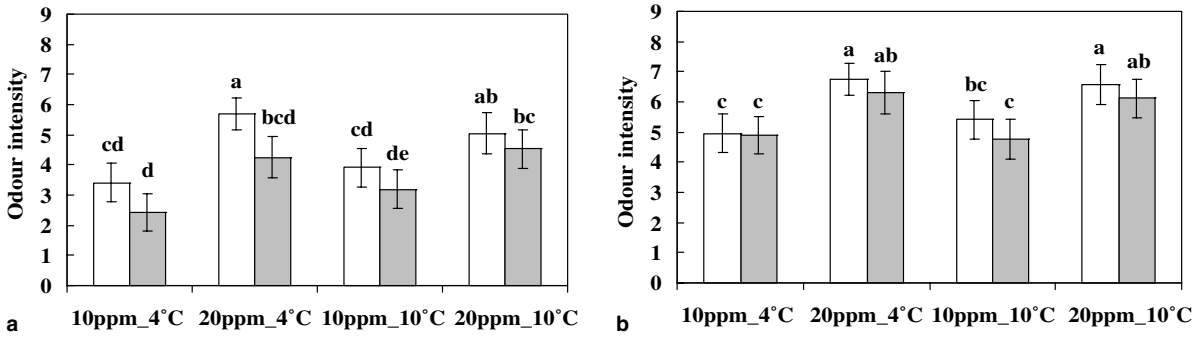


Fig. 4. Effect of the dairy gel fat content with 0 (□) and 5% fat (▩) upon the odour perception of the dairy (a) and pectin gels (b). For each gel, histograms with a different letter are significantly different at $P \leqslant 0.05$.

of the yoghurts increased from 0% to 3.5% or 10%. Conversely, Wendin, Solheim, Allmere, and Johansson (1997) studied the impact of fat (0.1% and 4.2%) in sour milk but they did not notice any effect neither on the smell nor on the flavour of ethyl 2-methylbutyrate.

In the pectin gel, the effect of fat was attributed to the modifications of flavour partitioning between the two gels. In fact, the transfer of the most hydrophobic ethyl esters were significantly affected by the presence of fat (Table 3). As these esters are important contributors to the fruity notes, their fall in concentration in the pectin gel caused a decrease in their perception.

Temperature variations from 4 to 10 °C induced changes in the volatility of the flavour compounds (Nongonierma, Springett et al. 2005). This effect was not shown by sensory evaluation as all the samples were evaluated at the same temperature to allow intersample comparisons. Also, there was no significant effect of the storage temperature upon the odour perception, both in the dairy and pectin gels samples which was shown by instrumental analyses. The reheating of the samples to 22 °C one hour before the evaluation might have cancelled out the storage temperature effect upon the partitioning of flavour compounds. Also, the increase in the temperature to 22 °C acted to reduce the pectin gel firmness (Lootens et al., 2003) which has a large impact on the flavour retention (Guinard & Marty, 1995; Rega et al., 2002).

The other flavour compounds which contribute to the strawberry odour are supposed to affect the intensity of the overall odour similarly to the ethyl esters. In fact, their concentration in both gels evolved as that of ethyl esters. Nevertheless in the presence of fat in the dairy gels, no effect upon their partitioning was seen, whereas the odour intensity of both gels was greatly modified. This result comfort the assumption that ethyl esters are responsible for the fruity attribute of the odour as their transfer was directly correlated with the intensity perceived.

Flavour transfer in the stirred fruit yoghurt models induced changes in the perception of both the pectin and dairy gels, which in turn affected the aroma fingerprint of each phase.

4. Conclusions

Flavour compound transfer between the pectin and the dairy gels were affected by different parameters such as composition of the matrices (i.e., fat content of the dairy gel) and the storage temperature. These modified the partitioning of flavour compounds between the two gels during storage, causing a modification in their perception. The higher the flavour concentration in the matrices, the higher the fruity odour intensity. These results were highly expected as the perception is linked to the concentration of flavour compounds in food matrices as demonstrated

by the Stevens or Fechner's laws. Fat increased transfers towards the dairy gel, causing a reduction in the pectin gel odour intensity. The storage temperature modified the flavour partitioning; nevertheless, this effect was lost when the product was held at ambient temperature for one hour.

To further this study, the effect of flavour compound transfer upon their in mouth retronasal perception should be investigated in order to understand better the interactions between senses that occur during food consumption. Controlling the transfer of flavours between the different phases of the fruit yoghurt during its storage could provide a means of delivering products with different sensory characteristics.

Acknowledgements

We gratefully acknowledge the Regional Council of Burgundy and Danone Vitapole for financial support, Louise Vincent who carried out part of the experimental work, Emmanuelle Eon and Catherine Dacremont for their helpful scientific discussions.

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