

# Modulation of perceived taste by olfaction in familiar and unfamiliar beverages

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## Abstract

The integration of olfactory and taste perception and the role of congruency and familiarity on perception have already been demonstrated in model solutions. The aim of the present study was to investigate the role of these factors in real food products. Therefore, we have investigated the impact of olfactory perception on perceived bitterness in a familiar (bitter cocoa beverage) and an unfamiliar (bitter milk) beverage. Sensory profilings with and without noseclip were conducted according to simultaneous product presentation. In a first experiment, an instant cocoa powder mixed with water was used to prepare a common base. Two types of flavourings were added: cocoa and vanilla, at three different levels (none, medium and high). Samples were compared within a flavouring type. In a second experiment a vanilla flavour was added at three levels to a milk base containing caffeine. The panellists scored bitterness, sourness, sweetness and body with noseclip. Without noseclip, overall aroma above the cup and in mouth were assessed in addition to the previous set of attributes. With noseclip, results showed that neither the cocoa nor the vanilla flavourings provided any additional taste to the beverages. Without noseclip, olfactory/taste interaction in the cocoa beverage led to an enhancement of bitterness induced by the cocoa flavouring and an increase in sweetness from the vanilla flavouring. On the contrary, in the caffeinated milk, the addition of vanilla flavouring did not significantly increase sweetness, but unexpectedly enhanced bitterness. This study is further evidence of the influence of olfaction on taste perception in complex matrices. In addition, our results suggest that taste–olfaction integration is product dependent and related to food experience, even when working with trained subjects. Furthermore, the unpleasantness due to the neophobia related to the consumption of a new product and to bitterness may enhance bitterness when the unfamiliarity of the product is increased by addition of vanilla flavouring to a bitter milk beverage.

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## 1. Introduction

Interactions between olfaction and taste modalities are well known and have been extensively investigated in model solutions. Pioneer studies on interaction between odour and taste perception showed that subjects attributed a sweet taste to pure ethyl butyrate solutions and that the sweet perception of a citral–sucrose mixture was enhanced by increasing the citral concentration (Murphy & Cain, 1980; Murphy, Cain, & Bartoshuk, 1977). Time intensity studies also demonstrated that sweetness was enhanced

by fruity odour whereas fruity odour was not increased by sweetness (Bonnans & Noble, 1993; Cliff & Noble, 1990). Frank, Shaffer, and Smith (1991) showed that perceptual similarity or dissimilarity between an odorant and a tastant in mixture was a good predictor of taste intensity change. An odour can acquire a taste quality when the odour–taste pair is perceived in food commonly experienced by consumers. Congruency was defined by Schifferstein and Verlegh (1996) as “the extent to which two stimuli are appropriate for combination in a food product”. Frank and Byram (1988) reported that strawberry odour enhanced whipped cream sweetness whereas peanut butter did not affect sweetness rating. Lavin and Lawless (1998) also highlighted the enhancing effect of vanilla flavouring

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on perceived sweetness when added to milk among children and adults. Prescott (1999) showed that pineapple flavouring enhances perceived sweetness. Besides Stevenson, Prescott, and Boakes (1999) reported that an odour can also decrease taste intensity when the odour–taste pair is not congruent in food. In their experiment, caramel odour, related to sweet taste, decreases sour taste intensity.

The intensity rating of a sensory dimension also depends on the response alternative provided to the subjects. According to Lawless and Clark (1992) and Clark and Lawless (1994), taste enhancement by an odorant can be due to (1) a halo effect “where one positive characteristic of a product may induce positive opinions on other seemingly unrelated characteristics”; (2) a dumping effect, for instance a transfer of the perceived olfactory enhancement on the taste scale when no olfactory intensity scale is available. Consequently, it is important to provide the subjects with an exhaustive list of attributes to limit such bias. Frank, van der Klaauw, and Schifferstein (1993) and Frank (2002) confirmed that taste rating was modulated by both odour perception, called the “*perceptual factor*” (congruency) and also by the response alternative proposed by the experimenter called the “*conceptual factor*”.

Stevenson, Prescott, and Boakes (1995) tested the effect of learning on sweet perception associations to demonstrate the role of food experience. They showed that, through learning, a tasteless odor can acquire a sweet or a sour taste quality after being tested in mouth either with sucrose or with citric acid. Consequently odour–taste interactions may be the result of associations experienced and memorized through food exposure without any explicit attention or learning (Köster, 2005; Köster, Prescott, & Köster, 2004). Thus, memory seems to be strongly involved in food expectation (Mojet & Köster, 2005). Small et al. (2004) confirmed this sensory evidence at a neuronal level. Using neuroimaging, they showed that brain activation representing olfactory/taste interaction was dependent on previous subject experience with smell/taste combinations. Stein, Nagai, Nakagawa, and Beauchamp (2003) demonstrated that repeated exposure to different bitter beverages during a 7-day period significantly enhanced familiarity rating and modulated rating of taste modalities when comparing measurements conducted before and after the period of exposure. Indeed sweetness rating significantly increased whereas bitterness declined, but not significantly.

The attentional strategy applied also affects odour-induced taste modulation. Prescott, Johnstone, and Francis (2004) reported that a synthetic exposure during joint exposure to either prune- or waterchestnut odour and a sucrose solution increased the ability of an odour to subsequently enhance the sweetness of the sucrose/prune (waterchestnut) mixture. A synthetic versus an analytical task instruction during exposure differentially affected the increase in sweetness of an odour/taste mixture judged afterwards. These findings suggest that procedures such as sensory profiling inducing an analytical attitude during exposure are less vulnerable to synthetic enhancement

and therefore less prone to show odour-induced taste enhancement. Bingham, Birch, de Graaf, Behan, and Perrin (1990) also highlighted an enhancement of sweetness by maltol addition in a sucrose solution when the evaluation was assessed by an untrained panel but not with a trained panel (used to evaluate products according to an analytical procedure).

The aim of this work was to investigate the impact of beverage familiarity on interaction between olfactory and taste perception. Indeed there is a need for the food industry to know whether such cognitive processes on food perception have similar effects in classical/familiar and new/unfamiliar products. In the present study, the impact of two different olfactory stimuli on bitter perception was investigated in two bitter beverages. Modulation of sweet and sour perception was also investigated to explore possible effects on these tastes. Beverages differed regarding their familiarity for consumers: a cocoa beverage and a caffeinated fat milk beverage frequently consumed and rarely/never consumed, respectively. Pure cocoa is a common bitter food frequently consumed in a beverage form as well as in chocolate tablet form. Even if the main consumption habit of cocoa powder is a liquid form with milk and sugar, in-house market research allows to strongly assume that for consumers cocoa is related to bitterness. Unlike cocoa, milk's main sensory characteristics in mouth are “creamy” and “sweet” (Lee, Lee, & Shin, 2003). Moreover milk is often used as a coffee additive to decrease harsh, bitter coffee taste and to increase acceptance (Cristovam, Russell, Paterson, & Reid, 2000). Adding caffeine to milk allowed us to obtain an unfamiliar bitter beverage. Our objectives were (1) to validate the enhancing impact on bitterness of odour congruent with bitter taste by boosting the natural odour of cocoa beverage with a commercial cocoa flavouring; (2) to explore the effect of an odour congruent with sweetness on bitter taste perception by adding vanilla aroma in the cocoa beverage; (3) to assess the role of beverage familiarity by measuring whether the bitter modulation induced by vanilla flavouring addition is the same in a familiar (cocoa) and an unfamiliar (caffeinated milk) beverage.

To avoid any confusion we will use the term “odour” to refer to the orthonasal olfactory perception evaluated above the cup, and “aroma” to refer to the retronasal olfactory perception i.e. the organoleptic attribute perceptible by the olfactory organ via the back of the nose (NF ISO 5492, 1995). The term “olfactory” regroups both odour and aroma perception.

## 2. Materials and methods

### 2.1. Beverage preparation

Two complex food matrices were investigated. A pure cocoa powder (Caillier-Nestlé, Switzerland) reconstituted at 14% in mineral water (Vittel Bonne Source, France) for the familiar bitter beverage and a caffeinated (0.08% of the reconstituted beverage) commercial 2.7% fat UHT

milk for the non-familiar beverage. A previous sensory study clearly showed that the two beverages were only bitter without any sweet taste.

Two flavourings were added: (1) a dark chocolate flavouring to the cocoa beverage and (2) a vanilla flavouring to the cocoa and caffeinated milk beverages. The cocoa flavouring was described by the supplier (Firmenich, Switzerland) as “dark chocolate”. It was chosen to match as closely as possible the flavour profile of the pure cocoa beverage and, therefore, to modulate only the cocoa intensity and not the quality of the product. Two concentration levels for cocoa flavouring were defined, on the basis of preliminary studies, to obtain a two-step enhancement of the cocoa beverage olfactory note. These two concentration levels were 0.15% and 0.24% of the reconstituted beverage (called “medium concentration” and “high concentration”, respectively). The cocoa beverage without added flavour was defined as the reference. The same procedure was repeated with the vanilla flavouring (Givaudan, Switzerland) to select two concentration levels for modulating the olfactory characteristics of the cocoa and caffeinated milk beverages. The two vanilla flavouring concentrations were 0.05% and 0.10% of the reconstituted beverage.

For each beverage, and within a same flavouring type, four samples were prepared: one sample without added flavouring (reference), one sample flavoured at medium concentration (replicated for control), one sample flavoured at high concentration. Sample preparation was carried out 1 h prior to evaluation.

## 2.2. Subjects and tasting conditions

Ten external assessors, all women, with an average age of 45, were recruited for this study. They were used to participating in sensory panels for coffee beverage evaluation. For a previous study, they had been trained on basic tastes and on overall odour/aroma intensity evaluation. No specific training sessions were conducted for this study. Samples were coded with three-digit random numbers and served at 65 °C in a 50-ml cup. Rinsing was done between samples with water and unsalted crackers. Tests were conducted in an air-conditioned room (18 °C), under white light in individual booths. Data was acquired on a computer screen with FIZZ software (Biosystèmes, 1990).

## 2.3. Sensory procedure

Each of the three sets of four samples (i.e. cocoa beverages with cocoa flavouring, cocoa beverages with vanilla flavouring and caffeinated milks with vanilla flavouring) was assessed, separately, during a 1-h session, by sensory profiling with simultaneous product presentation. The four samples were presented all at once, but the sample order in the tray was randomized across subjects. Subjects had to score comparatively the four products for each successive attribute on a nine-point structured scale anchored at the extremities with “not intense” and “very intense”. Sensory

profilings were conducted with and without noseclip. Noseclips prevent olfactory perceptions and therefore only taste and texture in mouth were evaluated. Noseclip evaluation of the beverage with flavour addition was essential to ensure that flavourings did not provide any taste by themselves to the beverage when olfaction was prevented. The subjects scored bitterness, sourness, sweetness and body intensities for the evaluation with noseclip. Without noseclip, the assessors were asked firstly to smell the beverages and to score overall odour, and secondly to taste and to score the overall aroma and the taste and body attributes. “Body” attribute describes the perceived viscosity, fullness and weight in the mouth ranging from “thin, watery” to “thick, heavy”.

Due to preparation constraints, sensory profilings were not balanced between the three 1-h sessions. Within each session and for each condition, sensory profiling was duplicated, samples being randomized over subjects according to a balanced experimental design.

## 2.4. Data analyses

Data analyses was analysed using FIZZ software. For each sensory profiling, the product effect at panel level was tested for each attribute, using a two-way analysis of variance with product as fixed and assessor as random factors. When the product effect was significant ( $P < 0.05$ ) highlighting a significant difference between the four samples for a given attribute, two multiple range tests were performed: a Duncan test to compare the mean intensities between the four samples and a Dunnett test to highlight sensory differences between each flavoured beverage and the non-flavoured reference. For the graphical representation, percentage of variation  $x'$  (%) between the average intensity (calculated across subjects) of the flavoured samples (Int.x) and the average intensity of the reference (Int.ref) was calculated according to the following formula:

$$x' (\%) = \left( \frac{\text{Int.x} - \text{Int.ref}}{\text{Int.ref}} \right) \times 100$$

## 3. Results

### 3.1. Cocoa and vanilla flavouring did not induce any taste

When evaluated with a noseclip, no significant taste and texture difference was observed (1) among the four cocoa beverages whatever the flavour added and (2) among the 4 caffeinated milk beverages with vanilla flavouring (Fig. 1). This means that cocoa and vanilla flavourings had no significant impact on taste nor on texture in mouth when olfactory perception was prevented.

### 3.2. Cocoa flavouring enhanced bitter perception of cocoa beverages

For cocoa beverages with cocoa flavouring evaluated without noseclip, two-way analyses of variance showed a

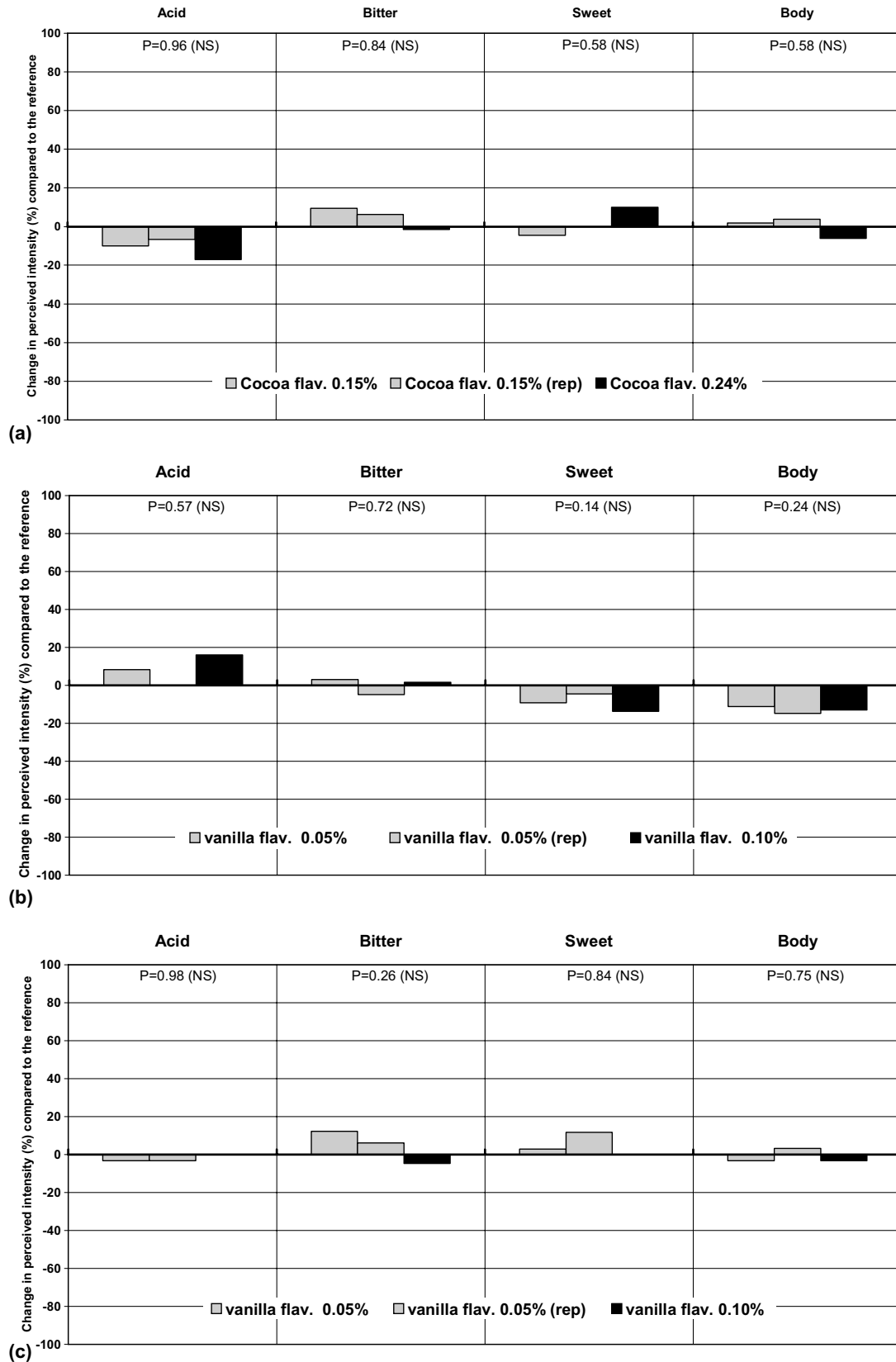


Fig. 1. (a–c) Flavouring impact on cocoa beverage taste and texture. Evaluation conducted with noseclip for (a) cocoa beverage with cocoa flavouring; (b) cocoa beverage with vanilla flavouring; (c) caffeinated milk beverage with vanilla flavouring. According to the *F*-ratio of the product factor ANOVA: NS means “non-significant”.

significant product effect for overall odour ( $P < 0.0001$ ) and bitterness ( $P < 0.05$ ). Cocoa flavouring enhanced perceived odour intensity. The three flavoured samples were significantly more intense than the reference sample, but no significant difference was perceived between the three flavoured samples according to the Duncan test at 5% (Fig. 2a). Panel mean scores for overall aroma intensity were higher for the three flavoured samples than for the reference (Fig. 2a), but product effect was not significant ( $P = 0.15$ ).

Bitterness intensity was also boosted by the addition of cocoa flavouring for the three flavoured samples but only the high level of flavouring enhanced significantly the perceived bitterness compared to the reference according to the Dunnett test (Fig. 2a). Even if differences among the four products for sourness and sweetness intensity were not significant ( $P = 0.17$  and  $P = 0.10$ , respectively), there is a trend for a decreasing impact of cocoa flavouring on perceived sweetness (Fig. 2a).

No difference in body intensity due to the the cocoa flavouring was observed ( $P = 0.88$ ). Mean panel scores for the flavoured samples were close to the reference (Fig. 2a).

### 3.3. Vanilla flavouring enhanced sweet perception of cocoa beverages

Without noseclip, the overall odour of cocoa beverages with vanilla flavouring was not perceived as different from the reference sample ( $P = 0.33$ ). However overall aroma and sweetness intensity significantly differed among the four products ( $P < 0.001$  and  $P = 0.03$ , respectively). The Dunnett test pointed out that only the beverage with the highest vanilla flavouring concentration was significantly more intense than the reference for both attributes.

No significant differences in sourness, bitterness and body intensity were observed between the four samples (Fig. 2b).

### 3.4. Vanilla flavouring did not affect significantly taste perception of caffeinated milk beverage

Although the odour and aroma intensities of the flavoured beverages were significantly higher than the reference (Fig. 2c), no significant impact on taste and texture was observed. However, bitterness  $P$ -value was close to significance ( $P = 0.06$ ) and a trend of increased bitterness with increased vanilla flavouring concentration was observed (Fig. 2c).

## 4. Discussion

### 4.1. Flavouring modulated cocoa beverage olfactory and taste perceptions

The addition of flavouring agents increased the olfactory intensity of the cocoa beverage. The cocoa flavouring added to the cocoa beverage led to a significant enhancement of

the perceived overall odour whereas the addition of vanilla enhanced significantly the perceived aroma. This finding suggests that both olfactory cues (orthonasal and retronasal) modulate taste. These results are confirmed by Sakai, Kobayakawa, Gotow, Saito, and Imada (2001) who reported that taste enhancement by olfaction was effective when the odorant was presented by the orthonasal or by the retronasal route, provided that olfactory and taste stimuli were presented simultaneously. The differences observed between olfactory perception of cocoa odorant (more intense for orthonasal stimulation) and vanilla odorant (more intense for retronasal stimulation) may be explained by their physico-chemical characteristics. Diaz (2004) showed that differences between orthonasal and retronasal perception depend strongly on the physical characteristics of the aroma chemicals. Significant differences in olfactory intensity between samples with the medium and the high flavouring concentrations were also difficult to reach. But we had to limit concentration levels because increasing the two flavouring contents led to strongly perceived off-taste formation when evaluated by the panel with a noseclip. Nevertheless, even if differences in odour and aroma intensity between samples were not as marked as expected, the olfactory impact on taste perception remained coherent in the familiar cocoa beverage. Cocoa flavouring, congruent with bitterness, boosted the bitter perception. Vanilla flavouring, congruent with sweet taste, induced a sweet perception.

Moreover, simultaneously with bitterness enhancement, the cocoa flavouring reduced the sweet perception of the three flavoured cocoa beverages. These differences were not significant, but followed a clear trend ( $P = 0.10$ ). Different hypotheses can be proposed to explain this decrease in sweetness: First a direct reducing effect of the aroma may explain this finding. Second a halo effect may occur, i.e. an increase in the unpleasant attribute, bitter, that leads to a decrease in the pleasant one, sweet (Clark & Lawless, 1994). Third but also the bitterness enhancement induced by the cocoa flavouring may have resulted in a suppression of the perceived sweet taste by odorant-induced taste/taste interaction. Beside the sweetness enhancement induced by the vanilla flavouring led to a slight bitterness decrease. These results suggested that symmetrically suppressive interactions between tastants (Keast & Breslin, 2003) seemed to be valid for odour-induced taste modulation. However the impact of the induced taste on the beverage taste perception was less powerful than the taste modulation induced by a congruent olfactory note. Indeed  $P$ -values of sweetness suppression induced by cocoa flavouring and bitterness suppression induced by vanilla flavouring were 0.10 and 0.34, respectively.

### 4.2. Olfactory/taste interaction are observed despite the analytical procedure

According to Prescott (1999) and Prescott et al. (2004), olfactory/taste interactions in water systems depend on the

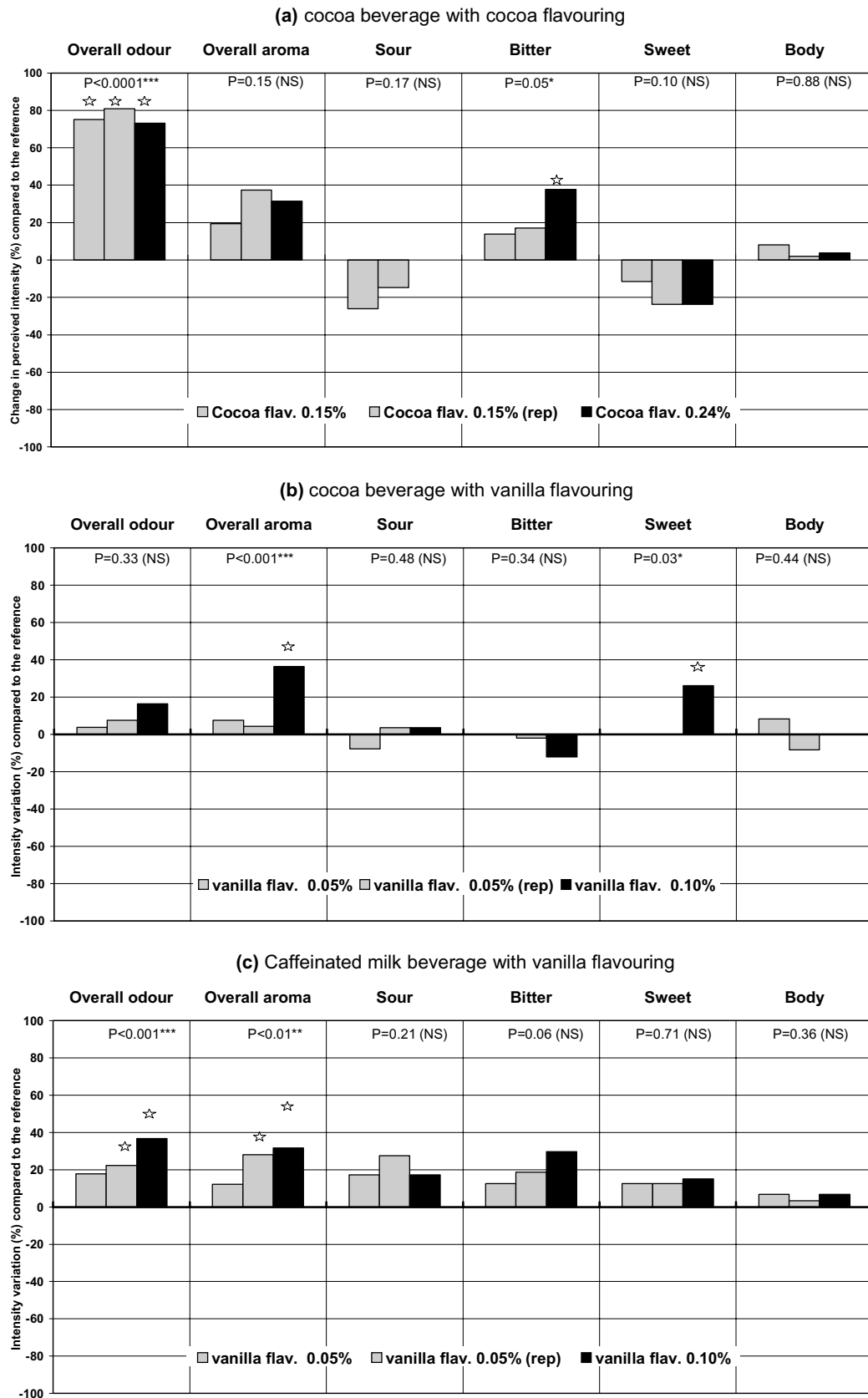


Fig. 2. (a–c) Flavouring impact on beverage odour, aroma, taste and texture/evaluation conducted without noseclip. According to the *F*-ratio of the product factor ANOVA: NS means “non-significance”; \*, \*\*, \*\*\* indicate product effect at  $P < 0.05$ ,  $P < 0.01$ ,  $P < 0.001$ , respectively. According to the Dunnett test, a white star indicates a significant difference between each sample and the reference ( $P < 0.05$ ).

exposure strategy applied to subjects. A synthetical exposure, encouraging subjects to evaluate olfactory and taste stimuli as a whole, promotes olfactory/taste interactions, whereas an analytical exposure, encouraging subjects to consider olfactory and taste stimuli independently, limits olfactory/taste interactions. Results of the present experiment show that adding cocoa and vanilla flavourings to the cocoa beverage induced a significant bitter and sweet enhancement, respectively. Although the attitude induced by the sensory profiling task was analytical, the outcome suggested a synthetical cognitive process. This may be due to previous subject food experience regarding the tested beverages. It is conceivable that the subjects have been often exposed to cocoa beverages. Interaction between senses may be therefore more easily suppressed when occurring in model solution (Bingham et al., 1990) than in food commonly consumed. This finding should be kept in mind when interpreting the results of a descriptive analysis conducted on commercial products.

#### 4.3. Familiarity of beverages affected olfactory/taste interactions

The importance of familiarity in the determination of sensory interactions can be further considered looking at the results obtained for the unfamiliar caffeinated milk beverage. Addition of vanilla flavouring to caffeinated milk did enhance sweetness, as in the familiar cocoa beverage, but unexpectedly enhanced bitterness. These observations therefore suggest that the degree of familiarity for the beverage may be an important factor in determining olfactory/taste interactions. But what is the cognitive mechanism leading to the enhancement of the perceived milk bitterness by vanilla? It is well known that bitterness is a signaling system against potentially poisonous materials (Scott & Verhagen, 2000). Consequently some individuals tend to avoid bitter tastes, which can partly explain aversion for certain foods such as brussels sprouts, cabbage or spinach (Drewnowski, Henderson, Levine, & Hann, 1999; Drewnowski, Henderson, Shore, & Barratt-Fornell, 1998). Additionally, a neophobic reaction to this new beverage may have occurred (Birch, 1999). Odour familiarity rating is usually strongly correlated to pleasantness rating (Stein et al., 2003; Sulmont, Issanchou, & Köster, 2002). The pleasant familiar vanilla note may therefore have induced a positive hedonic expectation, which was not fulfilled by the unfamiliar milk beverage's bitter taste. Based on these statements, the unfamiliar bitter milk beverage was probably judged unpleasant by tasters and the combination between this product and vanilla flavouring may have increased the product's unfamiliarity and consequently its unpleasantness. The subjects may have associated unpleasantness with bitterness, thereby boosting the perceived bitterness when the unpleasant sensation increased with addition of vanilla flavouring. Therefore, as for sensory interactions, a hedonic/sensory cognitive interaction may be at the origin of the taste modulation.

Moreover, a dumping effect may be involved in the bitterness enhancement (Clark & Lawless, 1994). Subjects had no liking scale available to report how they liked the product. They may have reported their hedonic judgment on the bitter scale, as we assumed that subjects associated bitterness with unpleasantness. The hedonic dimension could have been dumped onto the sensory dimension; this might explain the increase of the bitter taste attribute mean score.

#### 4.4. Effect of single unfamiliar odorant/tastant co-exposure on sensory interaction

Prescott et al. (2004) showed that a single unfamiliar odorant/sweet tastant co-exposure is sufficient to produce a cognitive association between both stimuli. Authors also reported that the adoption of a synthetic perceptual strategy during co-exposure is necessary to produce an odour that will enhance sweetness. Results obtained for the bitterness and sweetness evaluation of the four caffeinated milk beverages during the first and the second evaluation were analysed separately by a two-way ANOVA (products  $\times$  subjects). Indeed, the first evaluation may be considered as a first co-exposure between two stimuli in an unfamiliar context and the bitterness enhancement, highlighted when both evaluations were analysed conjointly, may be effective only during the second evaluation. But for both evaluations, flavoured caffeinated milk beverages were perceived as more bitter than the reference without any significant change in sweetness. Differences between the two replications were also assessed by a three-way analysis of variance (products  $\times$  subjects  $\times$  repetitions) on the three flavoured products. The repetition factor was significant for bitterness and sweetness ( $P < 0.001$  and  $P < 0.01$ , respectively). Indeed the three flavoured milk beverages were perceived significantly more bitter and less sweet during the second evaluation than during the first evaluation (considered as the first exposition). Even if a single odorant/tastant co-exposure was not at the origin of the unfamiliar milk beverage bitterness enhancement by vanilla flavouring, this odorant/tastant co-exposure occurring during the first evaluation enhanced the olfactory impact on taste during the second evaluation.

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