Odour-induced taste enhancement in normal-weight and obese people

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Abstract

The Odour-Induced Taste Enhancement (OITE) phenomenon allows, by addition of odorants in food or beverages, to enhance the perception of taste. To the best of our knowledge, only Proserpio *et al.* [1] studied OITE in obese people. Interestingly, in this study, the addition of butter aroma in custard dessert produced OITE only in obese and not in normal-weight people. Here we extended this result by comparing Odour-Induced Sweetness and Saltiness Enhancement in normal-weight and obese peoples using a ranking task on beverages. Forty-three normal weight (NW: 20< BMI< 25kg/m²) and 28 obese participants (OB: BMI> 30kg/m²) took part in the sensory evaluation of 2 sweet solutions and 2 salty solutions. The sweet base solutions were apple juice (Aj) and water and the added odorant was vanillin. The salty base solutions were a green-pea soup and water and the added odorant was a bacon aroma. For the ranking task, three additional solutions with increasing concentrations of either sucrose or sodium chloride (S1 to S3) were prepared for each base. Each solution was tested in a dedicated ranking trial. Subjects received four bottles in a given trial, the three sweet or salty concentrations of the base solution (e.g. AjS1, AjS2, and AjS3) and one of the odorant-added solutions (e.g. AjS1+vanillin). Participants had to rank the 4 bottles according to sweetness or saltiness intensity. The results showed that OITE occurred for all the solutions but differently according to the group and the complexity of the beverage base. In the sweet complex beverage (Aj), only OB perceived a sweet taste enhancement whereas in the green-pea soup OB and NW perceived a salty taste enhancement. OB and NW participants ranked the water-based solutions in a similar way, independently of taste, but with a lower effect size compared with the complex solutions. The highest OITE was observed for the sweet Aj+vanillin and the salty Wsa+bacon samples (sweetness and saltiness increased by at least 50% and 75%, respectively) in OB. To conclude, we showed that the OITE phenomenon significantly differed between NW and OB. Only OB experienced OITE in the sweet complex beverage, while OB and NW experienced OITE in the salty soup. Both groups experienced OITE in the sweet water solutions but with a lower effect size compared with the complex solution (Aj). Our results also demonstrated that the ranking task is efficient to assess OITE and to highlight OITE differences between groups and solutions.

Keywords: ranking task, flavour, OITE, perception, food, obesity, salty, sweet.

Introduction

During food consumption, tastants and odorants are released in the mouth. While odorants reach olfactory receptors in the nose through the retronasal pathway, tastants directly activate taste receptors on the tongue. The activation of these different receptors allows respectively odour and taste perceptions. When taste and odour perceptions co-occur repeatedly, our brain unifies the perceptions into a single holistic food percept called flavour perception. The integration of odour and taste into flavour also transfers a taste property to the odour. After which, the odorant can enhance a taste perception. This phenomenon called "Odour-Induced Taste Enhancement" (OITE) has been largely described in sweet [2] and salty simple beverages [2, 4] as water.

The study of this phenomenon in more complex beverages is challenging because multiple perceptual interactions occur between tastes, odours, and textures, which complicates the identification of taste-enhancing odorants. Therefore, few studies showed this phenomenon in complex beverages [5] or food [3, 6]. However, more studies on this topic are needed to understand if the strategy that aims to reduce salt and sugar while compensating taste loss with aroma would be effective in reducing salt and sugar intake. This strategy is promising in a society where the prevalence of obesity and food-related diseases is increasing.

While the study of the food base is of interest to delineate how OITE could be used in food, physiological factors like BMI should also be considered. Proserpio and collaborators assessed OITE between normal-weight (NW) and obese (OB) population [1]. Interestingly, they found that only obese participants presented a sweet enhancement when butter aroma was added to a custard dessert. Therefore, it seems that obese participants are more sensitive to this butter-induced sweetness effect. We wished to replicate and extend these results by comparing sweet and salty enhancements in OB and NW within a simple (water) and a complex (apple juice or green-pea soup) base. We hypothesized that OITE will occur in the normal-weight and the obese populations for sweet and salty tastes, but we expected that OB would find the OITE solution as more sweet/salty than NW.

We used a ranking task instead of intensity visual analogue scales traditionally used to assess the OITE. Sweet or salty intensity scales are often difficult to use and produce a large interindividual variability that includes bias

E. Guichard & J.L. Le Quéré (Eds): Proc. 16th Weurman Flavour Research Symposium, 2021.
DOI:10.5281/zenodo.5518084

linked to the scale use. It often necessitates training or at least references to delineate the scale's anchors or the intensity of the middle of the scales [7]. Compared to taste intensity scales, the ranking task is easily assimilated by participants and does not require training or references. Indeed, the ranking task was effectively used by children [8] or elderly [9]. It is also less prone to inter-individual variability and provides a direct measure of consensus across participants. Former studies showed that the ranking task was efficient to assess differences in taste intensities from different solutions [10] and it was previously used to measure OITE in water [11]. In this experiment, the participants had to rank 14 solutions containing different concentrations of sugar with and without the addition of the vanillin aroma. We simplified the ranking task design of Nguyen [11] and used three levels of concentrations among which the aroma-added and tastant-reduced solution had to be positioned to highlight the level of OITE.

Materials and Methods

Participants

We recruited 43 normal-weight (NW: 20< body mass index< 25kg/m²) and 28 obese (OB: body mass index > 30kg/m²) French participants. The sweet and salty solutions were evaluated in different sessions. The participants were scaled and weighed at the end of the first session. They should not eat, drink or smoke at least 1 hour 30 min before the sessions. The experimental procedure was explained to each participant before recruitment and again before each test session. Participants signed an informed consent form to participate in the study. They received 10€ compensation for each hour spent performing evaluations. The study was conducted following the Helsinki Declaration and was approved by the ethics committee CPP EST I #19.04.26 (ID RCB #2019-A00120-57).

Solutions

To study the odour-induced sweetness enhancement, two bases were used: Apple juice (Aj) and sweet Water (Wsw). The Aj base was constituted of apple juice (Carrefour, France) initially containing 10% of sugars that was diluted at 4% (w/w) with water (Evian, France). We selected vanillin (Sigma Aldrich, CAS: 121-33-5) as a potential sweet enhancer for both Aj and Wsw. The odorant was dissolved in Evian water at 4000 ppm and diluted in Aj at 300 ppm and in Wsw at 600 ppm. To study the odour-induced saltiness enhancement, two bases were used: Green-pea soup (Gp) and salty water (Wsa). The Gp base was prepared by extracting the supernatant of an unsalted green-pea puree (Bledina, France). A bacon complex (Firmenich, Switzerland) was chosen as a potential saltiness enhancer for both Gp and Wsa. The Gp and aroma solution were not diluted before mixing. For the ranking task, three solutions with increasing concentrations of either sucrose or sodium chloride (S1 to S3) were prepared for each food base. A fourth solution was prepared, containing the aroma diluted in the S1 solution (Table 1).

Table 1: Concentration (w/w) of each solution by food base used during the ranking task.

Beverage base	Aroma	S1	S2	S3	S1 + Aroma
Apple Juice (Aj)	Vanillin	4%	6%	8%	4% + 0.03%
Sweet Water (Wsw)	Vanillin	4%	7%	10%	4% + 0.06%
Green-pea soup (Gp)	Bacon	0.25%	0.50%	0.75%	0.25% + 0.005%
Salt Water (Wsa)	Bacon	0.10%	0.18%	0.25%	0.10% + 0.005%

Sensory procedure

The ranking task instructions and sensory data collection were monitored with Fizz software (Biosystèmes, Couternon, France). Each food base was tested in a dedicated ranking task (4 ranking tasks in total). Participants received three sweet or salty concentrations of the base solution (e.g. AjS1, AjS2, and AjS3) and one of the odorant-added solutions (e.g. AjS1+vanillin); they were asked to rank the 4 bottles according to the increasing sweetness or saltiness intensity. The ranking tasks' and solutions' orders were counterbalanced among participants. The solutions were delivered using spray bottles, which avoid orthonasal smelling before tasting. At the beginning of the session, participants were trained to use the spray bottles. To perform a ranking task, the panellist had to spray two pulses of each solution in the mouth, swallow and rank the bottles accordingly to their salty/sweet intensity; equally ranked were not allowed. When necessary, they could rinse their mouth. After a preliminary ranking, they were instructed to confirm their choice by testing once again each solution from the lowest to the highest salty/sweet intensity and register their ranking. Between two rankings, the subjects had to rinse their mouth with lukewarm Evian© water (40°C).

Data analysis

For each solution, the distribution of the participants that have ranked in the first, second, third, or fourth position was calculated. The position of the ranking (2nd, 3rd, and 4th positions) represented the strength of OITE. For each ranking task, a first Wilcoxon test was done to check whether the ranking was correct for each base solution (S1<S2<S3). Another Wilcoxon test was done to compare the ranking of the beverage with the aroma against the base solutions with different levels of sugars/salt (S1+aroma vs S1, S2, or S3). A between-group Wilcoxon test was performed to compare the ranking of the aroma-added solution in each food base to assess whether the enhancement is similar between groups. Finally, a within-group Wilcoxon test was performed to compare the ranking of the aroma-added solution between the salty and sweet bases for the water and the complex bases. The Wilcoxon tests were corrected with a False Discovery Rate (FDR) correction; a comparison was considered as significant for p<0.05 (*), p<0.01 (**), and p<0.001 (***).

Results

OITE in complex beverages

In the apple juice, 83% of OB ranked AjS1+vanillin at least in the second position, whose 33% in the third position and 17% in the fourth. By contrast, only 61% of NW people ranked AjS1+vanillin at least in the second position whose only 6% in the third position (Figure 1A). Therefore, AjS1+vanillin was ranked as significantly higher than AjS1 by OB (W= 156, p= 0.003) but not by NW (W= 316, p= 0.14). The distribution of the ranking is significantly different between the groups (W= 144, p= 0.003). These results showed an OITE in the apple juice for OB but not for NW. Interestingly, OB perceived AjS1+vanillin as sweet as AjS2 (W= 85.5, p= 1) while NW perceived AjS1+vanillin as less sweet than AjS2 (W=20, p< 0.0001). Therefore, the solution AjS1+vanillin was perceived as sweeter than AjS2 in the OB group but not in the NW group.

Different results were found with the green-pea soup, 80% of OB ranked GpS1+bacon at least in the second position whose 5% in third, and 5% in fourth. By contrast, 62% of NW ranked GpS1+bacon at least in second position, whose only 8% in third and 5% in fourth (Figure 1B). Therefore, GpS1+bacon was ranked as significantly higher than GpS1 by OB (W= 172, p= 0.007) and by NW (W= 472, p= 0.05). Even if a higher number of OB rated the aroma-added solution in the second position, the ranking was not significantly different between the groups (W= 320.5, p= 0.36). Both groups evaluated the GpS1+bacon as less salty than GpS2 (OB: W= 26, p= 0.003; NW: W= 92, p< 0.0001). Therefore, the solution GpS1+bacon was perceived as saltier than GpS1 but less than GpS2 in NW and OB and ranking was similar between the groups.

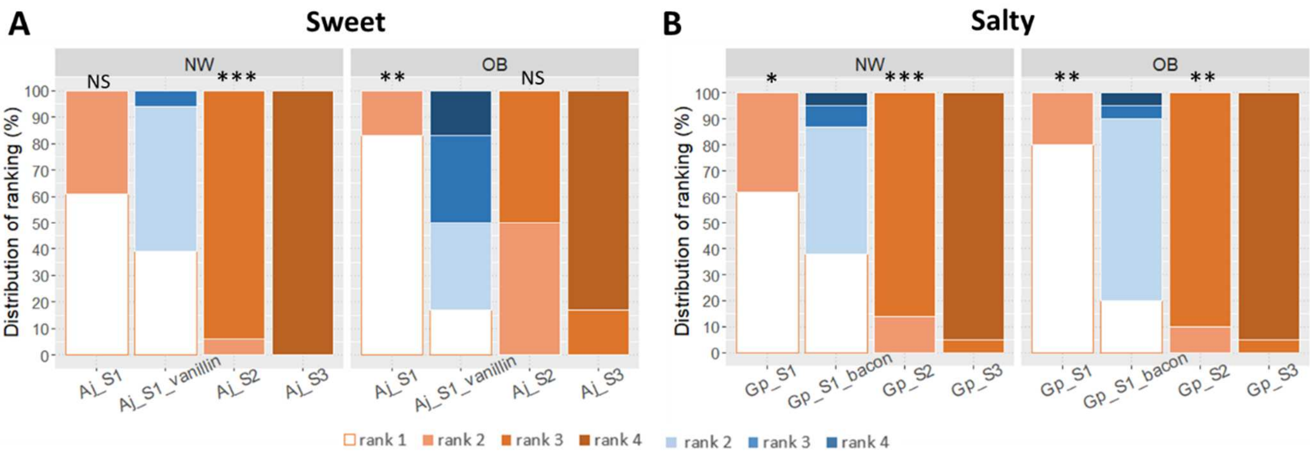

Figure 1: *Distribution of the participants who ranked in 1st, 2nd, 3rd and 4th position the A) three sweet levels of an Apple juice (AjS1, AjS2, and AjS3) and B) three salty concentrations of a Green-pea soup (GpS1, GpS2, and GpS3) and an odorant-added solution (AjS1+vanillin or GpS1+bacon). The colour gradient corresponds to the distribution of the participants who ranked in positions 1, 2, 3, or 4. The orange colours correspond to the solutions without aroma and the blue colours to the ranking of the odorant-added solutions. The stars indicate that the solution is significantly different from the solution containing the aroma at respectively: ***:p< 0.001; **:p< 0.01; and *:p< 0.05 (Wilcoxon test).*

OITE in water base beverage

In the sweet water, 89% of OB ranked WswS1+vanillin at least in the second position, whose 12% in third and 4% in fourth position. In contrast, 75% of NW people ranked WswS1+vanillin at least in second position, whose only 8% in third and 3% in fourth position (Figure 2A). Therefore, WswS1+vanillin was ranked as significantly sweeter from WswS1 by OB (W= 316.5, p= 0.0002) and by NW (W= 600, p= 0.001). These results correspond to an OITE for both groups in the sweet water. Both groups evaluated the WswS1+vanillin as less sweet than WswS2 (OB: W= 59, p= 0.002; NW: W= 77.5, p< 0.0001). Therefore, the solution WswS1+vanillin was perceived as sweeter than WswS1 but less than WswS2 in NW and OB and ranking was similar between the groups.

Similar results were found in the salted water (Figure 2B), 85% of OB ranked WsaS1+Bacon at least in second whose 10% in third, and 25% in fourth. In contrast, 77% of NW people ranked WsaS1+Bacon at least at the second position whose only 31% at the third position and 3% at the fourth. Therefore, WsaS1+bacon was ranked as significantly saltier than WsaS1 for the OB group (W= 189, p= 0.002) and the NW group (W= 566, p= 0.0002). These results correspond to an OITE for both groups in the salty water. Interestingly, WsaS1+Bacon was not ranked differently from WsaS2 for the OB group (W= 95.5, p= 0.73). Comparatively, WsaS1+bacon was not ranked differently from WsaS2 for the NW group (W= 186, p< 0.02). OB and NW both perceived OITE in salty water plus bacon, but the enhancement was higher in OB than in NW.

Within-group comparison between salty and sweet enhancements

In NW, the comparison between sweet and salty taste enhancements revealed no difference of ranking of the aroma-added solutions in the simple bases Wsw and Wsa (W= 564, p= 0.11) as well in the complex bases (Aj vs Gp: W= 542, p= 0.67). However, in OB even if no difference was found between the simple bases Wsw and Wsa (W= 216, p= 0.26), OITE tended strongly to be higher in the AjS1+vanillin than in the GpS1+bacon solutions (W= 241.5, p= 0.052). To conclude, it is not possible to say that differences between OB and NW are solely based on the type of OITE (salty or sweet).

Within-group comparison between complex and simple beverages

In OB, the complex AjS1+vanillin was ranked higher than the simple water solution WswS1+vanillin (W= 9, p= 0.03). No significant differences of ranking between the sweet beverages WswS1+vanillin and AjS1+vanillin in NW (W= 102.5, p= 0.45) were found. However, in the salty beverages, the NW group tended to rank higher WsaS1+bacon in comparison to the GpS1+bacon (W= 828.5, p= 0.054) and the same trend was observed in the OB group (W= 62, p= 0.07). Therefore, the complexity of the base solution alone cannot explain the differences of OITE observed in OB and NW.

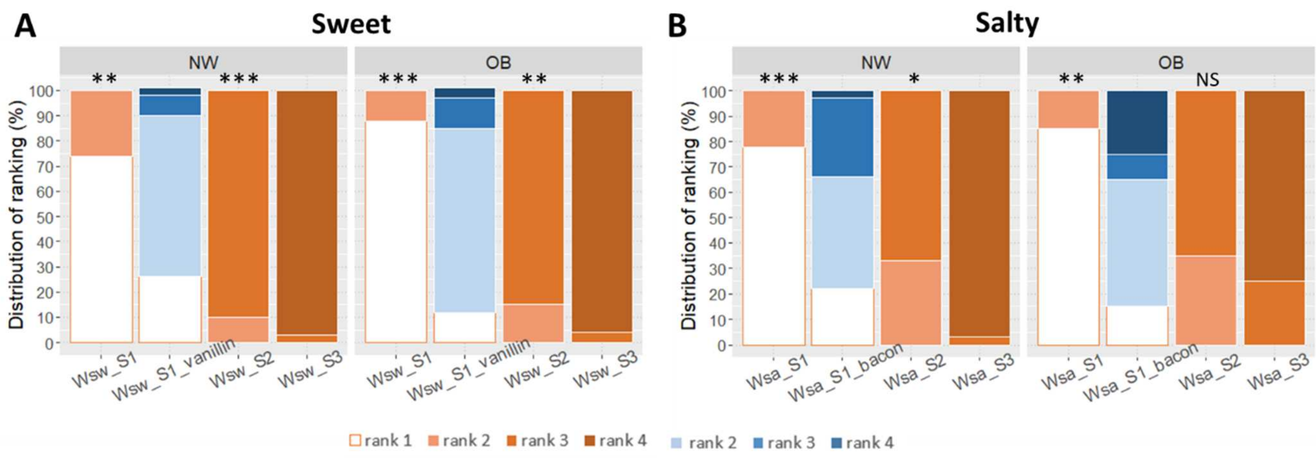

Figure 2*: Distribution of the participants who ranked in 1st, 2nd, 3rd, and 4th position the A) three sweet levels of a sweet water (WswS1, WswS2, and WswS3) and B) three salty concentrations of a salty water (WsaS1, WsaS2, and WsaS3) and an odorant-added solution (WswS1+vanillin or WsaS1+bacon). The colour gradient corresponds to the distribution of participants who ranked in positions 1, 2, 3, or 4. The orange colours correspond to the solutions without aroma and the blue colours to the odorant-added solutions.*

Discussion and Conclusion

The study aimed to determine odour-induced taste enhancement differences between obese and normal-weight populations on salty and sweet tastes. We hypothesized that OITE will occur in the normal-weight and in the obese population for sweet and salty tastes, but we expected that OB would find the OITE solution as more sweet/salty than NW.

We found a large consensus among OB participants (83%) concerning the OITE induced by vanillin in the apple juice. This OITE was not found in NW. In the sweet water solution, OITE was observed in both groups but did not differ between groups. In OB, sweetness enhancement is so high that it would allow decreasing sugar content by 33% while 50% of the participants still perceived it as sweet as before reduction. For the green-pea soup, the OITE was rather low in both groups. However, it was much higher in salty water. OB perceived a high salty enhancement, with a large consensus among participants (85%) in water solution with bacon although it was not significantly higher than NW. In the OB group, saltiness enhancement in water is so high that it would allow decreasing salt content by 75%, and 35% of the tasters would still perceive it as salty as before reduction. The OITE difference between OB and NW was explained neither by the complexity of the solution nor by the taste modality (salty or sweet).

The strong OITE observed in the apple-juice with vanillin in OB and the absence of OITE in NW is congruent with the results found by Proserpio and collaborators [1]. They showed an increase of the sweetness with a butter aroma added in a custard dessert only in the obese group. This result could be explained by differences in food habits between the groups. Obese people are generally more exposed to sweet drinks [12] and probably to sweet desserts with vanillin. The repeated exposure to this odorant in sweet desserts could lead to stronger associative learning between sweetness and vanillin [13]. This associative learning results in the unification of taste and odorant into a single perception (configuration) called flavour perception. This configural process follows integratory neuronal rules [14]. The subsequent experiences of this odour in food or beverage reactivate the configural encoding which leads to the perception of an odour as a taste [15-17].

We did not find clear OITE differences between salty and sweet beverages, more solutions should be tested in order to clarify the results. However, we should consider that sweet and salty solutions target differently the reward system, which may then modify OITE. The sweet perception involves the whole reward system while the salty perception targets only the amygdala [18]. Therefore associative learning effects might be less pronounced for saltiness than for sweetness. Because the apple juice is more caloric than the green-pea soup, the higher enhancement observed in the apple juice could also be due to a reinforcement of the association between the sweet taste and the aroma perception due to the caloric load.

Similarly, concerning the “complexity” effect (water vs complex base), while the OITE was more effective in the complex base for sweetness, the salty OITE was more effective in the simple water base. It is possible that an interaction between “taste” (salty or sweet), and “complexity” occurred. Therefore, here again, more solutions should be tested to ascertain the effect of complexity on OITE. Nevertheless, we should notice that tendencies for higher OITE with the bacon in water solution compared with the green-pea soup were found in both groups. This result could be explained by taste-taste interaction. Indeed, green peas are naturally sweet, therefore, the saltiness brought by the bacon could be reduced by the sweetness of the green peas leading to a lower OITE. As in the green-pea soup, the taste-taste interaction could also be present in the apple juice. Indeed, the typical apple juice flavour consists in a balance between the sweet and the sour tastes. Finally, the bacon-induced saltiness enhancement and the vanillin-induced sweetness enhancement in complex bases could be modulated by these taste-taste interactions.

Our results showed that the ranking task is an efficient method to highlight OITE. To our knowledge, only Nguyen [11] used this sensory procedure to assess odour-taste interactions. However, in that study the ranking task was rather complex due to a high number of solutions. Here, we simplified the task using only three levels of sweet or salt concentrations and one concentration of odorant. The results were contrasted in terms of OITE, some odorants did not produce OITE, and some odorants produced OITE with different strengths depending on the group, which validate the methodology.

To conclude, as a main result, we showed that the OITE phenomenon is present in obese and normal-weight people for sweet and salty tastes, but with stronger OITE in OB for vanillin in apple juice and bacon in salty water. As flavour perception is a non-conscious brain construction, it would be interesting to go further in the understanding of the OITE phenomenon by investigating the brain mechanisms that underlie odour-taste interactions in normal-weight and obese people in different food bases.

Acknowledgements

This work was supported by the French “Investissements d’Avenir” program, project ISITE-BFC (contract ANR-15-IDEX-0003) awarded to C. Sinding for the EATERS project, and by Firmenich, Geneva, Switzerland. We would like to thank Dr. Marie Claude Brindisi as the medical investigator of the study. We would like to thank for their technical and logistical support on the experiment: Noëlle Béno, and Françoise Durey from the ChemoSens platform, and Chantal Septier, Claire Follot, Gaia Maillard, Marianela Santoyo Zedillo, Marie Simon and Yue Ma from the FFOPP team of CSGA.

References

1. Proserpio, C., Laureati, M., Invitti, C., Cattaneo, C., and Pagliarini, E., “BMI and gender related differences in cross-modal interaction and liking of sensory stimuli,” Food Qual. Prefer. 2017;56:49–54. doi: 10.1016/j.foodqual.2016.09.011.
2. Djordjevic, J., Zatorre, R.J., and Jones-Gotman, M., “Odor-induced changes in taste perception,” Exp. Brain Res. 2004;159(3):405–408. doi: 10.1007/s00221-004-2103-y.
3. Frank, R.A. and Byram, J., “Taste-smell interactions are tastant and odorant dependent,” Chem. Senses 1988;13(3):445–455. doi: 10.1093/chemse/13.3.445.
4. Lawrence, G., Salles, C., Septier, C., Busch, J., and Thomas-Danguin, T., “Odour-taste interactions: A way to enhance saltiness in low-salt content solutions,” Food Qual. Prefer. 2009;20(3):241–248. doi: 10.1016/j.foodqual.2008.10.004.
5. Barba, C., Beno, N., Guichard, E., and Thomas-danguin, T., “Selecting odorant compounds to enhance sweet fl avor perception by gas chromatography / olfactometry-associated taste (GC / O-AT),” Food Chem. 2018;257:172–181. doi: 10.1016/j.foodchem.2018.02.152.
6. Lawrence, G., Salles, C., Palicki, O., Septier, C., Busch, J., and Thomas-Danguin, T., “Using cross-modal interactions to counterbalance salt reduction in solid foods,” Int. Dairy J. 2011;21(2):103–110. doi: 10.1016/j.idairyj.2010.09.005.
7. Depledt, F., “Evaluation sensorielle Manuel méthodologique,” in SSHA 3rd edition, 2009, p. 146.
8. Liem, D.G., Mars, M., and de Graaf, C., “Consistency of sensory testing with 4- and 5-year-old children,” Food Qual. Prefer. 2004;15(6):541–548. doi: 10.1016/j.foodqual.2003.11.006.
9. Barylko-Pikielna, N., Matuszewska, I., Jeruszka, M., Kozlowska, K., Brzozowska, A., and Roszkowski, W., “Discriminability and appropriateness of category scaling versus ranking methods to study sensory preferences in elderly,” Food Qual. Prefer. 2004;15(2):167–175. doi: 10.1016/S0950-3293(03)00055-7.
10. Carabante, K.M. and Prinyawiwatkul, W., “Serving Duplicates in a Single Session Can Selectively Improve Sensitivity of Duplicated Intensity Ranking Tests,” J. Food Sci. 2018;83(7):1933–1940. doi: 10.1111/1750-3841.14194.
11. Nguyen, H.D., “Contribution à l’étude des intéractions entre entrées sensorielles : l’effet de la présence d’un arôme sur la percepion d’une saveur,” PhD thesis, Université de Bourgogne, 2000.
12. Morenga, L. Te, Mallard, S., and Mann, J., “Dietary sugars and body weight: Systematic review and meta-analyses of randomised controlled trials and cohort studies,” BMJ-British Medical Journal 2013;346:e7492. doi: 10.1136/bmj.e7492.
13. Stevenson, R.J., Boakes, R.A., and Prescott, J., “Changes in Odor Sweetness Resulting from Implicit Learning of a Simultaneous Odor-Sweetness Association: An Example of Learned Synesthesia,” Learn. Motiv. 1998;29(2):113–132. doi: 10.1006/lmot.1998.0996.
14. Wilson, D.A. and Stevenson, R.J., Learning to smell: Olfactory perception from neurobiology to behavior. Baltimore, Maryland (USA): The Johns Hopkins University Press, 2006.
15. Stevenson, R.J., Prescott, J., and Boakes, R.A., “Confusing tastes and smells: How odours can influence the perception of sweet and sour tastes,” Chem. Senses 1999;24(6):627–635. doi: 10.1093/chemse/24.6.627.
16. Stevenson, R.J., Prescott, J., and Boakes, R.A., “The Acquisition of Taste Properties by Odors,” Learn. Motiv. 1995;26(4):433–455. doi: 10.1016/S0023-9690(05)80006-2.
17. Stevenson, R.J., Boakes, R.A., and Wilson, J.P., “Counter-conditioning following human odor-taste and color-taste learning,” Learn. Motiv. 2000;31(2):114–127. doi: 10.1006/lmot.1999.1044.
18. Spetter, M.S., Smeets, P.A.M., de Graaf, C., and Viergever, M.A., “Representation of Sweet and Salty Taste Intensity in the Brain,” Chem. Senses 2010;35(9):831–840. doi: 10.1093/chemse/bjq093.