Objective

Competitive benchmarking, which consists of comparing one's products or processes to the leaders' ones, is a technique commonly employed by companies. This type of studies allows to position one's products in the market versus competitors and to give indications in order to improve, re-engineer or re-formulate products.
In this study, an Electronic Nose and an Electronic Tongue were used to analyze and compare several brands of smoothies. The objective was to position the various brands and get detailed sensory information about target competitive products.

Materials & Methods

Samples

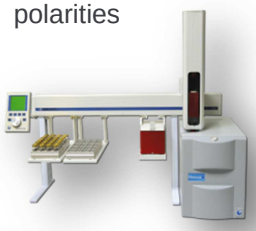
Eight types of smoothies (table 1), among which two recipes of the customer company (A1 and A2), were compared using an electronic nose and an electronic tongue.

Sample label	Composition
A1	Carrots
A2	Banana, Strawberry, Kiwi, Beet Juice, Carrot , Apple
B	Pineapple & apple concentrate, Mango, Banana & Kiwi puree, green tea extract
C	Apple, Orange, Red grape, Pomegranate & Cranberry concentrate, Banana, Strawberry & Raspberry puree
D	Apple & Orange concentrate, Strawberry & banana puree
E	Peach flavor, pasteurized low fat milk, live & active cultures
F	Apple, Pineapple, Kiwi & Lime concentrate, Mango puree
G	Strawberry concentrate & beet juice, pasteurized organic low fat milk, live & active cultures

Table 1: Smoothie samples

E-Sensing Instruments

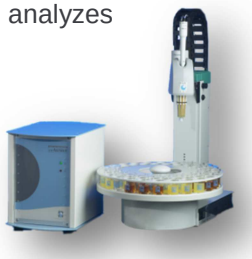
Tests on odor, taste and visual attributes were conducted respectively with HERACLES electronic nose, ASTREE electronic tongue and IRIS electronic eye (Alpha MOS, France).
The HERACLES is based on the technology of ultra fast chromatography, with two metal columns of different polarities (RXT-5 and RXT-1701, length = 10m, diameter = 180µm, Restek) in parallel and coupled to 2 Flame Ionization Detectors (FID). Two chromatograms are obtained simultaneously, allowing a sharper identification of the chemical compounds.



HERACLES
Electronic Nose

The integrated solid adsorbent trap thermo-regulated by Peltier cooler (0-260°C) achieves an efficient pre-concentration of light volatiles and shows a great sensitivity (in the pg range).
The electronic nose is coupled to an autosampler (HS 100, CTC Analytics) to automate sampling and injection. The analysis was conducted with headspace injection mode.
The HERACLES e-nose was additionally equipped with AroChembase module (Alpha MOS, France). It consists of a library of chemical compounds with name, formula, CAS number, molecular weight, Kovats retention Index, sensory attributes and related bibliography. It allows pre-screening the chemical compounds and giving sensory features by directly clicking on the chromatograms' peaks generated by HERACLES e-nose.

The ASTREE electronic tongue analyzes organic and inorganic compounds dissolved in liquids that are responsible for taste. The detection principle is based on a potentiometric measurement with seven ChemFET (Chemical modified Field Effect Transistor) sensors.



ASTREE
Electronic Tongue

Data acquisition and data processing was achieved with AlphaSoft software (Alpha MOS, France) for the three instruments.

The analytical parameters optimized for this analysis are described in table 2.

HERACLES electronic nose parameters	
Sample mass	1g of smoothie in a 20mL vial
Headspace generation	20 min at 40°C
Injected volume	5 mL
Trap temperature	40°C / 240°C (desorption)
Columns program	40°C (2s) to 280°C (18s) by 3°C/s
FID temperature	280°C
ASTREE electronic tongue parameters	
Sample volume	25 mL of smoothie
Acquisition time	120 s

Table 2: Analytical parameters of the instruments

Odor analysis

The comparison of the chromatograms obtained with HERACLES e-nose shows some significant differences between the flavor profiles of the various brands of smoothies (Figure 1).

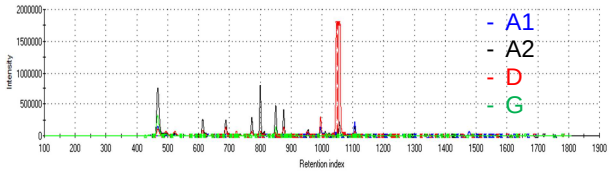


Figure 1. Superimposed chromatograms of several brands of smoothies, obtained with HERACLES e-nose

An odor map based on Principal Components Analysis (PCA) was generated based on the volatile compounds detected in the headspace of smoothies (Figure 2).

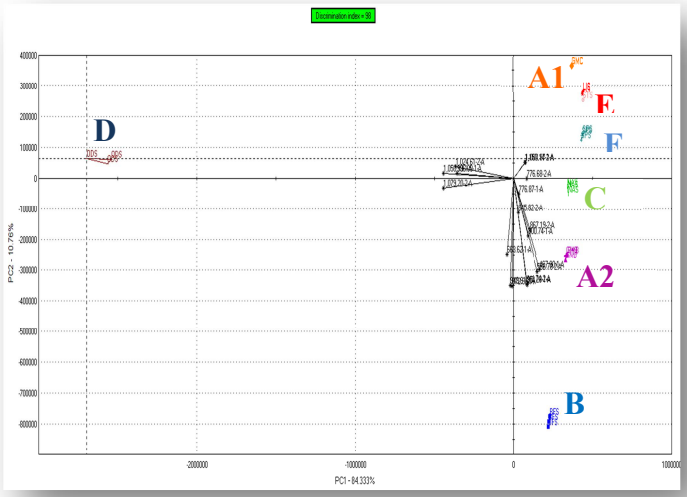


Figure 2: odor map of smoothies based on Principal Components Analysis (PCA)

In terms of odor the PCA tells us that smoothies D and B are completely different from the rest of the samples.

Samples G, E, A1 are closer to each other. The reason why E and G are so close may be due to the fact that they both contain pasteurized low fat milk with active cultures.

A2 and C are also close one to another.

The nature of the most discriminant volatile compounds involved in smoothies flavor was investigated using their Kovats index and the AroChemBase database (Table 3).

Smoothies B, F, A2, D, and C show presence of Methyl-2-methyl butanoate and ethyl isovalerate which gives them apple or fruity odors (Figure 3).
Gamma terpinene is seen in highest proportion in smoothie D due to the presence of orange in it and L-limonene is present prominently in smoothie F due to the presence of lime concentrate in it.

Presence = Area peak x 10-2										
KI MX-5 ±20	KI MXT-1701 ±20	A1	A2	B	C	D	E	F	G	Possible compounds and description
468	567	645	3300	4977	3926	614	1803	1256	1363	propanal (pungent..);propanone (pungent,fruity…)
664	777	0.58	20	44	216	27	15	316	5.14	pent-1-en-3-ol (milky…)
777	846	0	1378	475	118	383	1.58	1479	48	methyl-2-methyl butanoate (fruity, apple…)
801	867	0.55	3165	859	1433	200	33	1297	138	ethyl butyrate (banana, pineapple, fruity, sweet…)
850	914	0.81	2239	5643	962	255	0	1561	572	ethyl isovalerate (apple, fruity, sweet…)
873	950	12	1661	2831	178	656	19	117	3	isoamyl acetate (banana, fruity, sweet, fresh…)
996	1025	718	402	131	45	1222	0.64	4	0.88	1-octen-3-ol (carrot, earthy…)
1050	1079	406	1036	3694	1053	22544	57	269	12	gamma terpinene (citrus, fruity, sweet…)
1081	1157	7	0	3	0	12	0	2970	0	L-limonene (citrus, lemon, turpenine…)

Table 3. Possible volatile compounds contained in the different brands of smoothies

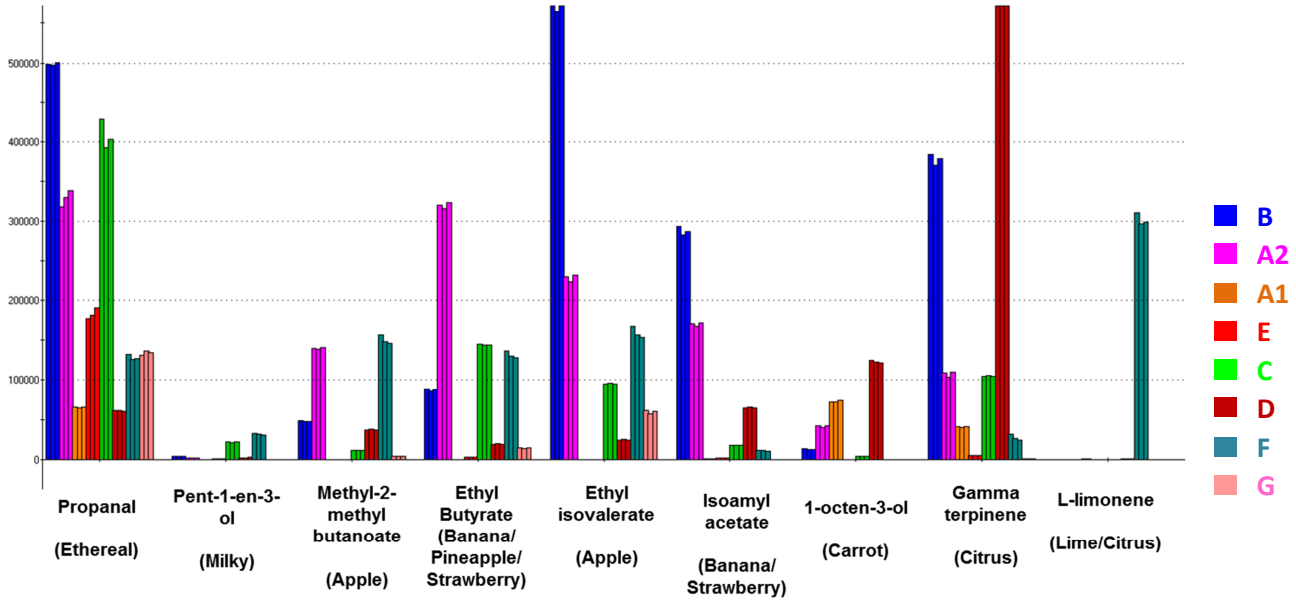


Figure 3. Proportion (peak area) of the main volatile compounds identified with AroChemBase in the different smoothies

Taste analysis

Based on ASTREE measurements, the taste map set up with Principal Components Analysis model shows that samples E and G are very similar to each other while A1 is very different from rest of the samples (Figure 4).

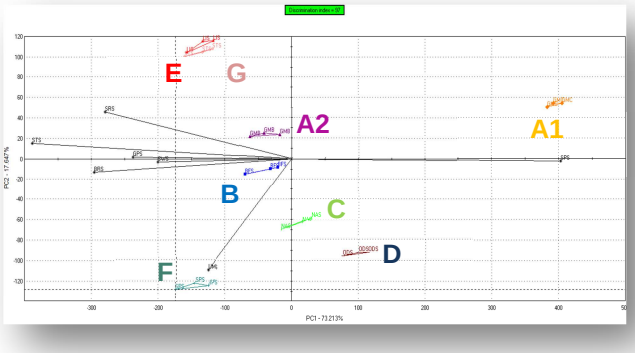


Figure 4. Taste map (Principal Components Analysis) of the different brands of smoothies obtained with ASTREE e-tongue

Combined Odor & Taste Analysis

Upon combining the Electronic Nose and Electronic Tongue measurements, a sensory map is obtained (Figure 5).

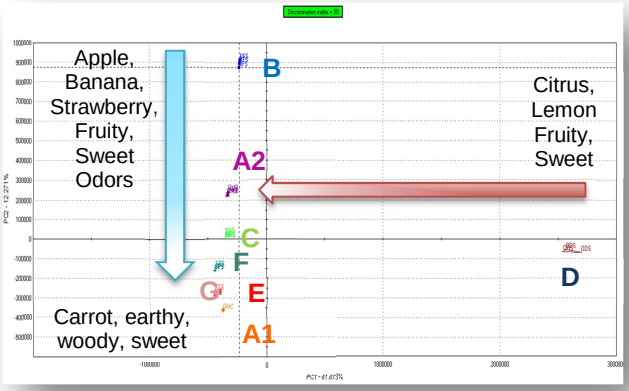


Figure 5. Principal Components Analysis model applied to e-nose & e-tongue measurements for smoothie samples

Samples are distributed according to the intensity of citrus notes (mainly on the x-axis), and fruity notes (mainly on the y-axis):

- sample D has high citrus notes

- sample B has the highest fruity, sweet, banana, apple, strawberry and pineapple odor notes

- sample A1 has earthy, woody and carrot notes.

Conclusion

This benchmarking study conducted on various brands of smoothies with sensory analysis instruments (e-nose, e-tongue) showed that the products analyzed have different taste and odor attributes.

Regarding odor features, the e-nose showed that smoothie B has a high proportion of ethyl isovalerate and isoamyl acetate which have a characteristic odor of fruity, sweet, apple, banana and strawberry while smoothie D contains a high concentration of gamma terpinene which has a characteristic odor of citrus, lime, fruity and sweet. The company sample A1 showed a high amount of 1-octen-3–ol which has a characteristic odor of woody, sweet, earthy and carrot.

Regarding the taste profile, the e-tongue demonstrated significant differences between the smoothies.