Context

In 1912, while working for the Parke Davis pharmaceutical company, Wilbur Scoville developed a method to measure the heat level of a Chile pepper. This test, the Scoville Organoleptic Test, is a dilution-taste procedure: pure chiles were grounded with a sugar-water solution and panelists sipped the concoctions, in increasingly diluted concentrations, until the liquid no longer burned the mouth. A score was then assigned to each Chile based on how much it needed to be diluted before you could taste no heat.

The pungency of Chile peppers is measured in multiples of 100 units, from the bell pepper at zero Scoville units to the incendiary Habanero at 300,000 Scoville units. The substance that makes a Chile hot, is Capsaicin and pure Capsaicin rates over 15,000,000 Scoville Units. Scoville's test is a comparative taste test that is considered as subjective by today's standards, and a more sophisticated method is used today. But in honor of Wilbur Scoville the unit of measure is still called the Scoville Index.

Current methods for the determination of red pepper heat

American Spice Trade Association (ASTA) Method 21.0, the old Scoville Heat Test used by industry for many years, had a large variability due to:

- Lack of reference standard
- Lack of statistical validity
- Poor test reproducibility
- Ethanol bite in sample
- Increase taste threshold
- Rapid taste fatigue
- Build-up of heat.

Therefore in December 1998, ASTA determined that methods 21.0 an 21.1, as methods to determine capsicum, were made obsolete. ASTA Method 21.3, pungency of Capsicums and their Oleoresins (HPLC method) was adopted December 1998 as the official method.

Main advantages:
- ✓ Objective
- ✓ Standardized and official

Main drawbacks:
- ✓ Long sample preparation (almost one hour for extraction)
- ✓ Long analysis time (around 20mn per analysis)
- ✓ Standard solution needed for each analysis.

The aim of this application note is to present an objective method faster than HPLC.

ASTREE electronic tongue

The ASTREE Electronic Tongue (fig. 1) is based on liquid sensor array allowing a measurement of potential difference between each sensor and a reference electrode. Each sensor has a specific organic membrane, which interacts with chemicals present in the liquid sample in a specific manner. Recorded data are processed by the software as a global taste fingerprint.

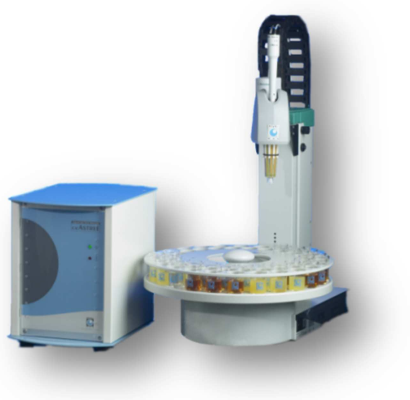


Fig.1: ASTREE Electronic Tongue (Alpha MOS, France)

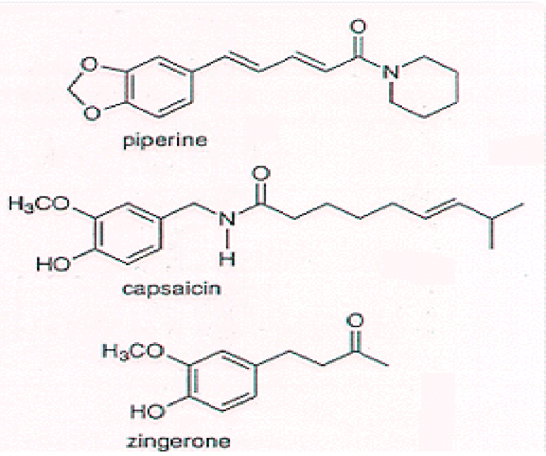
Prediction of Heat index of compound responsible for hot taste

The heat index of pure chemical has been investigated to see the ability of Astree to quantify the spicy taste.

The chemical components of a chile pepper that cause the well-known burning sensation are all members of capsaicinoids.
Of the capsaicinoids, there are two compounds that are typically responsible for about 80-90% of the capsaicinoid content of a pepper, and thus for most of the pepper's pungency. The common names of these two compounds are capsaicin and dihydrocapsaicin

Capsaicin is the substance responsible for the spiciness associated with members of the genus Capsicum, which includes most of the red and green peppers used in Mexican, South American, Cajun, and some Asian foods. Ginger is another "hot" spice common in Asian cooking, and the substance responsible for its pungency is zingerone. “

Piperine is the active component of white and black pepper (Piper nigrum) and is presumably of use to the plant because of its insecticidal properties.



So, we performed a first analysis on 4 major chemicals responsible for hot taste: Zingerone, Capsaicin, Piperine and Dihydrocapsaicin.

Analytical Conditions

Sample volume used	100 mL
Temperature	ambient
Time between analyses	180 sec
Acquisition time	120 sec

Analysis 1: Discrimination of hot compounds

Samples

Capsaicin (M=305.40 g/mol)
Dihydrocapsaicin (M=307.40 g/mol)
Zingerone (M=194.23 g/mol)
Piperine (M=285.34 g/mol)

Sample preparation: solutions = 50 mg / 100 ml ethanol.

Results

The four chemicals are well discriminated with Astree.

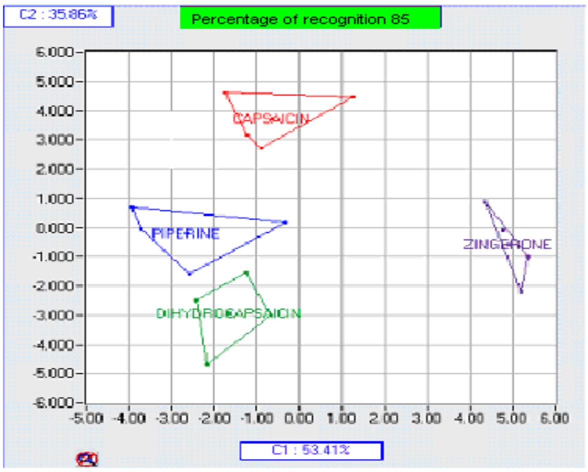


Figure 2: DFA with all samples

So, Electronic tongue discriminates successfully the chemicals responsible for hot taste… but can we quantify how hot it is?

Analysis 2: Quantification of Zingerone compound

Samples

Zingerone solutions at different concentrations were investigated:

- ✓ 0.1M (S1): 4.856g / 250ml ethanol.
- ✓ 0.075M: 75ml S1 / 100ml ethanol.
- ✓ 0.050 M: 50ml S1 / 100ml ethanol.
- ✓ 0.020 M: 20ml S1 / 100ml ethanol.
- ✓ 0.010 M: 0.486g / 250ml ethanol.

Sample	Dilution Index
Solution 0.1 M	10 000
Solution 0.075 M	7 500
Solution 0.050 M	5 000
Solution 0.020 M	2 000
Solution 0.010 M	1 000
Solution 0.1 M	10 000

Table 1: Index of the solutions

Results

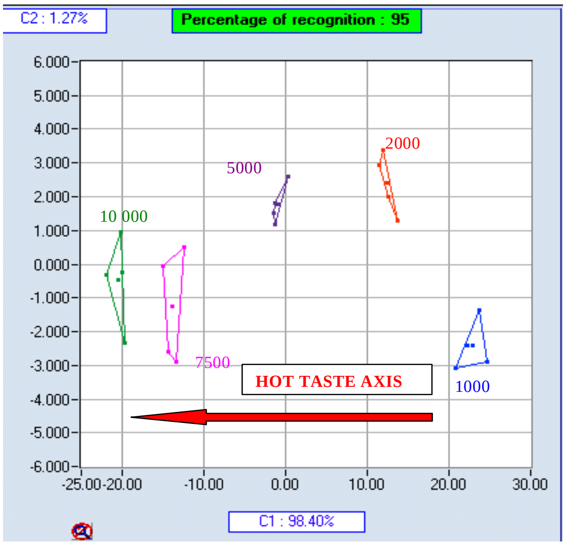


Figure 3: DFA with all the samples

A clear discrimination is obtained with the Astree system (See figure 2). A concentration axis can be observed (C1).

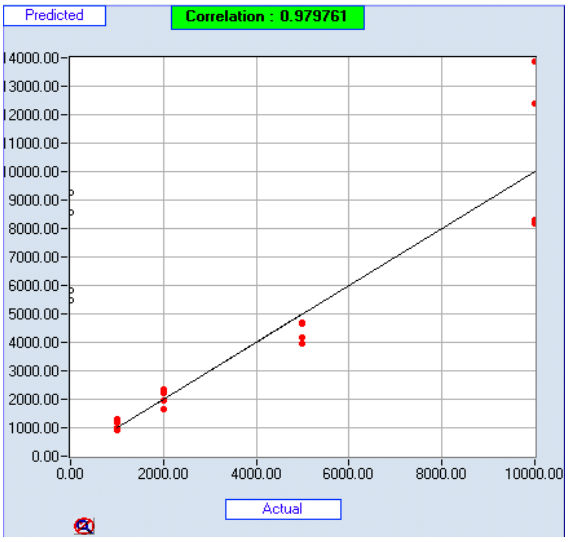


Figure 4: PLS for quantification

Samples labeled 1000, 2000, 5000 and 10 000 are used as training samples and the sample 7500 has been used as "unknown" to validate the model.

Sample	Heat Index Astree	Scoville Index	Difference
1000	1096	1000	96
2000	2051	2000	51
5000	4361	5000	639
10000	10691	10000	691

Table 2: Results for training samples

Sample	Heat Index Astree	Heat Index	Difference
7500	7278	7500	222

Table 3: Result for the "unknown" sample

Astree Electronic Tongue can discriminate various Zigerone concentrations and quantify the dilution level of these compounds, related to Scoville Heat Index, with a high level accuracy (a difference of 222 Scoville units on a 7500 value, so a less than 0.3% deviation).

Correlation with Heat Index of Tabasco Sauce

The E-Tongue can successfully tests compounds as well as finished products. The following is an overview of an analysis conducted to quantify the heat index in 4 Tabasco sauces.

Samples

4 Tabasco sauces were collected.

Sample	Composition	Label	Heat Index
Tabasco original	Vinegar, chilli, salt	Original	3700
Tabasco garlic	Vinegar, Chilli, , water, salt, garlic	Garlic	1500
Tabasco jalapeño	Vinegar, jalapeño pepper, water, salt, starch, xanthan gum, ascorbic acid	Green	900
Tabasco Chipotle	Vinegar, Chipotle pepper, water, salt, sugar, garlic powder, spices	Chipotle	2000

Table 4: Reference name and composition of tabasco samples

Results

Discrimination:

- An easy to see discrimination is obtained with the Astree system. (Figure 5)
- The 4 Tabasco samples are well discriminated (discrimination index of 90%). The information displayed on each axis in 66% for the X axis and 31% for the Y axis, showing the discrimination is mainly performed on these two axes.

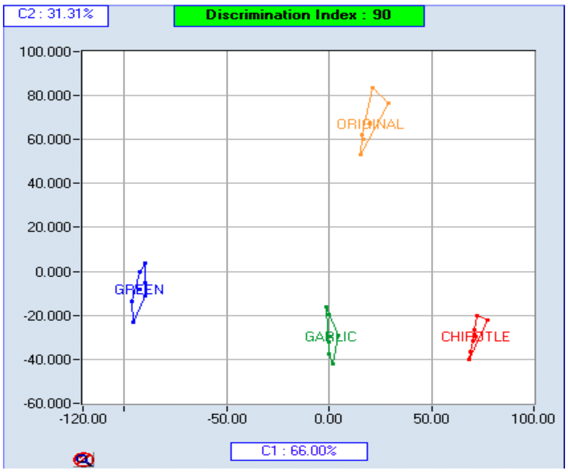


Figure 5: PCA with all samples

Quantification:

The correlation between Astree measurements and Scoville Heat Index is very good (> 0.99). The Astree results also present a very good reproducibility (see table below). The average difference between the Astree and sensory evaluation is typically around 71 on a 3000 unit scale, so a less than 2% difference.

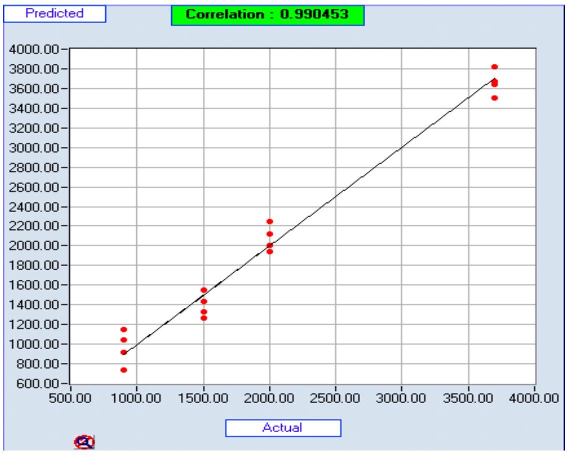


Figure 6: PLS with all samples

Label	Scoville Index Astree	RSD Astree	Sensory panel Heat Index	Difference
Green	961	152	900	61
Garlic	1397	108	1500	103
Chipotle	2081	113	2000	81
Original	3661	112	3700	39

Table 5: Results of Astree quantification

Prediction of Heat index

The application has been further validated by calibrating the Astree using the same samples at different concentration level (obtained by dilution) and by projecting unknown samples to validate the model obtained.

Samples

Preparation: X g (see table) / 100g of water

Sample	Mass X (g)	LABEL and new Heat Index
Tabasco original	50	O_3700
Tabasco original	45	O_3330
Tabasco original	35	O_2590
Tabasco chipotle	50	C_2000
Tabasco chipotle	45	C_1800
Tabasco garlic	50	GA_1500
Tabasco garlic	40	GA_1200
Tabasco green	50	GR_900
Tabasco green	25	GR_450
Tabasco green	5	GR_90
Tabasco green	2.5	GR_45

Table 6: Dilution level of the various samples

Results

Discrimination:

All samples are well discriminated (Figure 7), on the sample type side as well as different heat level.

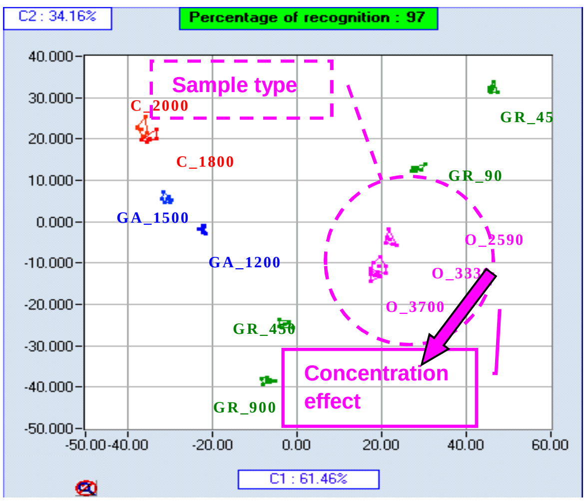


Figure 7: DFA with all the samples

To check the ability of E-tongue to quantify the spicy taste, the following data treatment has been performed :

- Training set : O_3700, O_3330, GR_900, GR_450, GR_90, GR_45
- Unknown samples : O_2590, C_2000

Quantification:

The system allows to have a good linearity (correlation coefficient of 0.97) between the values given by the system and the ones assessed by sensory test (figure 8).

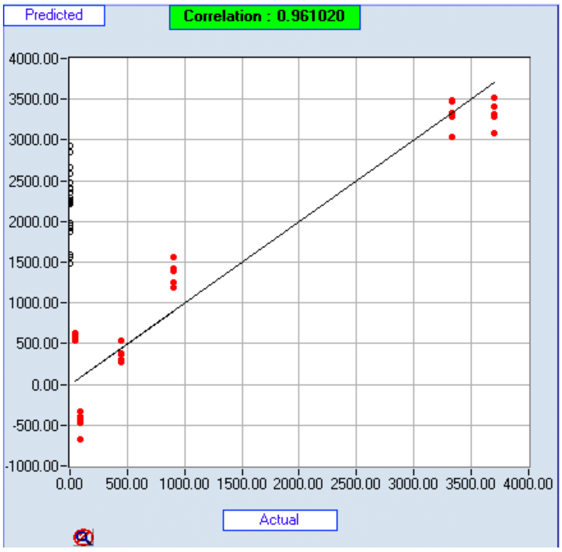


Figure 8: PLS calibration curve

The unknown samples are correctly recognized as presented below. The identification of the unknown samples are achieved with less than 10% difference:

Label of the unknown	Astree Heat Index	Sensory Heat Index	Difference
O_2590	2675	2590	85
C_2000	2250	2000	250

Table 7: Prediction results

Conclusion

The results obtained using the Astree Electronic Tongue accurately predicts the Heat Index of various sample types.

Representing the data by PCA and prediction using a DFA model provides an objective measurement.

Pure chemicals have been successfully analyzed as well as finished products such as Tabasco sauces.

Astree Electronic Tongue provided an easy, fast and objective alternative to subjective sensory panel or time consuming HPLC for pungency level assessment and spiciness quantification of food.