Taste Assessment & Synergistic Effect
Application to Umami, GMP & IMP Nucleotides

Results obtained at Alpha MOS Laboratory, Toulouse, France

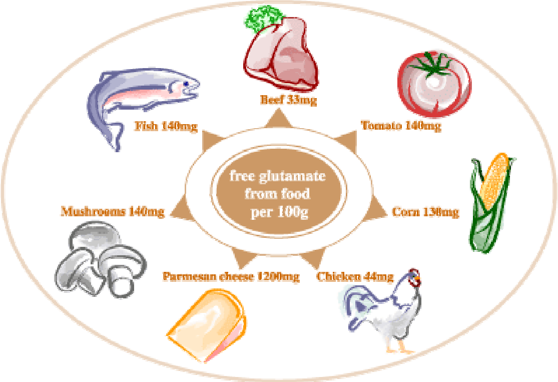
Umami (Japanese translation of deliciousness) taste has been widely accepted as a unique taste quality, which does not belong to any of the other four basic taste qualities (Salt, Sweet, Acid and Bitter).

This taste, due most of time to the presence of the Monosodium Glutamate (MSG) appears in various food sources including fish, meats, mushrooms, cheese ...

Umami taste can be also provided by the nucleotides IMP (disodium 5’-inosine monophosphate) and GMP (disodium 5’-guanosine monophosphate) naturally present in many protein-rich foods.

MSG is also used as taste enhancer in a wide range of savory food to create a smooth, rich and full-bodied flavor. It can be added to meat, fish, poultry, vegetable and seafood dishes, or used as a table-top seasoning.

There is a synergistic effect between MSG, IMP and GMP. Synergism in taste refers to mixtures that have a stronger perceived intensity than the sums of the perceived intensities of the mixture components.



Nucleotides strengthen the taste and the flavour of many food preparations. They improve slightly the other four basic tastes. They are claimed to:

- Bring richness in taste "meat", a round and rich aroma in fat free products
- Mask the acid aftertaste without hiding the profile
- Improve the taste of vegetables, cheese or soy sauce attributes

Additionally, they allow a cost reduction of the mixture by adding a little amount of nucleotides to enhance the taste.

Objective

The following is an overview of various experiments conducted with the Alpha MOS Electronic Tongue.

The aim of these analyses is to study:

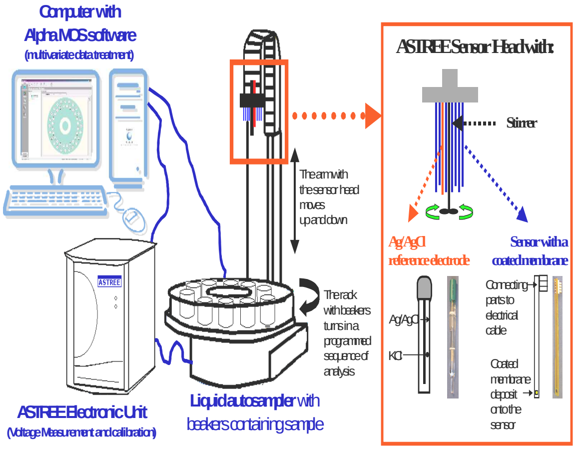
- the umami taste provided by the MSG
- the synergistic effect provided by adding IMP and GMP nucleotides.
- the correlation between ASTREE Electronic Tongue results and synergistic effect quantification provided by literature [1, 2 & 3].

Experimental Plan and System Conditions

1. System used for the study

The ASTREE Electronic Tongue performs global taste analyses in a similar way to the human taste receptors.
The system includes a sensor array, an auto-sampler and an easy-to-use software for data analysis.

Schematic view of the ASTREE Electronic Tongue



ASTREE Sensors

- **are based on the ChemFET technologies** (see Technical Note T-SAS-01 & 04). Each sensor has an organic membrane, interacting with all ionic, neutral and chemicals present in the liquid sample in a manner, specific to the coating. Any change at the membrane interface (ionic or molecular interaction) is detected by the sensor and converted into electronic signal.
- **have a partial sensitivity** (Each sensor is sensitive to various compounds) and are **cross-sensitive**: Information given by each sensor is different.
- **detection principle is based on a potentiometric detection**, i.e. measurement of potential difference between each sensor and the reference electrode: Potential Measurement # V $_{RF}$ (Reference Electrode) - V $_{S}$ (sensor)

Data acquisition and treatment

- **A measurement of voltage difference is performed and recorded**. For this analysis, **120 sec** has been chosen as the measuring time for each sample.
- Each sample is analyzed with 4 replicates and the ASTREE sensor head is rinsed between each measurement.
- The pattern recognition software then analyzes the response. It allows data acquisition and processing with multivariate statistical methods.
- In the present study, the Potential Measurements Mean (MPM) of the 4 replicates per sample were used. A mean of the results obtained for the 4 replicates have been performed.
  Each mean has been normalized, i.e.
  (Mean of replicates – Mean of results for all samples by sensor] / standard deviation for all samples by sensor).

2. Analytical Conditions

Sensor array #1:	ZZ, BA, BB, CA, GA, HA, JB
Sample volume used	100 mL
Temperature	ambient
Time between analyses	180 sec
Acquisition time	120 sec
Rinsing Time	60 sec

3. Samples preparation

Three compounds have been studied in their sodium salt forms. These solutions have been prepared once for all the experiments. Each product has been weighted and diluted into distilled water. The solutions have then been split into several containers and have been frozen until the analysis has taken place.

Samples	Synergic effect	[MSG] (M)
MSG_1	1.000	10^{-3}
MSG_2	1.000	10^{-2}
MSG_3	1.022	10^{-1}
MSG_4	1.344	0.5
MSG_5	2.011	1

Samples	Synergic effect	[MSG] (M)	[IMP] (M)
MSG_IMP_1	1.023	10-3	5.10-4
MSG_IMP_2	1.098	10-2	5.10-4
MSG_IMP_3	1.234	10-1	5.10-4
MSG_IMP_4	1.526	0.5	5.10-4
MSG_IMP_5	2.087	1	5.10-4
MSG_GMP_1	1.033	10-3	5.10-4
MSG_GMP_2	1.144	10-2	5.10-4
MSG_GMP_3	1.333	10-1	5.10-4
MSG_GMP_4	1.611	0.5	5.10-4
MSG_GMP_5	2.122	1	5.10-4

Each sample is analyzed with 4 replicates

Results

1. Reproducibility

In order to show the reproducibility of results, Standard Deviation (SD) and Residual Standard Deviation (RSD) have been calculated for each sensor and each sample.

	ZZ	**ZZ**	**BA**	**BA**	**BB**	**BB**	**CA**	**CA**	**GA**	**GA**	**HA**	**HA**	**JB**	JB
Sample Name	**SD**	**RSD**	**SD**	**RSD**	**SD**	**RSD**	**SD**	**RSD**	**SD**	**RSD**	**SD**	**RSD**	**SD**	RSD
MSG_1	18,60	**0,39%**	8,97	**0,42%**	6,81	**0,19%**	44,94	**1,02%**	30,76	**0,65%**	12,98	**0,41%**	12,67	0,73%
MSG_2	11,37	**0,27%**	9,56	**0,56%**	15,95	**0,47%**	22,36	**0,57%**	34,17	**0,81%**	23,10	**0,74%**	20,42	1,28%
MSG_3	4,39	**0,11%**	6,76	**0,54%**	13,44	**0,42%**	3,75	**0,10%**	22,02	**0,53%**	40,52	**1,37%**	32,60	2,26%
MSG_4	2,35	**0,06%**	5,41	**0,52%**	13,01	**0,42%**	2,59	**0,07%**	25,10	**0,61%**	51,79	**1,86%**	37,50	2,81%
MSG_5	2,23	**0,06%**	4,98	**0,51%**	11,44	**0,37%**	2,38	**0,06%**	24,49	**0,59%**	52,24	**1,92%**	40,32	3,20%
MSG_GMP_1	10,14	**0,22%**	6,05	**0,29%**	13,70	**0,39%**	11,73	**0,28%**	7,76	**0,17%**	15,88	**0,51%**	8,11	0,48%
MSG_GMP_2	8,39	**0,20%**	11,70	**0,69%**	8,97	**0,26%**	12,69	**0,31%**	29,20	**0,69%**	25,68	**0,83%**	21,97	1,38%
MSG_GMP_3	4,41	**0,11%**	6,77	**0,54%**	12,30	**0,38%**	3,24	**0,08%**	22,60	**0,54%**	40,06	**1,34%**	30,73	2,11%
MSG_GMP_4	2,28	**0,06%**	5,96	**0,57%**	13,20	**0,42%**	2,60	**0,07%**	24,73	**0,60%**	46,64	**1,66%**	35,77	2,66%
MSG_GMP_5	3,89	**0,10%**	5,54	**0,56%**	12,44	**0,41%**	1,74	**0,04%**	23,91	**0,57%**	45,68	**1,67%**	38,52	3,03%
MSG_IMP_1	20,21	**0,44%**	7,24	**0,35%**	6,39	**0,18%**	20,85	**0,50%**	22,95	**0,52%**	16,02	**0,51%**	8,46	0,49%
MSG_IMP_2	12,64	**0,30%**	8,26	**0,49%**	11,39	**0,34%**	17,26	**0,43%**	40,36	**0,98%**	20,03	**0,64%**	12,85	0,80%
MSG_IMP_3	3,88	**0,10%**	8,56	**0,68%**	13,51	**0,42%**	3,72	**0,09%**	20,47	**0,49%**	36,09	**1,20%**	30,03	2,06%
MSG_IMP_4	2,49	**0,06%**	7,31	**0,70%**	12,25	**0,39%**	2,08	**0,05%**	23,38	**0,56%**	42,24	**1,50%**	28,76	2,14%
MSG_IMP_5	3,15	**0,08%**	3,67	**0,37%**	13,89	**0,45%**	1,51	**0,04%**	24,00	**0,57%**	49,31	**1,80%**	34,27	2,69%

75 ml S1 / 100 ml ethanol.

Residual Standard Deviations are always inferior to 1.92% showing a very good reproducibility.

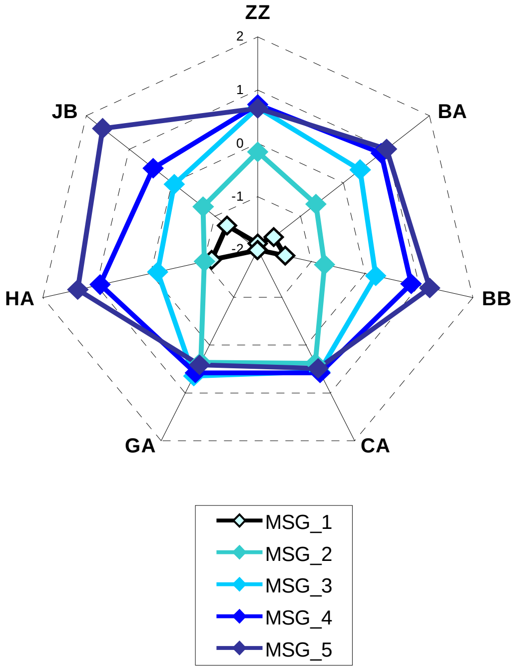
2. The Umami taste quantification

The ASTREE have been used to study the Umami taste provided by MSG at 5 various concentrations.

Results can be represented thanks to 3 different ways according to the user preference:

- A radar plot
- A Partial Least Square analysis
- A polynomial regression analysis.

➢ A radar plot of the results obtained for each sample according to each sensor:

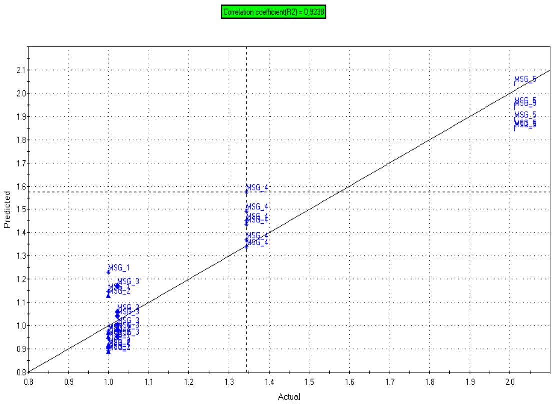


This graph shows that, each sensor can detect MSG, and according to the sensor, the discrimination of the five solutions is different.

- ➢ A Partial Least Square analysis to correlate ASTREE results to the synergistic effect obtained from literature.

The Partial Least Square analysis is a **linear regression performed on multidimensions,** as ASTREE is equipped with 7 sensors.

A very good correlation is observed (coefficient $R^2 = 0.9238$).



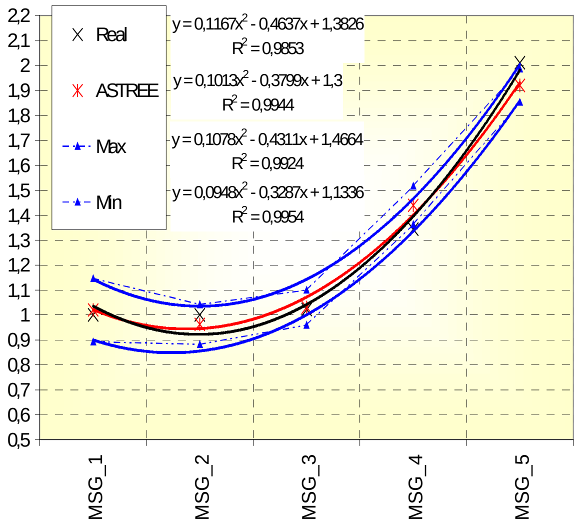
Astree Synergistic effect results

- ➢ A polynomial regression analysis to fit the MSG Synergistic effect found in literature and the one measured by the Electronic Tongue:

The curve of point least squares is calculated using the following equation: $Y = b + C_1X + C_2X^2 + C_3X^3 + \ldots + C_6X^6$ with b and $C_1 \ldots C_6$ as constant values.

We can see that the polynomial curve of ASTREE results is very close to the one of real (literature) values.

Moreover the real values are always comprised between minimal (Min) and maximal (Max) ASTREE results.



Synergistic Effect Real Values

The ASTREE can be efficiently used to predict the MSG Umami taste.

3. The synergistic effect of the GMP and IMP nucleotides on the Umami taste resulting from MSG

The ASTREE has been used to study the synergistic effect of a little amount of GMP or IMP on the Umami taste provided by MSG at 5 various concentrations.

Results can be represented thanks to 2 different ways according to the user preference:

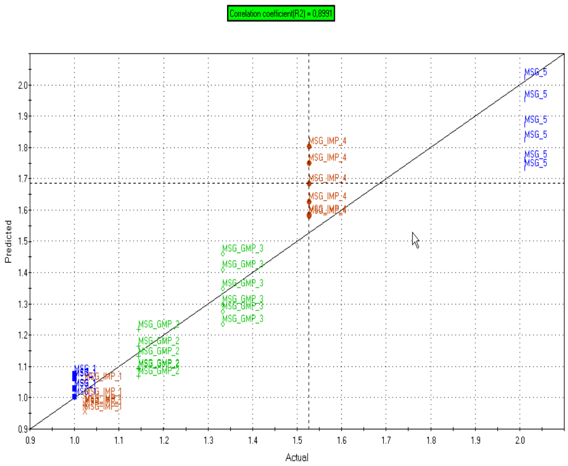
- ▪ A Partial Least Square analysis which is used to predict the synergistic effect of unknown samples
- ▪ A simple curve representation of results obtained for training and unknown samples.

- ➢ A Partial Least Square analysis to correlate ASTREE results to the synergistic effect obtained from literature.

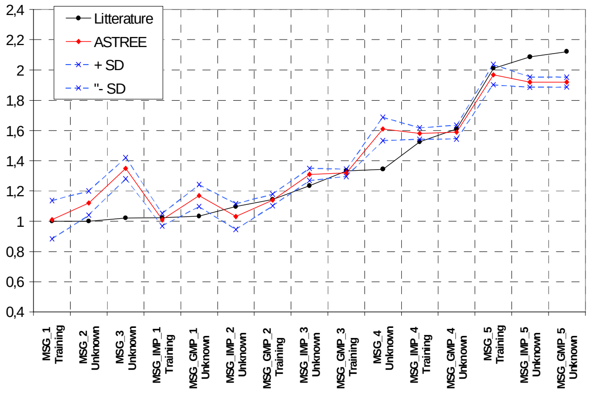
Some samples have been chosen to build the model:
MSG_1 and 5; MSG_GMP_2 and 3; MSG_IMP_1 and 4.

A very good correlation is observed (coefficient $R^2 = 0.9767$).

The other samples have been used as unknown and the Partial Least Square model is used to predict their synergistic effect thanks to ASTREE results. Training and unknown results are represented below.



ASTREE synergistic effect results



Synergistic effect

	Real	ASTREE	SD
MSG_1	1	1,01	0,13
MSG_2	1	1,12	0,08
MSG_3	1,022	1,35	0,07
MSG_IMP_1	1,023	1,01	0,04
MSG_GMP_1	1,033	1,17	0,07
MSG_IMP_2	1,098	1,03	0,09
MSG_GMP_2	1,144	1,14	0,04
MSG_IMP_3	1,234	1,31	0,04
MSG_GMP_3	1,333	1,32	0,02
MSG_4	1,344	1,61	0,08
MSG_IMP_4	1,526	1,58	0,04
MSG_GMP_4	1,611	1,59	0,05
MSG_5	2,011	1,97	0,07
MSG_IMP_5	2,087	1,92	0,03
MSG_GMP_5	2,122	1,92	0,03

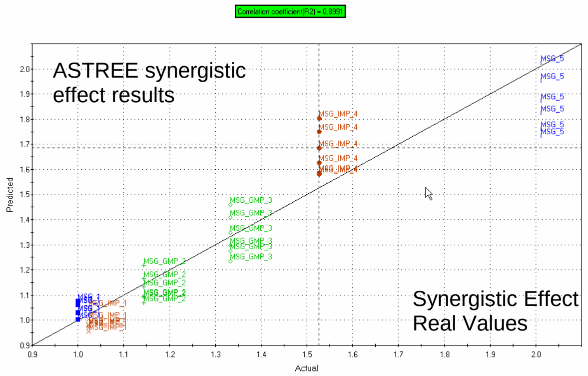
The same way of data processing has been performed for one selected sensor: HA

- A Partial Least Square analysis to correlate ASTREE results to the synergistic effect obtained from literature.

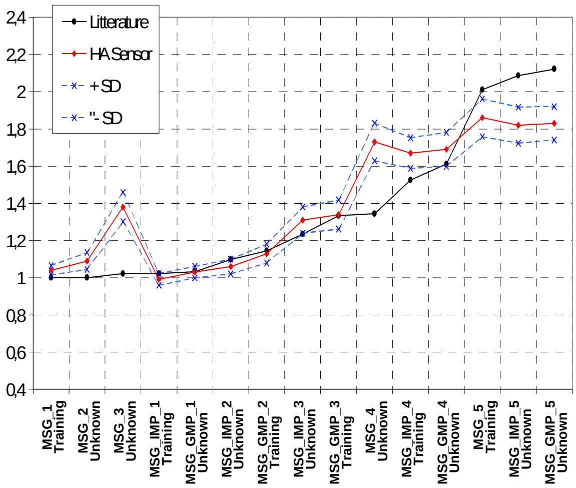
The same samples have been chosen to build the model:

MSG_1 and 5; MSG_GMP_2 and 3; MSG_IMP_1 and 4.

A good correlation is observed (coefficient R^2 = 0.8991).

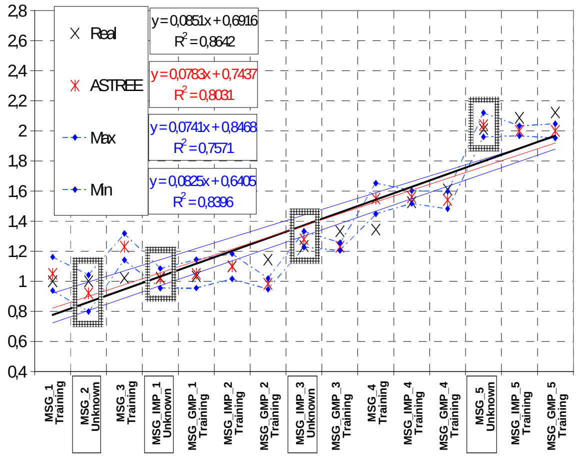


The other samples have been used as unknown and the Partial Least Square model is used to predict their synergistic effect thanks to ASTREE results. Training and unknown results are represented below.



	Real	HA	SD
MSG_1	1	1,04	0,03
MSG_2	1	1,09	0,05
MSG_3	1,022	1,38	0,08
MSG_IMP_1	1,023	0,991	0,03
MSG_GMP_1	1,033	1,03	0,03
MSG_IMP_2	1,098	1,06	0,04
MSG_GMP_2	1,144	1,13	0,05
MSG_IMP_3	1,234	1,31	0,07
MSG_GMP_3	1,333	1,34	0,08
MSG_4	1,344	1,73	0,10
MSG_IMP_4	1,526	1,67	0,08
MSG_GMP_4	1,611	1,69	0,09
MSG_5	2,011	1,86	0,10
MSG_IMP_5	2,087	1,82	0,10
MSG_GMP_5	2,122	1,83	0,09

To optimise the predictive model build with all the sensors, the number of the training samples can be improved. More samples have been chosen to build the model and only 4 samples have been chosen as unknown samples: MSG_2 and 5, MSG_IMP_1 and 3. A traditional linear regression have been performed to fit the Synergistic effect found in literature (real) and the one measured by the ASTREE Electronic Tongue.



Synergistic Effect

The linear regression of ASTREE results is very close to the one of real (literature) values. The real values are always comprised between minimal (Min) and maximal (Max) ASTREE results. Results predicted with ASTREE Electronic Tongue for the unknown samples are very close to real (literature) values.

	Real	Mean	SD
MSG_2	1	1,05	0,045
MSG_IMP_1	1,02	0,96	0,031
MSG_IMP_3	1,23	1,27	0,07
MSG_5	2,01	1,81	0,101

Conclusion

Based on the performed experiments, several items have been characterised:

➢ ASTREE results are correlated with the MSG Umami taste intensity ($R^2 = 0.9238$)

➢ Addition of GMP & IMP nucleotides enhances MSG Umami taste: a synergistic effect can be observed.

➢ ASTREE results and synergistic effect data are very well correlated ($R^2 = 0.9767$).

➢ ASTREE can predict the MSG Umami taste intensity and the synergistic effect of GMP and IMP.

ASTREE system is a reliable & accurate tool to analyse the Umami taste and the synergistic effect.

1. Taste synergism between monosodium glutamate and disodium 5'-guanylate. - Rifkin B,- Physiol Behav. 1980 24(6):1169
2. Large synergism between monosodium glutamate and 5'-nucleotides in canine taste nerve responses. - Kumazawa T – Am
3. J Physiol. 1990 259 (3 Pt 2):R420 Canine taste nerve responses to umami substances.- Kumazawa T. - Physiol Behav. 1991 49(5):875-81

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