New trends of healthy foods and associated challenges: Electronic nose and tongue usefulness

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How to design healthy / functional foods or beverages without taste compromised or increased costs. A challenge for Electronic Nose and Tongue

Improved nutrition has been a key goal of all modern societies to improve the human condition. In 1900, the predominant nutritional problems were low caloric intake and inadequate intakes of certain vitamins and minerals. With prosperity come new challenges. Around half a million European children are suffering from health problems because they are overweight or obese. Over the past three decades, the childhood obesity rate in USA has more than doubled for preschool children aged 2-5 years and adolescents aged 12-19 years, and it has more than tripled for children aged 6-11 years. The demand is for healthier food and beverages but without compromise on taste.

Furthermore, in food and beverage industries and markets, innovation is one of the keys to success. New products currently account for, on average, 33% of company sales.

So let's summarize, the food and beverage makers' challenges:

- Designing or reformulating products into new competitive positions for health, nutrition, and taste;
- Fitting an active lifestyle: quick to prepare but meeting consumer requirements: health, comfort, sensory perception and convenience;
- Taking innovation to market fast;
- Low development cost.

Besides condemned for contributing to the worsening health problems in the population, food makers are under pressure and sometime even orders to design products, which are healthy. For example, they are asked to cut salt levels in their processed food formulations. But replacing this cheap compound is a challenge. Any alternatives will add cost to replace both flavor enhancer and the preservative functions of salt.

The deal is: How to design a product which have nutritional fortification or lower sugar or lower fat or reduced calories without compromising on taste and without increasing costs?

One of the answers is to multiply the possible candidates of new product design and enhance the research of new ingredients in order to replace one by another – with healthier effect but equivalent taste – or to include new ones to add functional property. But functional ingredient – as protein, vitamin, mineral or botanical/herbal – incorporation often disturbs the mix by introducing stray notes and can lead to an unacceptable flavor. Adding a stronger flavor to overpower the bad taste or off-flavor unfortunately is not efficient. The addition of sweeteners, starches or fats can suppress off-notes but is not recommend when you would like to design sugar free, or reduce fat products! To achieve this, product designers have to first identify the ingredient(s) bringing the off-note, why it has this note, how to change or to overcome it. These require examining the process as well as the ingredients and flavors. Formulators must identify how the product is going to be manufactured as some treatments can create many off-notes. They can also maximize ingredient delivery by identifying a source that can deliver the highest level of the active component and can minimize an off-note in the finished product. Finally, many off-notes can be masked using flavors that are compatible or flavor combinations.

To test for sensory attributes, food designers use tools such as sensory evaluation and consumer-acceptance testing. Those tests aren't known for providing rapid results, as they require trained taste panel, strict procedures, specific environment, taking human panelist fatigue into account. Taking into account time and money required for sensory panel test, the number of products food designers wish to test are always limited. Take a simple example: one of the ingredients to add to design a functional product is bitter. Thanks to food designer experience, four sweeteners and five flavors are selected because they are known to be able to mask this bad taste. As the concentrations to use and the combinations of masking agents (sweeteners and/or flavors) are unknown, some sensory tests have to be done. If all the possible combinations of two masking agents want to be systematically screened, 990 products [1] have to be tested! Such a work that you cannot ask to humans.

One possible way to go round these limitations is to use analytical instrumentation. Results from instrumental tests are faster and more cost-effective compared with sensory paneling as they can be used night and day. For those reasons, they are more practical as systematic R&D screening and quality control tools. Those electronic sensing technologies, so called Electronic Nose and Tongue, based on sensor arrays, perform fingerprint analysis of complex chemistry products, correlated with its odor or taste profile.

Taking always the same example of this bitter ingredient to mask, 990 samples will be analyzed in approximately 10 days by the Electronic Nose and Tongue – analysis time without sample preparation, which is minimal, and data processing.

Figure 1 – Top: FOX Electronic Nose; Bottom: ASTREE Electronic Tongue.
Alpha MOS (Toulouse, France and Baltimore, USA)

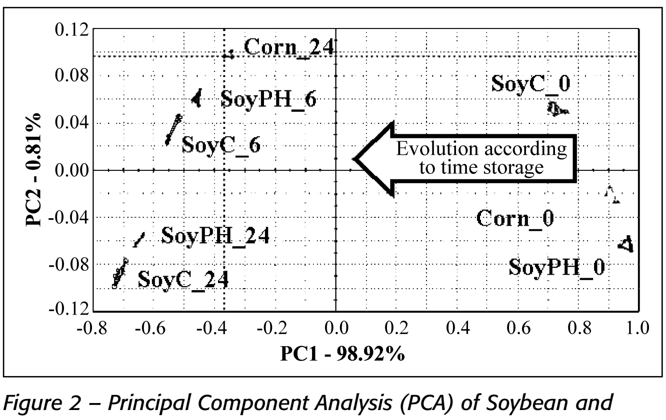

Figure 2 – Principal Component Analysis (PCA) of Soybean and corn oil samples. The PCA allows the representation of relative positions of samples in a mathematical space with 2 dimensions – while the real space is multidimensional (18 dimensions as there are 18 sensors). The axes of the map do not correspond to a sensor answer but to an optimal gathering of many variables called principal component

ELECTRONIC NOSE AND TONGUE TECHNOLOGIES

Electronic Nose and Tongue instruments mimic the whole principle of human nose and tongue. We process odor or taste at three levels: the detection, the transmission, and the integration level.

- **Detection level** – Chemoreceptors for gustation (taste) and olfaction (smell) respond to chemicals in an aqueous environment. Chemicals dissolved in saliva excite the taste receptors of the mouth, and airborne chemicals dissolved in epithelial mucus excite the olfactory receptors of the nose. The receptors are able to transform this chemical signal into a change of the cell state involving an electrical signal.
- **Transmission level** – When this electrical signal reaches a threshold, it generates another electrical signal, which will be propagated through nerves to specific areas of the brain.
- **Integration level** – Sensory information is coded in patterns of neural firing via nerve fibers. The brain combines sensory information and other information as memory of experiences to be able to recognize or differentiate a taste or an odor.

The E-Nose and Tongue (Figure 1) mirrors those three levels:

- **Detection level** – Instruments are equipped with sensors, which are like human receptors, are partial and cross-selective and can react to many substances responsible for various odors or tastes.
- **Transmission level** – Transducers are incorporated in the E-Nose and Tongue to transform a chemical interaction (between compounds in the tested sample and sensitive material of the sensors) into an electrical signal.
- **Integration level** – Instruments include software for data processing and mathematical analysis. For each analyzed sample, one measure by sensor is obtained, i.e. 7 for the Electronic Tongue and from 6 to 18 for the Electronic Nose. This data set allows the generation of a fingerprint for each sample. Thanks to multivariate data treatments, a classification of samples according to qualitative or quantitative criteria can be performed. The aim is to provide from numerous and complex data, simple visual representations and interpretations.

UNSATURATED FATS: A SHELF LIFE STUDY

Many food companies are switching to heart-healthy oils, such as soybean or corn oils – rich in polyunsaturated fat. One of the main challenge if that those vegetable oils could have a shorter shelf life than other saturated oils. Crude oil (non-processed oil) is oxidatively unstable. To improve its shelf life, a hydrogenation step is performed during the oil process. But the practice creates trans fatty acids, which,consumers need to avoid. Researches have been performed to develop new soybean oil

1. n = total number of products = 45; k = number of products in the combinations = 2; number of combinations = n! / [k!(n-k!)]

variety that reduces the need of hydrogenation.

The shelf life of a kind of this new variety of soybean oil has been studied thanks to the Fox Electronic Nose. Fresh samples of partially hydrogenated soybean oil (SoyPH_0), crude soybean oil (SoyC_0), and corn oil (Corn_0) have been analyzed and compared to the same products after 6 hours (SoyPH_6, SoyC_6) and 24 hours of storage at high temperature (SoyPH_24, SoyC_24 and Corn_24).

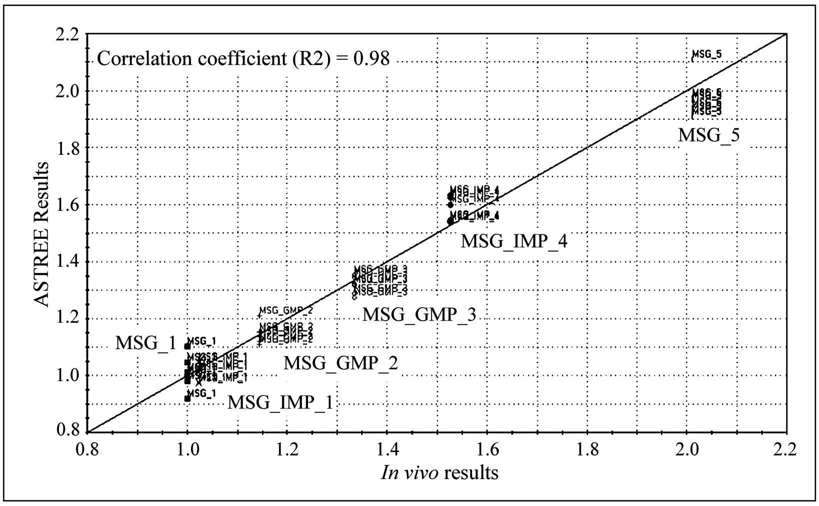

Figure 3 – A Partial Least Square (PLS) analysis of the synergistic effect measured either by ASTREE or in vivo

The results of this study are shown in Figure 2. The Principal Component 1 (PC1), on X-axis, represents 98.92% of the global information given by the instrument analysis. Looking only on this axis, it can be easily observed that:

- the corn and soybean oil samples (fresh or stored) are differentiated by the instrument.
- the soybean oil samples appear to be less stable than the corn ones as the profile of the corn oil sample after 24 hours of storage (Corn_24) is very close to the profile of the soybean oil samples after only 6 hours of storage (SoyPH_6 or SoyC_6).
- the soybean samples, crude or partially hydrogenated samples (fresh or stored), have well distinct profiles.
- the crude or partially hydrogenated soybean samples appears to have similar evolution of stability.

Thanks to this short study, the stability of two types of oil samples (corn and soybean) and the stability of a new variety of soybean oil has been analyzed. The new variety of soybean oil has a similar stability profile with or without hydrogenation. The Electronic Nose makes available fast and reliable stability evaluations of food and beverages products, and so a rapid method to screen stability of new products before going into long and complex other techniques.

TASTE ENHANCER: SYNERGISTIC EFFECTS OF SOME NUCLEOTIDES ON THE UMAMI TASTE

Umami – Japanese translation of deliciousness – taste, has been widely accepted as a unique taste quality, which differs from other basic tastes (Salt, Sweet, Acid and Bitter). This taste is due to the presence of the Monosodium Glutamate (MSG), which is part of various foods (fish, meats, mushrooms...). MSG is also widely used as taste enhancer 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 tabletop seasoning. Umami taste can be also provided by the nucleotides IMP (disodium 5′-inosine monophosphate) and GMP (disodium 5′-guanosine monophosphate). There is a synergistic effect between MSG, IMP and GMP. It means that adding a little amount of nucleotides will strengthen the taste and the flavor of food preparation. This would allow a cost reduction of the mixture, as the addition of small quantity of nucleotides will considerably reduce the MSG amount needed for the same taste.

The ASTREE Electronic Tongue has been used to study the synergistic effect of a little amount of GMP or IMP on the Umami taste provided by MSG at five different concentrations. A Partial Least Square (PLS) model is used to build a linear regression (i.e. a correlation) between ASTREE instrumental data set and synergistic taste effects provided by the literature (1-3). Some samples have been chosen to build the model – training samples: MSG_1 and 5; MSG_GMP_2 and 3; MSG_IMP_1 and 4. The PLS regression is represented in Figure 3 and it can be noticed that a very good correlation is observed (coefficient $R^2 = 0.9767$). The others are used as unknown samples, i.e. their synergistic effects are predicted thanks to the Electronic Tongue and results can be compared to the synergistic taste effects found in the literature (Table I). Results predicted with ASTREE Electronic Tongue for the unknown samples are very close to *in vivo* values.

In this study, the synergistic effect of GMP and IMP nucleotides on the MSG Umami taste has been studied. The Electronic Tongue, after training, is able to predict the taste enhancement of a substance on the umami taste. A food designer would then used this umami taste model to know if a new substance would have a synergistic effect, which GMP or IMP concentration have to be used to reduce a specific amount of MSG.

Table I – Synergistic effect of IMP and GMP nucleotides on the umami taste provided by MSG

Samples (concentration mol/L) Not bold = Training samples **Bold = Prediction of Unknown**	*In vivo* results	ASTREE results	ASTREE Standard Deviation
MSG_1 (0.001)	1.000	1.01	+/- 0.13
MSG_2 (0.01)	**1.000**	**1.12**	**+/- 0.08**
MSG_3 (0.1)	**1.022**	**1.35**	**+/- 0.07**
MSG (0.001)_IMP_1 (0.0005)	1.023	1.01	+/- 0.04
MSG (0.001)_GMP_1 (0.0005)	**1.033**	**1.17**	**+/- 0.07**
MSG (0.01)_IMP_2 (0.0005)	**1.098**	**1.03**	**+/- 0.09**
MSG (0.01)_GMP_2 (0.0005)	1.144	1.14	+/- 0.04
MSG (0.1)_IMP_3 (0.0005)	**1.234**	**1.31**	**+/- 0.04**
MSG (0.1)_GMP_3 (0.0005)	1.333	1.32	+/- 0.02
MSG_4 (0.5)	**1.344**	**1.61**	**+/- 0.08**
MSG (0.5)_IMP_4 (0.0005)	1.526	1.58	+/- 0.04
MSG (0.5)_GMP_4 (0.0005)	**1.611**	**1.59**	**+/- 0.05**
MSG_5 (1)	2.011	1.97	+/- 0.07
MSG (0.5)_IMP_5 (0.0005)	**2.087**	**1.92**	**+/- 0.03**
MSG (0.5)_GMP_5 (0.0005)	**2.122**	**1.92**	**+/- 0.03**

NON CALORIC SWEETENER: A SWEETNESS INTENSITY STUDY

Non-nutritive sweeteners also called artificial or non-caloric sweeteners, are intensely sweet synthetic substances, often used in place of other sugars in food manufacturing and cooking because they are calorie-free. Aspartame, produced from two amino acids – aspartic acid and phenylalanine – is 200 times sweeter than sucrose.

The ASTREE Electronic Tongue has been used to study the sweetness intensity of various sweeteners. A Partial Least Square (PLS) model is built between ASTREE instrumental data set and sweetness intensity

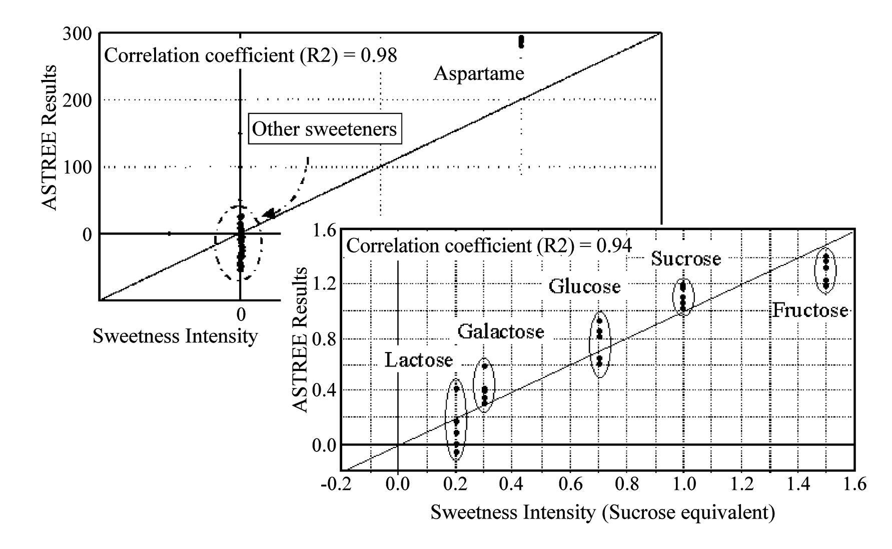

Figure 4 – Two Partial Least Square (PLS) analyses of the sweetness intensity (sucrose sweetness intensity = 1) measured either by ASTREE or in vivo

(found in the literature).

As the aspartame and the other sweeteners have not a similar range of sweetness intensity (200 compared to around one), two various models have been built: one with all the sweeteners and another one without the aspartame.

The PLS regressions (i.e. a correlation) are represented in Figure 4 and it can be noticed that very good linearity are observed (coefficient $R^2 = 0.98$ or 0.94). Results obtained with ASTREE Electronic Tongue are very close to *in vivo* values (Table II).

The sweetness intensities of various sweeteners have been studied with the Electronic Tongue. A food designer would then use this sweetness taste model:

– to know which is the sweetness power of a new non-carbohydrate sweetener;
– to identify which sweetener (and its concentration) has to be used for replacement of another one (costs reduction) while conserving the same sweet taste in a food and beverage product.

NUTRITIVE DRINKS: COMPLEX TASTE PROFILES

Many bottled nutritive drinks are available in the market for indications such as chronic fatigue, or for supplementation of nutrients. These drinks contain many different combinations of ingredients, including vitamins, minerals, amino acids, and active components of medicinal plants, and consequently differ considerably in taste. The taste and odor of bottled nutritive drinks greatly influence their sales. An evaluation of the palatability of 15 bottled nutritive drinks, all commercially available in the Japanese market, has been performed (4). Well-trained healthy volunteers were asked to score the drinks for nine various descriptors and for the four basic tastes. The results suggest that overall palatability is particularly positively correlated with sourness and fruitiness intensity and negatively correlated with bitterness intensity and the tasting of medicinal plants. Those nutritive drinks (S1 to S15) have been analyzed by Electronic Nose & Tongue and the four characteristics (sourness, bitterness, fruitiness, and tasting of medicinal plant intensity) have been studied.

One of the representations of the Electronic Tongue results is shown in Figure 5. The Principal Component 1 (PC1), on X-axis, represents 94% of the global information given by the instrument analysis. Looking only on this axis, it can be easily observed that:

– Very sour drinks are located on the left side, and not sour ones on the right side of the PCA map.
– Reciprocally, very bitter drinks are located on the right side, and not bitter ones on the left side of the PCA map.

A bitter / sour axis can then be defined on the map: left to right more and more bitter, less and less sour.

Moreover, beverages with a high medicinal taste are located on the bottom right side and those with fruity taste on the right side of the PCA map (with an increasing gradient from top to bottom).

Even if fruitiness and tasting of a medicinal plant are more detected by olfaction thanks to retro-olfaction way in human, they are detected by the Electronic Tongue (Electronic Nose results, presented in the reference publication, show better differentiation of samples according to those descriptors).

Thanks to this Electronic Tongue model, food designer would then be able to develop new nutritive drinks, to project them in this model and determine their main taste characteristics. They can try every new ingredient or combinations to design a product with exactly the desired taste profiles.

ELECTRONIC NOSES AND TONGUES: EFFICIENT AND COMPLEMENTARY TOOLS TO SENSORY PANELS

Electronic Noses and Tongues, which require minimal sample preparation, can objectively, safely and quickly characterize the global taste and odor profiles of ingredients or formulations.

Table II – Sweetness intensity found in literature of various sweeteners

Samples	Sweetness intensity (C = 0.01 mol/L)	ASTREE results
Aspartame	200	288 [1]
Sucrose	1	1.1
Fructose	1.5	1.3
Glucose	0.7	0.8
Galactose	0.3	0.4
Lactose	0.2	0.1

1. The aspartame sweetness intensity has been obtained by a first PLS, and the sweetness intensity of the other sweeteners by another one

Using various examples in this article, the broad usefulness of these analytical instruments has been highlighted:

– Electronic Nose makes available rapid and reliable stability evaluations of raw materials, ingredients, additives, and finished products to allow a faster prescreening during formulation development. This tool is also used in routine quality and process control as it permits to obtain in few minutes simple answers to the question: is the product or the process quality conform?
– Thanks to the Electronic Tongue taste model, food product designers are able to know taste characteristics or ingredients or whole product while avoiding long and sometime costly panels. They will study the taste profile of complex mixture, compare taste of new candidate product with already marketed ones and this according to specific descriptor, predict taste enhancement of a

specific agent, or taste intensity of a new ingredient.

More widely, the Electronic Nose and Tongue can be used for:

- Development of new formulations;
- Optimization of product quality and consumers' acceptance;
- Benchmarking and comparison of products;
- Raw materials / finished products analyses – consistency of quality / origin, shelf life and storing effect, contamination detection;
- Process monitoring – mixing, drying, distillation, fermentation, cleaning in place, process efficiency;
- Packaging selection and interaction studies;
- Fraud and counterfeiting detection.

Useful as R&D and QC tool, E-Nose and Tongue can be efficient instrument to speed up and optimize the food designer and manufacturer efforts and works.

REFERENCES

1) Rifkin B. "Taste synergism between monosodium glutamate and disodium 5'-guanylate" *Physiol. Behav.* **1980**, *24* (6), 1169
2) Kumazawa T. "Large synergism between monosodium glutamate and 5'-nucleotides in canine taste nerve responses" *Am. J. Physiol.* **1990**, *259* (3 Pt 2), R420
3) Kumazawa T. "Canine taste nerve responses to umami substances" *Physiol. Behav.* **1991**, *49* (5), 875-81
4) Uchida T. "Evaluation of the taste and smell of bottled nutritive drinks" *Int. J. Pharm.* **2005** *305*, 13-21

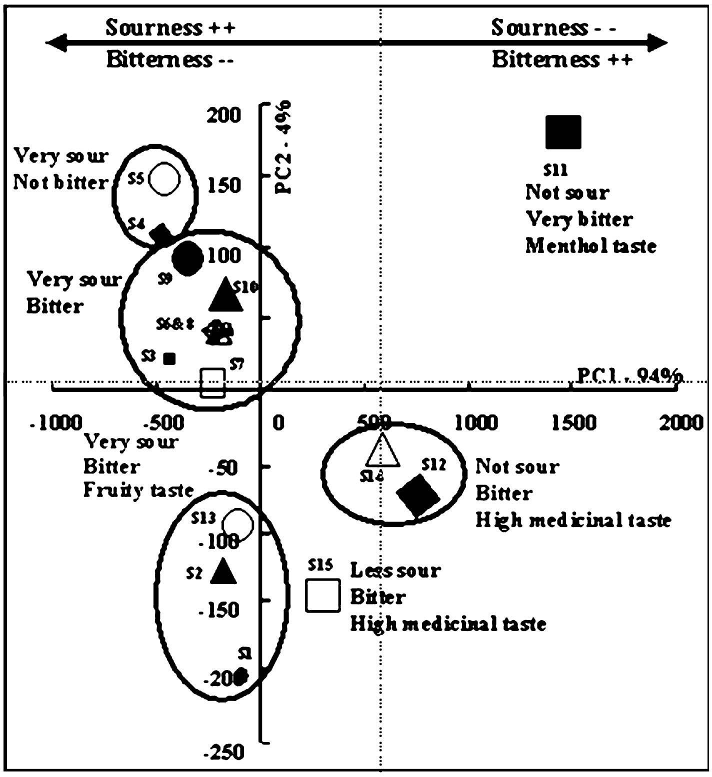

Figure 5 – Principal Component Analysis (PCA) of 15 bottled nutritive drinks obtained with ASTREE Electronic Tongue analysis. The PCA allows the representation of relative positions of samples in a mathematical space with 2 dimensions – while the real space is multidimensional (7 dimensions as there are 7 sensors). The axes of the map do not correspond to a sensor answer but to an optimal gathering of many variables called principal component

NutraCos news

FUNCTIONAL FOODS A HIGHLIGHT FOR ALLTECH'S SYMPOSIUM

Health conscious consumers are continuously demanding more nutritious and natural products. As a result there is a growing demand for more functional and designer foods in the marketplace and they are set to grow at a rate of 20% in 2006. Minerals such as selenium will play a functional role as an antioxidant, particularly in the areas of immunity, fertility and muscle function. These areas of concern and more are being addressed at the food session of **Alltech's 22nd International Feed Industry Symposium** on April 23-26, 2006. The event brings industry leaders from around the world to Lexington, Kentucky, USA, to discuss these latest advances and their impact on animal and human health.

SOFT GEL TECHNOLOGIES SUPPORTS LONZA'S L-CARNIPURE® L-CARNITINE SEMINAR

Lonza hosted William J. Kraemer, PhD, as a speaker at the **Natural Products Expo West** trade show in Anaheim, California, on March 25, 2006. Dr. Kraemer, a professor in the Department of Kinesiology at the University of Connecticut, presented attendees with information about the various benefits of Lonza's *L-Carnipure®* L-Tartrate in a seminar entitled, "*L-Carnipure® L-Carnitine – Its Role in Exercise and Recovery*." In cooperation with Lonza, **Soft Gel Technologies, Inc**. provided free literature and samples of *Carnisol®*, the exclusive soft gel encapsulation of *L-Carnipure®* L-Tartrate, to seminar participants.

FENCHEM TO EXPAND MANUFACTORY FOR IP PRODUCTS

Fenchem is a new-tech based manufacture of nutrition ingredients in China, who specialize in isolation and purification. We are the first company who offered IP concept and got the IP certification for Soya derived natural vitamin E, phytosterol and isoflavone. By the end of last year, Fenchem took the first place of exporting phytosterol in China. In the meanwhile, with its expert R&D team and in-house lab Fenchem successfully standardized sodium hyaluronate, natural Lycopene and Ginkgo Biloba P.E.

In year 2006, Fenchem is going to build its second 28,000 m² plant base in Nanjing with US GMP condition. The initial investment will be around $ 3 million. The facility is estimated to be finished by 2007. The new production line will focus on fermentation and isolation with some patent issues under arrangement. With the new facility building, Fenchem will be in a fasting growing way to Top 3 nutrition companies in China.

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INSTITUT ROSELL LAUNCHES NEW WEBSITE

Institut Rosell is launching its new website, on www.institut-rosell.com. Reflecting the updated corporate image of the company, it is a simply designed, easy-to-navigate platform of information about probiotics and Institut Rosell's expertise and capabilities in the field. The website showcases exclusive probiotic strains and some of Institut Rosell's products and their fields of application: intestinal discomfort, diarrhoeas (antibiotic-associated, *C. difficile* infection, traveler's diarrhoea), irritable bowel syndrome (IBS), stress-induced gastro-intestinal symptoms, gastric discomfort, and unbalanced vaginal flora. For more information about Institut Rosell's products and technologies, the visitors are welcome to contact us directly: human@institut-rosell.com.