Application of Taste Sensing System to Beef

Hiroyasu NAKAI, Hidekazu IKEZAKI*, Katsushi SATO*, Keisuke SASAKI and Mitsuru MITSUMOTO

National Institute of Animal Industry, Tsukuba, Ibaraki, 305-0901, Japan
*Anritsu Co. Research Laboratory, Onna, Atsugi-shi, Kanagawa, 243, Japan

1. Background:

Evaluation of food taste in food manufacturing still largely depends on sensory tests carried out by a panel who actually taste the food. The same thing can be said in the meat manufacturing. Although the tenderness used to be thought the most important element for evaluation, quality of the taste itself became more important as the demand on lean meat increasing recently. However, the data obtained present problems in terms of objectivity and repeatability due to the individual taste differences and health conditions of the panel, while the tests tax the panels to the point of fatigue. Against this background, development of a taste sensing system capable of detecting human taste senses which is aimed at supporting the panel in new product development and/or food manufacturing lines has been awaited.

2. Objectives:

Currently, electrical conduction meters are generally used for detecting salty tastes, pH meters for sour taste, and refractometers for sweet tastes. But it cannot be said that these meters actually measure taste. For instance, magnesium chloride which produces a bitter taste contributes much to electrical conduction, and sodium chloride which produces a salty taste to the refractive index. Therefore, it is impossible to discuss human taste senses as a whole.

Meanwhile the taste cell membranes in living organisms which have in the taste receptors called taste buds on the surface of the tongue receive the taste substances. However, where taste substances are detected using a mechanism different from human taste receptors, chemical analysis cannot reproduce the phenomena of sense of taste such as the interaction between taste substances. For example, when a spoonful of sugar is added to a cup of coffee, the bitterness of the coffee is reduced, despite the fact that the amount of bitter substances does not change (control effect). And when the stock of both bonito and sea tangle soup are used together, the taste is increased remarkably, compared with when the stock is used independently (synergistic effect).

Therefore, we studied an artificial taste sensor which utilizes lipids, the principal components of taste receptors of living organisms. This is the first application of such taste sensors (made by Anritsu Co.) to beef samples.

3. Methods:

3.1. Taste Sensing Mechanism of Living Organisms:

When a taste substance touches the human tongue, it is adsorbed by the microvillus of the taste cell. This adsorption produces an electric potential charge in the taste cell membrane. Although there is no established theory on the interaction mechanism between the taste substance and the cell membrane, one model is proposed as follows.

The surface of the taste cell is covered by the bilayer lipid membrane, and salty and sour substances are adsorbed by the hydrophilic radical (the part having the electric charge) of the lipid membrane surface, changing the amount of the electric charge, while bitter substances enter more deeply into the hydrophobic radical (the part without the electric charge), changing the characteristics of the lipid membrane. Furthermore, amino acids in "umami" taste and sugar in sweet substances are adsorbed by their own receptor protein floating on the lipid membrane. In this way, when taste substances are adsorbed by the lipid membrane on the taste cell surface, the electric characteristics of the membrane (electric potential and impedance of the membrane) change and different output signals (electric impulses) are obtained from the taste cells having different characteristics (see Fig. 1a). It is thought that the neural network of the brain calculates them (pattern recognition) and discriminates the various tastes.

3.2. Imitating the Taste Sensing Mechanism:

Development of a taste sensing system which imitates the taste sensing mechanism of living organisms had been attempted. Lipid membranes imitating living organisms were artificially composed, and taste sensing by recognizing the signal patterns from lipid membranes having different characteristics was tried. An outline of this is shown in Figure 1b.

Taste sensors were made by fixing the lipids which play an important role in taste detection, using a polymer and data were obtained on the electric potential changes of the lipid membranes when the taste substances were adsorbed. At that time, instead of taste cells with different characteristics, lipids having different response characteristics were selected as membrane materials, to make taste sensors with different properties. Taste discrimination was carried out by recognizing the signals obtained from these taste sensors in the form of patterns (pattern recognition).

3.3. Output Patterns for Five Basic Tastes:

Five tastes were received by the taste cells: sour, salty, bitter, sweet and umami taste. Typical examples of these taste substances are: hydrogen ions for sourness, metal ions such as sodium chloride for saltness, alkaloid like caffeine for bitterness, and saccharose for sweetness. The umami tastes, discovered by the Japanese, are specific to monosodium glutamate (MSG) and sodium inosinate which are received by the taste cells to produce the tastes. So the taste sensors are required to indicate different output patterns for these different tastes. Figure 2 shows eight response patterns of the taste sensors corresponding to five basic tastes.

The lipid membranes used in the taste sensors are divided into positive and negative charged membranes according to the electric charges which the hydrophilic radical of the lipid possesses. Since salty and bitter tastes are adsorbed by the hydrophilic radical, the responses are roughly classified into negative and positive charged membranes. In the case of NaCl for saltness, the negative charged membrane responds positively and the positive charged membrane responds negatively to almost the same extent (shaded part of the saltness in the figure). Meanwhile, in the case of hydrochloric acid (HCl) for sourness, the positive charged membrane responds less, although the negative charged membrane responds more intensively. Saccharose for sweetness, quinine for bitterness and MSG for deliciousness are adsorbed by the hydrophobic radical of the lipid and exhibit their own unique output patterns.

Furthermore, several other substances which present tastes similar to the five basic tastes were selected and their response patterns were examined. When a substance has the similar taste, it exhibits a similar pattern. For example, hydrochloric acid, acetic acid and citric acid which produce a sour taste, all have similar patterns. Likewise, MSG, sodium inosinate and sodium guanylate which produce a umami taste, all exhibit similar patterns, too. This indicates that the lipid membrane action is common in different substances, if they produce a similar taste.

3.4. Sensing Mechanism of the Taste Sensor:

Figure 2 shows the specific mechanism of the electric potential changes of a negative charged membrane for a sour substance, HCl. As can be seen from the figure, when hydrogen ions are adsorbed by the hydrophilic radical of the membrane, the density of the electric charge on the surface of the membrane changes, resulting in changes in the electric potentials of the membrane and water solution surfaces. Thus, these changes are measured as electric potential responses. In the salty substance, NaCl, a double layer electric potential change is the main effect (screening effect). The sensing mechanism of bitter and sweet substances have yet to be clarified. The bitter substance, quinine, is thought to enter the hydrophobic chain of the membrane, changing its surface electric charge density. In the "umami" substance, MSG, it is assumed that the adsorption effect of the glutamic acid itself and the screening effect of the sodium ions appear simultaneously. The sweet substances are thought not to have electric charges themselves, rather the electric potential of the membrane changes by changing the density of the electric charge of the surface of the membrane or affecting other coexisting ions.

3.5. Samples and Method of Analysis:

Three kinds of beef (Wagyu, domestic Holstein and imported beef) samples from sirloin were used. Each fat free sample was cut into dice cubes and extracted "umami" components by boiled water for several minutes. Five kinds of sensors related to beef taste were selected for the evaluation. This trial was repeated three times. The sensor output values was utilized by applying principal component analysis.

4. Results and Discussions:

Figure 3 shows the results of principal component analysis applied to the sensor output of beef extracts. X and Y dimensions signify principal component 1 (PC1) and principal component 2 (PC2), respectively. The proportions of PC1 and PC2 show 93.0% and 4.9%, respectively.

Each trial shows same tendency and there are significant differences between Wagyu beef and Holstein or imported beef against horizontal axis (X dimension of PC1), and there are no differences in between Holstein beef and imported beef. However, the differences between Holstein beef and imported beef was shown in Y dimension of PC2.

We have shown that Wagyu beef can be distinguished from Holstein and imported beef, although the reasons are not yet clean. This approach against the evaluation of beef taste has just started, although applications of this sensors to beverage such as coffee, beer, tea, sake and mineral water were already carried out in success.

5. Conclusion:

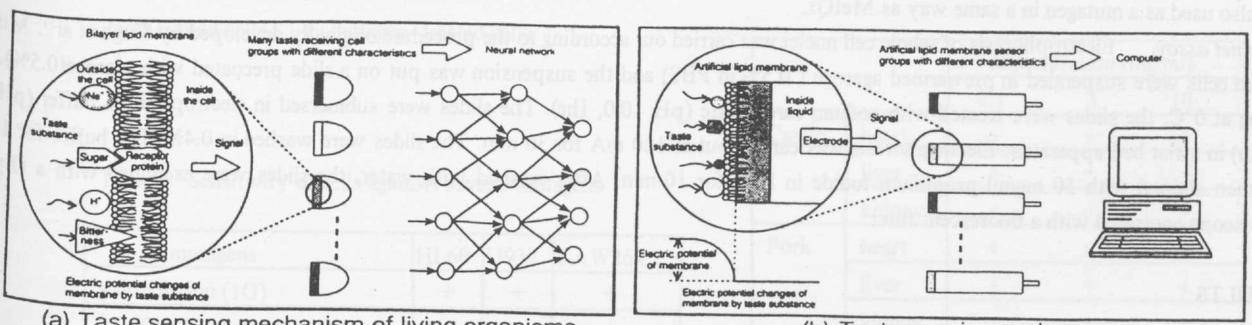
We applied the first to develop a system utilizing taste sensors (made by Anritsu Co.) to beef samples, and explicated that the taste of Wagyu beef is distinguished from Holstein and imported beef with the use of this system.

6. References:

Iiyama, S., Toko, K. and Yamafuji, K. 1987. Taste reception in a synthetic lipid membrane. Maku (Membrane) 12: 231-237.

Toko, K., Hayashi, K. and Yamafuji, K. 1990. Development of a taste sensor. Anritsu Technical Bulletin. No 60: 19-30.

Ikezaki, H. 1996. SA401 Taste sensing system. Anritsu Technical Bulletin. No 71: 114-123.



(a) Taste sensing mechanism of living organisms

(b) Taste sensing system

Fig. 1. Taste sensing mechanism

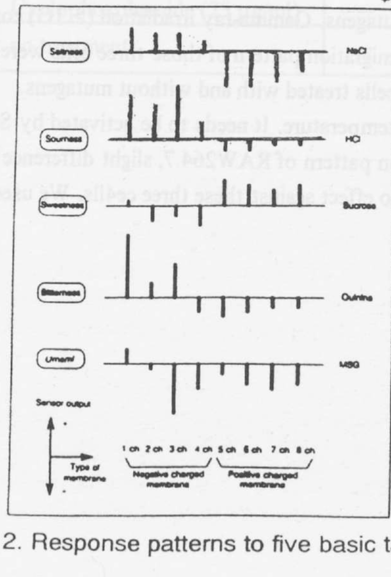
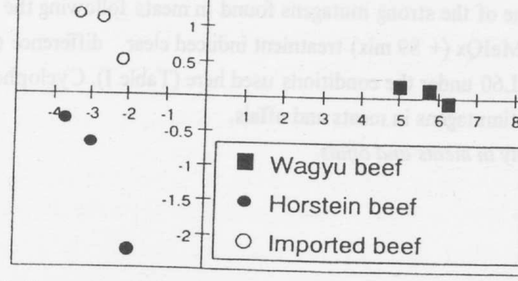


Fig. 2. Response patterns to five basic tastes



X dimension ; PC1 (93.0%). Y dimension ; PC2 (4.9%).

Fig. 3. Principal component analysis applied to the sensor output of beef extracts.