4.0 GUSTATORY SENSATION TEST: HUMAN PANEL

Gustatory sensation test usually were carried by well-trained volunteers to evaluate basic tastes. In the gustatory sensation tests, intensity scores ranging from 1 to 5 (1, extremely; 2, slightly; 3, neither; 4, slightly; 5, extremely) were usually applied for overall palatability, for nine components of palatability (astringency, good aftertaste, tasting of medicinal plant, fruitiness, refreshing, seeming beneficial, irritating to the throat, pungency, and the desire to drink/eat again), and for the four basic tastes (sweetness, saltiness, sourness and bitterness). Correlation is made between taste intensity values obtained in human gustatory sensation test and predicted intensity scores basic taste that obtained from taste and smell sensor . Precise potential evaluation of palatability can be performed by combination of taste and smell sensor systems.

4.1 SENSE OF SMELL: OLFACTION

- Stimulus modality: odorants
- Olfactory receptor cells > 1,000 types
  - Each cell contain one receptor protein
  - 1000 odorant receptor genes
- Human can discriminate ~10,000 odorants)
- Olfactory receptor neurons
  - Lie in the olfactory epithelium
  - Live for two months
  - New cells produced from stem cells
  - Cilia contain the receptor proteins

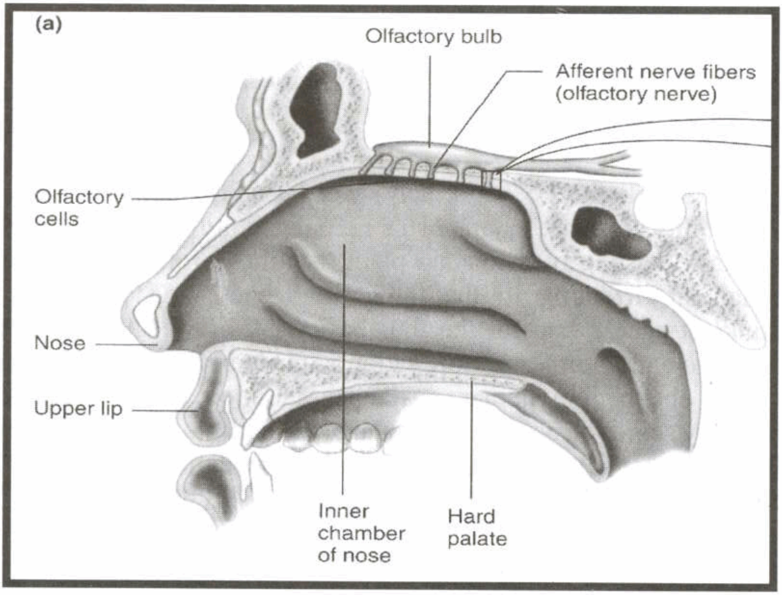


Figure 4(a): Location of Olfactory Epithelium

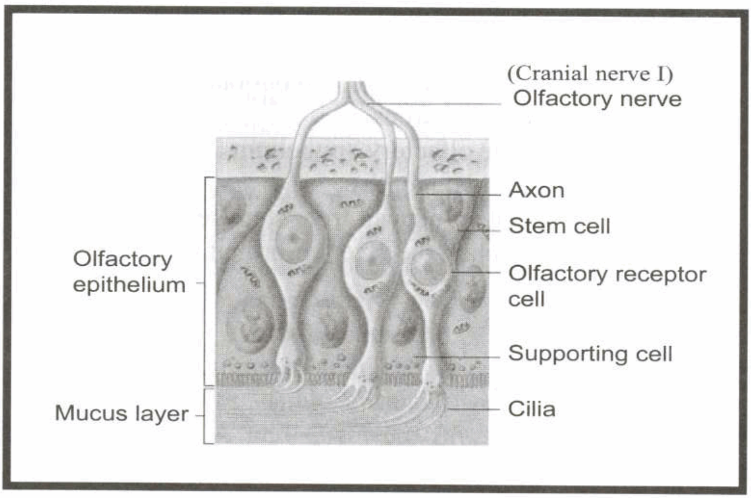


Figure 4(b): Details of Olfactory Epithelium

4.2 SENSE OF TASTE: GUSTATION

- Stimulus modality
  - Sour, sweet, bitter, salty, pungency, umami (glutamate in food)
- Taste buds
  - 10,000 taste buds
  - Receptor cells arranged like the segments of orange

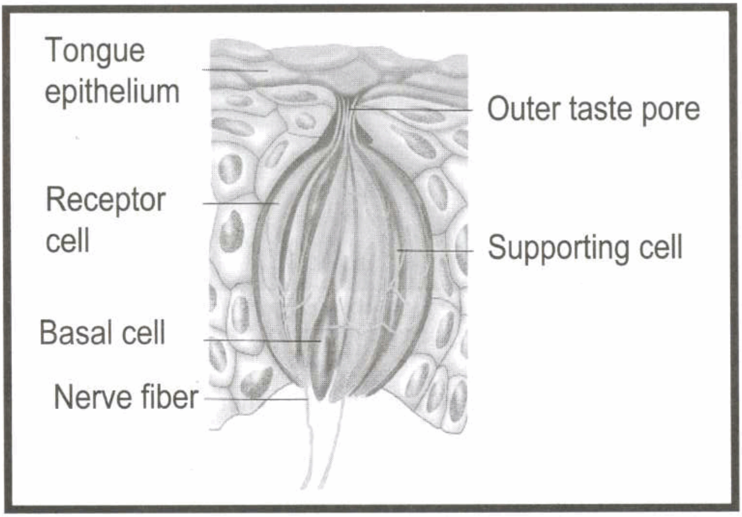


Figure 4(c): Taste Bud

5.0 QUARTZ CRYSTAL MICROBALANCE (QCM) VOLATILE SENSORS

The QCM odor sensor comprises of a slice of a single quartz crystal, typically around 1 cm in diameter, with thin-film gold electrodes which are evaporated onto both surfaces of sliced crystal. The quartz crystal oscillates in such a manner that practical displacements on the QCM sensor surface are normal to the direction of wave propagation. For typical AT-cut quartz crystal operating at 10 MHz, a mass change of the order of 1 nano gram produces a frequency change of about 1 Hz. Thus small changes in mass can be measured using QCM coated with molecular recognition membrane on which odorant molecules are absorbed.

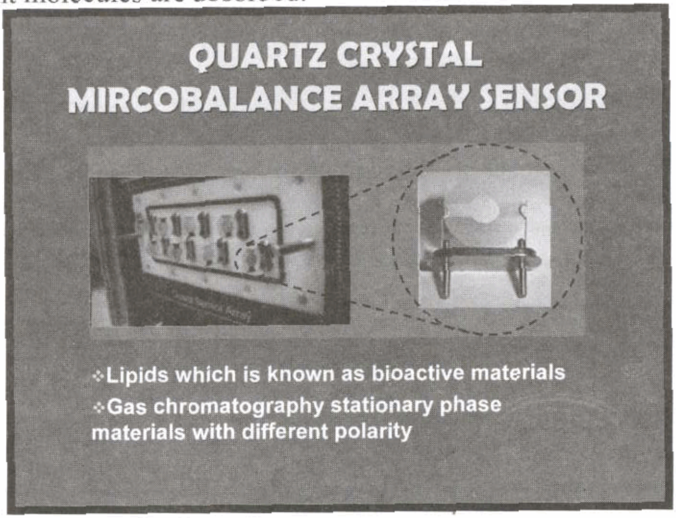


Figure 5(a): QCM array Sensor

Quartz crystal has an interesting property whereby when mechanical stress is applied on the surface of quartz crystal, the corresponding electrical potential across the crystal surface changes and is proportional to the applied stress. This is called the piezoelectric effect. There is a converse piezoelectric effect. If voltage is applied on the quartz crystal, there will be a mechanical stress on the surface. This converse piezoelectric effect is the basis of quartz crystal microbalance.

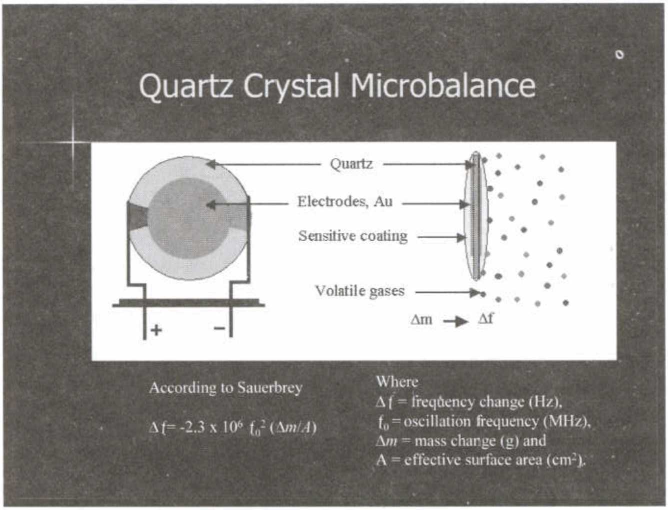


Figure 5(b): Sensing mechanism of QCM

6.0 FIGARO SEMICONDUCTOR GAS SENSORS

6.1 CONDUCTIVE POLYMER

Conducting polymers, such as polypyrrole (PPy), polyaniline (Pani), polythiophene (PTh) and their derivatives, have been used as the active layers of gas sensors since early 1980s. In comparison with most of the commercially available sensors, based usually on metal oxides and operated at high temperatures, the sensors made of conducting polymers have many improved characteristics. They have high sensitivities and short response time; especially, these feathers are ensured at room temperature. Conducting polymers are easy to be synthesized through chemical or electrochemical processes, and their molecular chain structure can be modified conveniently by copolymerization or structural derivations. Furthermore, conducting polymers have good mechanical properties, which allow a facile fabrication of sensors.

6.2 SEMICONDUCTOR GAS SENSOR

Semiconductor gas sensors are used to indicate concentration of gases such as CO and H_2S. The device responses to the change in the composition of the surrounding atmosphere with a change in conductance of a gas sensitive semiconductor. Oxide semiconductors with wide band gaps ($Sn0_2$, ZnO, WO_3, In_2O_3) are typical sensing semiconductors, since the sensors operated at elevated temperatures up to 500° C.

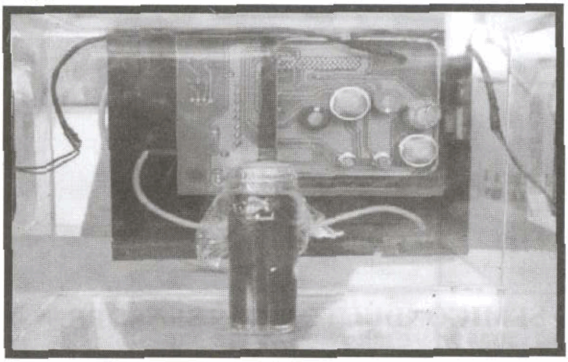


Figure 6(a): Figaro array sensor ENose for herbal quality control

6.3 CONDUCTING POLYMER ARRAY GAS SENSORS

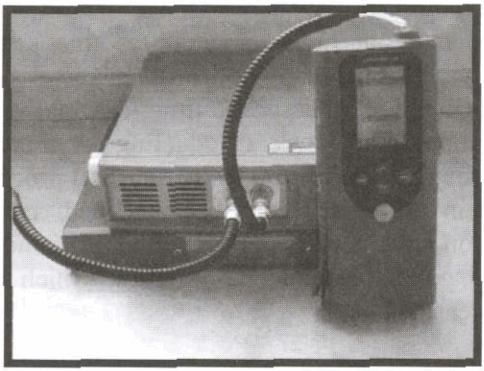


Figure 6(b): ENose with preconcentrator

6.4 ELECTRONIC TONGUE

Figure 6(c): Electronic tongue

The basic principle of electronic tongue is to combine unspecific and overlapping sensor signals with pattern recognition routines. The electronic tongue is made of eight different lipid membranes and an AgIAgC1 reference electrode

- **FUNCTION:** Multisensor systems for liquid analysis based on chemical sensor arrays and pattern recognition
- **APPLICATION:** Herbals analysis
- **PRINCIPLE:** Potentiometric measurement

7.0 THE DISPOSABLE SCREEN-PRINTED ARRAY SENSOR STRIP AND ITS PRINCIPLE

The disposable screen-printed array sensor strip with lipid membranes, immobilized in polymer blend of methacrylate acrylate and PVC, consists of five different types of lipid analogs namely decyl alcohol (DEA), oléic acid (OA), dioctyl phosphate (bis-2-ethylhexyl)hydrogen phosphate (DOP), trioctylmethyl ammonium chloride (TOMA), oleyl amine (OAm) and together with the mixtures of these. The mixtures between the mentioned lipids in different ratio produces altogether eight different membranes which are dispensed onto a screen-printed polyester substrate where the working electrodes and the reference electrode are being integrated together in the same strip using screen printing technology. The measurement consists of potentiometric difference between each coated sensor with the Ag/AgCl reference electrode.

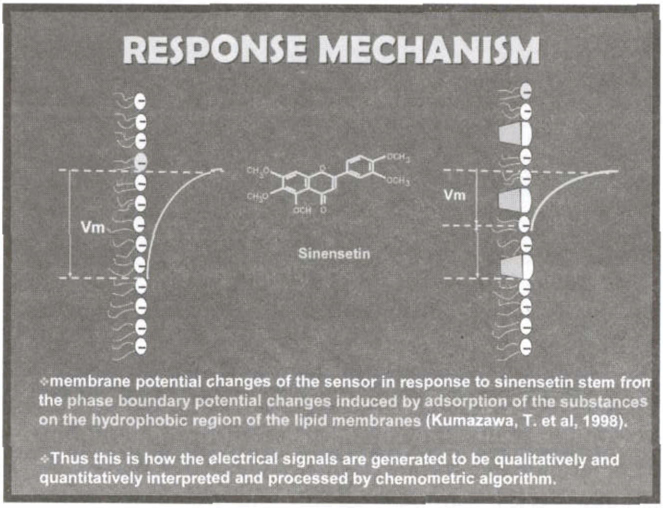


Figure 7(a): Response mechanism of the bitter substance to negatively charge membrane

Figure 7(a) shows the mechanism for potential changes in the negatively charged membrane. The electrical double layer is formed near the surface of the aqueous solution. The biology of bitter taste perception is poorly understood. However, the response of sensor to bitter substances (quinine) is the result of the adsorption of hydrophobic bitter substances to the hydrophobic part of the lipid material. In addition to that, it is also reported that the bitterness of amino acids is expressed in a way similar to the bitterness of quinine although it is believed that receptors of amino acids differ physiologically from those of alkaloids such as quinine.

This result suggested that it may be the lipid (hydrophobic) part of biological membranes that forms the receptor for bitter taste. Mechanism of electrical potential changes for other taste substances is understood by taking into account the interactions of lipid membrane with chemical substances such as protons, which produce sourness bind with the head group (hydrophilic part) of the lipid molecule resulting changes in surface charge density of the lipid membrane. Potassium and chloride ions on the other hand which interact electrically with the lipid membranes lead to changes in surface electric potential. Thus this is how the electrical signals are generated to be qualitatively and quantitatively interpreted and processed by chemometric algorithm.

7.1 SCREEN-PRINTING TECHNOLOGY

Screen-printing is a set of procedures based on thick film technology where an ink paste is forced through a mesh screen, pattern stencil or mask by a squeegee onto the surface of planar substrate materials (refer Figure 7(b)) (example polyester, PVC, plastic, alumina and others) followed by a proper thermal curing.

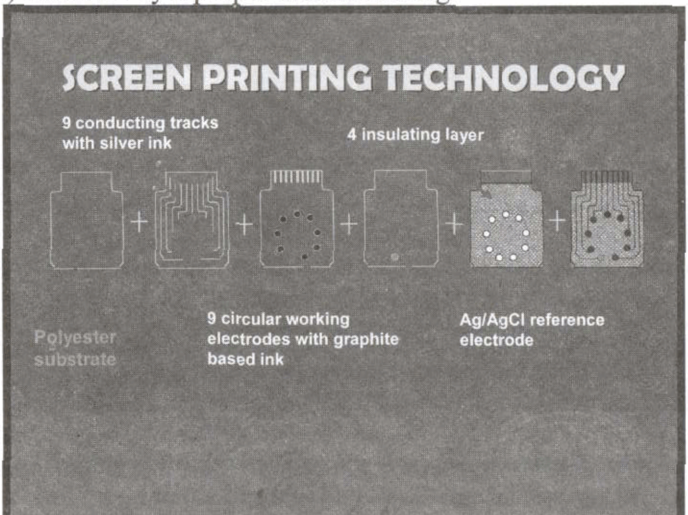


Figure 7(b): Scheme of a screen-printed strip preparation which consists of four consecutive printing steps

In line with the continuous emerging trend towards simplicity, disposability and cost competitive in the art of sensor production, this technology would be one of the most promising technologies allowing sensors to be placed large-scale on the market in the near future because of advantages such as miniaturization, versatility at low cost and also particularly the possibility for mass production.

With respect to the success in market penetration of the commercialized one shot glucose and metal ion sensors which utilizes screen-printing technology in its fabrication procedure, the adoption of the same technology for the current reported array sensor in this dissertation would somehow create a wider opportunity for further development and advancement of this made in Malaysia sensor system towards commercialization.

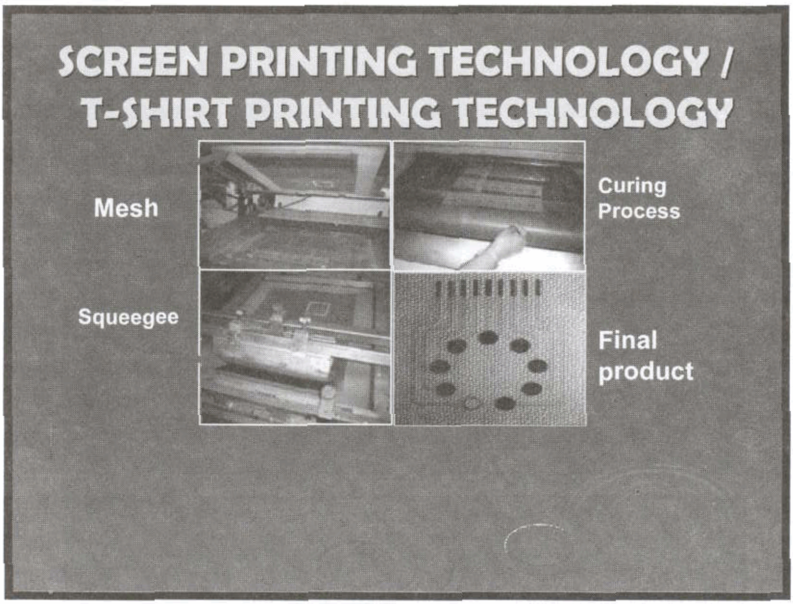
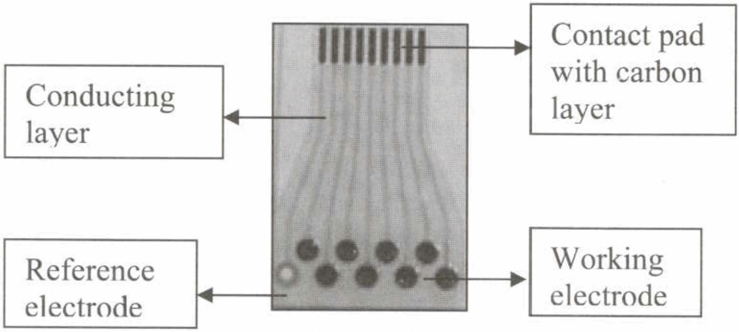
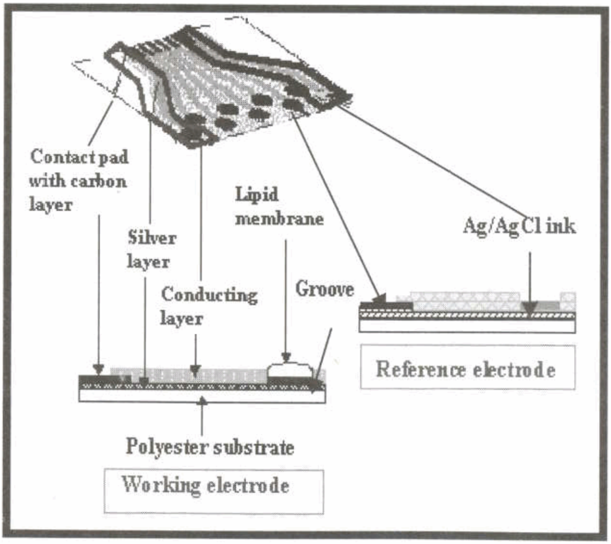


Figure 7(c) : Screen-printing is a set of procedures based on thick film technology where an ink paste is forced through a mesh screen by a squeegee onto the surface of planar substrate materials (example polyester, PVC) followed by a proper thermal curing



a) Front view



b) Cross-sectional view

Figure 7(d): Front and cross-sectional view of disposable sensor strip

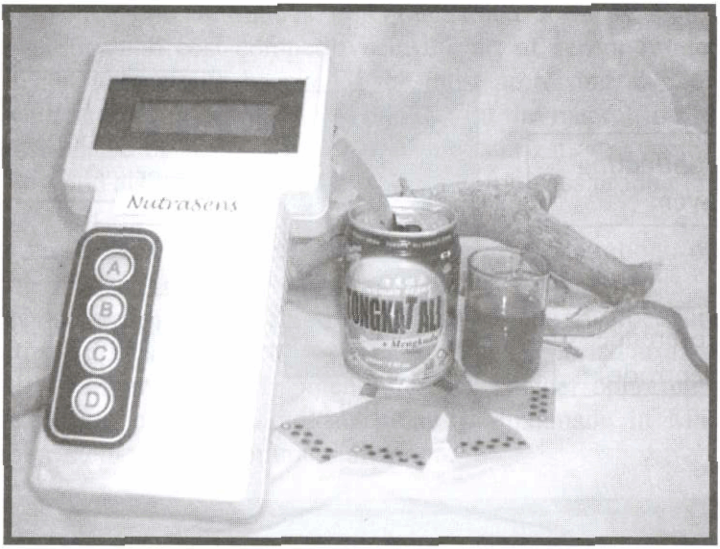


Figure 7(e): Disposable artificial tongue for *E.longifolia* verification

The taste of the Tongkat Ali sample is sensed using a specially fabricated disposable screen-printed (T-shirt technology) array of non-specific lipid membrane sensors and is verified/classified by means of Artificial Neural Network (ANN), the overall system is controlled by an embedded micro-controller chip which performed the data acquisition, the ANN-based pattern recognition and the user interface tasks. The system is able to correctly verify Tongkat Ali that conformed to the prescribed standard. The system is flexible and can easily be trained for any herbals for taste sensing verification.