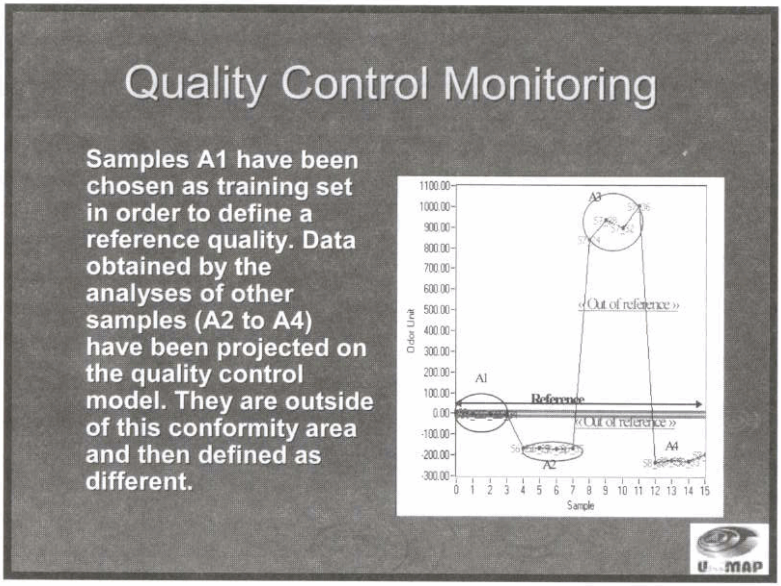



**Figure 8(k): Data have been treated with the Statistical quality control model, showing on a simple chart the ability of the instrument to be used as a fast QC tool.**

## 9.0 FUTURE / CURRENT WORKS

### 9.1 BIOCHEMICAL OXYGEN DEMAND BIOSENSOR FOR WATER QUALITY

#### AIM

To develop a rapid biological assay, based on microbial respiration, for measuring the environmental parameters biochemical oxygen demand (BOD).

#### INTRODUCTION

Biochemical oxygen demand (BOD) is one of the most important and frequently used parameters for estimating the level of water pollution. However, this conventional method is time-consuming (5 days of incubation) and usually requires experience and skill to

achieve reproducible results. As such, studies have already been conducted to develop alternative methods namely, BOD Biosensor. BOD Biosensor is a measurement of the amount of oxygen consumed by microorganisms in the degradation of the organic matter. The acceleration of respiration rate are measured by the change in current when the oxidative degradation is coupled to oxygen reduction through the microbial respiration pathways.

$$\underset{\text{organic substrate}}{CH_2O} + \underset{\text{electron acceptor}}{O_2} \xrightarrow{\text{Microorganisms}} H_2O + CO_2$$

The developed BOD biosensor is capable of assimilating most of the organic matter present in different types of wastewaters as well as industrial e uents.

## ADVANTAGES

- Fast
- Easy to use
- Simplicity
- Specificity / Accurate
- Detect small amounts
- On-line monitoring

## PRELIMINARY RESULT

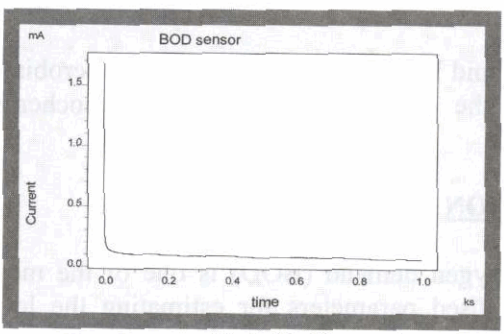



**Figure 9(a): Buffer only**

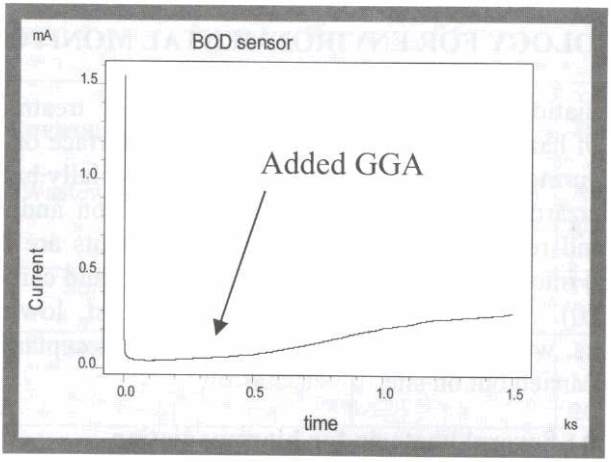
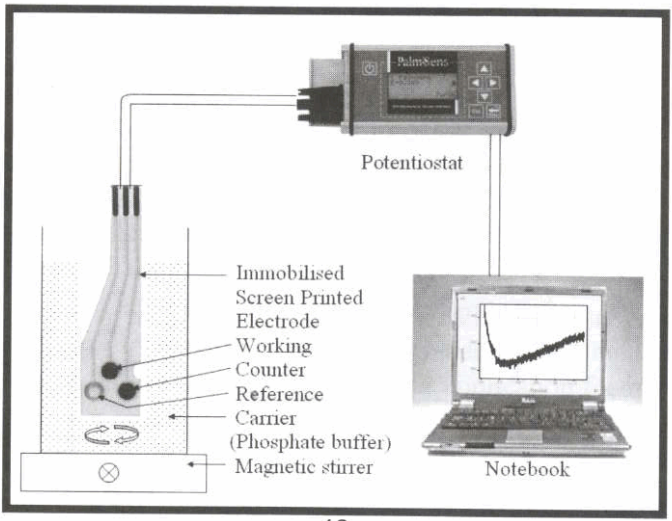



**Figure 9(b): Buffer + GGA**

**Condition :**

- Buffer : 50 mM PO4, pH 7.0
- GGA : Glucose – glutamic acid (220ppm)- BOD Standard Solution
- Method: Amperometric Detection (potential: +0.45)



## 9.2 BIOREMEDIATION AND BACTERIA SENSOR TECHNOLOGY FOR ENVIRONMENTAL MONITORING

Bioremediation is the application of biological treatment to the cleanup of hazardous pollutants in the soil and surface or subsurface waters. During the process, microorganisms, especially bacteria, feed on the hazardous pollutants. They derive nutrition and energy for growth and reproduction. The hazardous pollutants are used up or converted into a less harmful form, such as water and carbon dioxide (Table 1.0). As such, it uses relatively low-cost, low-technology techniques, which generally have a high public acceptance and can often be carried out on site.

**Table 1.0 : Several bacteria for bioremediation**

| Hazardous pollutants | Environment | Type of bacteria | Reference |
|---|---|---|---|
| Ammonia | Obtained from culture collection | *Nitrosomonas europaea* | Bernice *et al.*, 2006 |
| Phenol | activated sludge | *Serratia* sp. | Kobayashi *et al.*, 2007 |
| Mercury | wastewater | *Bacillus* sp. | Carlos, 2006 |
| Arsenate | Soil | Arsenate-Reducing Bacterium, *Bacillus* sp. | Shigeki *et al.*, 2005 |

Bacteria digestion / degradation can be used as a sensor. Table 2.0 show some biosensor used in pollution determination. Microbial sensors are composed of immobilization microorganisms and an electrochemical device and are suitable for the online control of biochemical processes (Chang TMS 1977; Guilbault 1976; Aizawa et al., 1974; Satoh *et al.*, 1977).

**Table 2.0 : Several bacteria sensors used in pollution determination**

| Analyte | Environment | Type of bacteria | Transducer | Reference |
|---|---|---|---|---|
| Ammonia | Wastewater | ammonia-oxidizing bacteria | Electrochemical | Annette et al., 2005 |
| Phenol | Soil | *Pseudomonas sp.* | Amperometric | Petr et al., 2002 |
| Mercury and arsenite | Soil | *Pseudomonas fluorescens* | Optical | Tiina and Martin, 2002 |

## OUTPUT / BENEFIT FROM RESEARCH

- Development and application of isolation techniques and characterization of the isolated strains useful for the recovery of bacteria from rubber wastewater.
- The treatment system proposed used to clean up hazardous waste sites
- To realize the commercial potential of the prototype, and through IP protection, applying the technology on a broader basis.

## 9.3 INNOVATIVE EXTRACTION TECHNOLOGY: MOLECULAR IMPRINTED POLYMER FOR SINENSETIN (PHARMACOPHORIC FLAVONOID) FROM *Orthosiphon stamineus* (MISAI KUCING)

## AIM

Development of solid phase extraction (SPE) using a molecular imprint polymer (MIP) as the separation medium for Sinensetin, an active compound from Misai Kucing. MIP application for medicinal plants is very recent and could become a sought-after technology.

## INTRODUCTION

Molecularly imprinting is an innovative technique for the preparing of polymeric materials possessing highly selective and affinitive properties. MIPs have been used in areas in which selective recognition of particular molecules in necessary or desirable including separations (e.g., chiral separations), immunoassay, sensors and catalysis / artificial enzymes. Recently MIPs have attracted considerable attention as solid-phase extraction (SPE) sorbents for the clean up and reconcetration of samples before determining drugs in complex biological fluids, nicotine in chewing gum and tobacco, and triazine herbicides in beef liver, and water. Generally, extraction or separation active components from herb are tedious and inefficient resulting from poor affinity and selectivity of conventional separation materials.

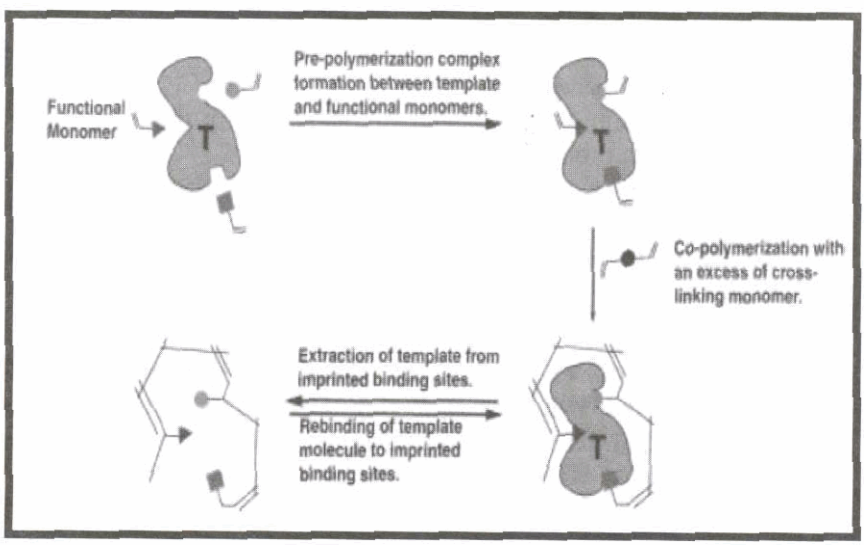



**Figure 9(d): Schematic representation of molecular imprinting process**

## ADVANTAGES

- efficient extraction of pure active / marker compounds
- high selectivity and affinities
- inexpensive and easy to prepare
- stable at low/high pHs, pressure and temperature (<1800C)

## COMMERCIAL POTENTIALITIES

- Could be widely used for herbals extraction and also biopharmaceutical analysis.
- Useful for chemical sensor development for quality control of herbs.
- Viable alternative for environmental and bio-sample analysis

## 9.4 CONTROLLED ENVIRONMENT MONITORING SYSTEM

**Figure 9(e): Greenhouse**

A greenhouse is a building with its walls and roof is made by glass or plastic and the main structure is made by steel. Greenhouse is build to grow plants commercially or as a hobby in control environment. Basic parameter that is controlled by this structure is temperature. Most commercial greenhouses are

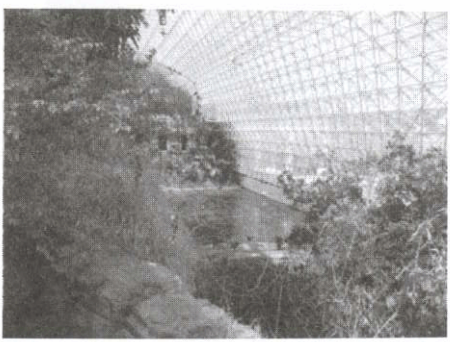


**Figure 9(f): Biosphere**

equipped with cutting edge technology to keep the quality of productions. Heating, cooling, irrigation, lighting systems of the environment is controlled by computer system.

Biosphere is another type of control environment structure that is built to be an artificial closed ecological system. If greenhouse is build to grow vegetables and flowers for commercial and hobby, biosphere is a huge laboratory that is builds for experiment and study of nature in controlled environment. The most popular biosphere is Biosphere 2 near Tucson, Arizona in United States of America that was built in 1987. The complex mimics rainforest, savannah, ocean, desert, agriculture site, modern houses and equipped with atmospheric pressure control centre, energy centre and cooling towers. Biosphere is not only to study plants but other nature entities like air or atmosphere, soil, water, microorganisms, animals and human itself can be studied their physical, behavior and interaction with each other.

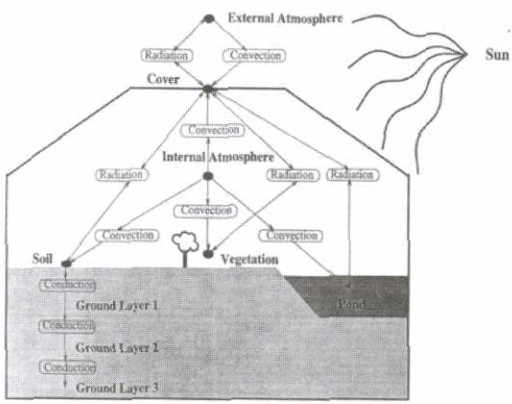



**Figure 9(g): Biosphere Control System**

The 9th Malaysia Plan emphasize on agriculture industry as a commodity to nation wealth. One of the key performances of successful of this industry is Research and Development (R&D). Industrial research that cannot be commercialized is considered fail even though it has new scientific and high technology values. Like Biosphere 2 project may be considered as a fail project because it is remain as research scientific laboratory without any contribution to other industries. The complex management always changes due to financial burden.

Controlled Environment is a combination of greenhouse and biosphere in other word, commercial laboratory is a solution of above problem. One of the important aspects of Control Environment is monitoring system. Basic parameters that must be monitored continuously in real time are temperature, humidity and light intensity. To meet those requirements, SCADA and intelligent sensors can be implemented.

SCADA (Supervisory Control and Data Acquisition) or Automation is refer to a large-scale, distributed measurement and control system. SCADA system is a combination of Programmable Logic Controller (PLC), Remote Terminal Unit (RTU), networks, communications, computer, Human Machine Interfacing (HMI), databases, view panel, sensors and actuators. The powerful feature of SCADA is the system can perform automatic monitoring and controlling system in real time.

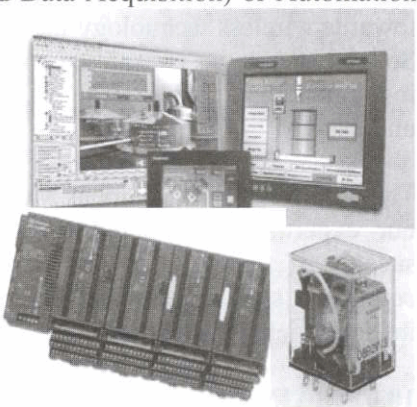


**Figure 9(h): SCADA System**

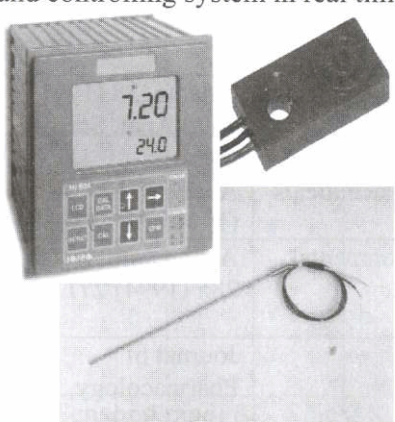



**Figure 9(i): Intelligent Sensors**

All the distribute sites can be remotely monitored and controlled from a centralized control room. Data can be kept safely inside databases for a long period of time at the same time it can be represented in varies views such as in graphical (site illustrated), graph and table. The system has integrated warning and alarm systems that help operators to avoid hazardous damage at site.

Sensors are important device in automobiles, machines, aerospace, medicine, industry, robotics and etc. Recent technology allows sensors to be fabricated on an extremely small size especially using MEMS technology. Enhancement in material technology makes sensor become more precise, more accurate, more sensitive, high resolution, faster reaction and varieties. Sensor that integrated with microcontroller and artificial intelligence algorithm is considered as intelligent sensors. Recent trend shows, sensor itself is moving towards wireless technology that refers to Wireless Sensor Network. So, sensor can be considered multidiscipline area not just involves instrumentation and material engineering like most people understand.

The Controlled Environment Monitoring System is a project where our expertise that related to sensor technology is applied. The success of this project will bring science and technology in our country a step a head and at the same time increase agriculture industry yield that will bring wealth to Malaysia.

## 10.0 MAIN PUBLICATIONS ON CHEMICAL SENSORS INVESTIGATED

| Type of Sensor and Category | Electroactive Material | Sample Tasted | Publication |
|---|---|---|---|
| Chloroquine (SE) | Ion-pairing agents | Pharmaceuticals | Talanta, 38 (1991) 1399;Anal. Sci., in press. |
| Primaquine (SE) | 24-crown-8 | Pharmaceuticals | Analyst,117 (1991)1319-1321 |
| Paraquat (SE) | Octyl cyclotetra-siloxane | Environmental, urine | Anal. Chim. Acta, 285 (1994) 271. |
| Kidney stone (SA) | Calcium oxalate | Urine | Journal of Pharmacology, 2 (1996) S29. |
| Taste Sensor | Lipid | a. *Centella* | Sensor and |

| | | | |
|---|---|---|---|
| (SA) | | *asiatica* (Pegaga)<br><br>b. *Eurycoma longifolia* (T. Ali) | Materials, 15 (2003) 209<br><br>Sensors 2006, 6, 1333-1344 |
| Disposable taste sensor strip (SA) | Lipid | a. Milk<br><br>b. Jackfruit<br><br>c. *Eurycoma longifolia* (T. Ali)<br><br>d. *Orthosiphon stamineus* (Misai Kucing) | Sensors (2003) 340. Sensors, 3 (2003) 555. Sensors and actuators B 101 (2004) 191; Transaction of The Institute of Measurement and Control, 26 (2004) 19; New Dimension in Complementary Health Care: (2004) 21; Sensors and Actuators B: Chemical, 120(1) 2006, 245-251; Sensors 3(2003) 458 Microchim Acta (2008): (Article in press); |
| Quartz crystal microbalance (SA) | Lipids | a. Volatile Organic Compounds (VOCs)<br><br>b. *Eurycoma longifolia* (T. Ali) | Sensor and Actuator B Chemical, 109 (2005), 238 – 243. |

SA- Sensor Array SE- Single Sensor

**11.0 THESIS**

1. A disposable lipid membrane taste sensor based on global sensor array (MSc. 2001)
2. Embeded neural network of taste sensor instrument (MSc. 2002)
3. Fabrication of taste sensor and its application in pharmaceutical and herbal quality evaluation (MSc.2002)
4. Performance evaluation of neural network based electronic taste sensing system (MSc. 2002)
5. Development of ENose system using quartz crystal microbalance odour sensor array (MSc. 2005)
6. Disposable biomimetic array sensor strip coupled with chemometric algorithm for quality assessment of *orthosiphon stamineus benth* sample (MSc. 2006)
7. Fabrication of an ENose and its application for the verification of *Eurycoma longifolia* extractions. (PhD. 2007)
8. Disposable ETongue for the assessment of water quality in fish tanks (MSc. 2008)

## 12.0 CONCLUSION

A low and high level data fusion technique was used to merge the datasets of electronic nose and tongue together, considering all extracted parameters, in order to increase the amount of information available for classification of *E. longifolia* extract samples. PCA was used to eliminate redundant or irrelevant features in order to develop an application specific system. Then a subset of the sensor was selected by considering the maximum loadings for each sensor system on the principal components.

In the data fusion technique, information from headspace volatiles and electrical potential properties of the solution are combined together. Electronic nose classifies *E. longifolia* spray and freeze dried extracts and cluster some similar samples. Electronic tongue also shows some cluster of similar extracts. Combining all the sensors show some individual clustering, but does not classify similar extracts. The best discriminating features of both sensor

systems were obtained by fusing (in a high-level data fusion) the first principal component of the electronic nose data and the second principal component of the electronic tongue data. Data fusion enhances classification using limited number of sensor from a wide range of data set. The overall analysis of samples is considerably improved by combining the information from the electronic nose and tongue.

The in-house fabricated multichannel artificial lipid-polymer membrane sensor possesses the capability to qualitatively determining different parts of plant, maturity stage, batch-to-batch variation and mode of extraction of *E. longifolia* through the acquired potentiometric and headspace volatiles fingerprint and multivariate analysis. With the incorporation of the sensor, quality control and standardization of herbal products no longer a time consuming, complicated and expensive task to be accomplished as compared to conventional chromatographic separation techniques. However, further study that emphasized on quantification of the marker compounds in the complex herbal mixture is needed for fully demonstrating the analytical capability of the developed biomimetic sensors.

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## ACHIEVEMENTS AND AWARDS

### INTERNATIONAL

1. GOLD MEDAL in GENEVA, Switzerland, Invention and Competition 2002, for invention of "AkuaSens, a Device for Mineral Water Verification".

2. SILVER MEDAL in International-Exhibition-Ideas-Invention-New Product (IENA) 2004, Nuremberg, Germany for "Nutra-Biostrip for Herbal Verification".

3. INNOVATION AWARD in International-Exhibition-Ideas-Invention-New Product (IENA) 2004, Nuremberg, Germany for "Nutra-Biostrip for Herbal Verification".

4. INNOVATION AWARD in Virtual Instrumentation Application Contest 2004 (organized by National Instrument, Asian Region) for "Nutra-Biostrip-Multi Use Disposable Sensor for Herbal Verification".

5. SILVER MEDAL in INPEX 2007, Pittsburg, PA USA for a "GanoBuster hand-held Enose for Early Detection of Ganoderma Rot in Oil-Palm".

6. GOLD MEDAL in British Invention Show 2007, London for a "Combined ENose and ETongue for the verification of Herbal Products".

## NATIONAL

1. SILVER MEDAL in invention and design exhibition 1996 (Mindex–Innotex'96) for invention of "Microprocessor based electrolyte analyzer device for uriliathiatic (kidney stone) urine".

2. GOLD MEDAL in National Science and Technology Expo 2001 (MOSTE) for Invention of "AkuaSens" (A Device for Mineral Water Verification).

3. GOLD MEDAL in ITEX 2002 for Invention of "NutraSens Artificial Tongue for Eurycoma Longifolia (T. Ali) Verification".

4. GOLD MEDAL in National Science and Technology Expo 2003 (MOSTE 2003) for Invention of "Nutra-Biostrip-Multi Use Disposable Sensor For Herbal Verification".

5. FIRST WINNER in Malacca Biogenesis Challenge 2004 for "Nutra-Biostrip-Multi Use Disposable Sensor for Herbal Verification".

6. SILVER MEDAL in ITEX 2005 for the invention of "Xantine Oxidane Disposable Biosensor for Herbal Antioxidant Evaluation".

7. GOLD MEDAL in ITEX 2006, for a "Combined ENose and ETongue for the Verification of Herbal Products".

# SENSOR BIOMIMETIK UNTUK KAWALAN MUTU DAN PEMIAWAIAN HERBA

*PROFESOR MOHD NOOR AHMAD*

Kawalan mutu dan pemiawaian fitoperubatan (phytomedicine) berhadapan dengan cabaran yang besar kerana herba merupakan campuran yang amat kompleks. Tambahan pula, bahan semula jadi yang lain, herba memberikan variasi yang signifikan terhadap kualiti dan kuantiti zat fitokimia berdasarkan variasi spesis, perbezaan masa tuaian, keadaan penanaman dan pemprosesan. Kawalan mutu dan pemiawaian adalah langkah fundamental ke arah permodenan dan pembangunan fitoperubatan dan ke arah perubatan berlandaskan bukti (evidence based medicine). Oleh yang demikian, pendekatan dan keadah nobel yang mampu memastikan konsistensi dan keberulangan formulasi sesuatu herba sedang diterokai sehingga kini.

Dalam kajian tumbuhan ubat, teknik kromatografi lapisan nipis (TLC), kromatografi gas (GC) dan kromatografi cecair prestasi tinggi (HPLC) sering digunakan bagi mendapatkan ciri-ciri profil cap jari yang mewakili kehadiran kandungan kimia sampel sesuatu herba. Walau bagaimanapun, kaedah pemisahan-pengesanan konvensional ini mengambil masa yang lama, mahal dan sangat bergantung kepada kekutuban fasa bergerak (TLC dan HPLC) dan kemeruapan zat-zat (GC) yang hendak dipisahkan.

Mengambil kira cabaran-cabaran di atas, kumpulan penyelidik Sensor dan Aplikasi sejak hampir 12 tahun lalu telah mempelopori keadah analitik yang inovatif, pantas, ekonomi dan yang lebih penting ialah ketepatan dan keberulangan. Ini dapat dicapai melalui teknologi terkini (state-of-the-art technology) terutamanya untuk aplikasi industri fitoperubatan. Baru-baru ini kami telah melaporkan di Journal Sensors and Actuators dan beberapa jurnal antarabangsa lain berkenaan dengan pemakaian e-hidung dan e-lidah menggunakan analisis cap jari untuk kawalan mutu.

ISBN 978-983-42371-8-9


Pada masa kini analisis cap jari untuk kawalan mutu dan pemiawaian formula fitoperubatan adalah berdasarkan kepada teknik pemisahan kromatografi. Syarahan ini akan membentangkan keadah inovatif tanpa kaedah pemisahan menggunakan sensor-sensor yang di fabrikasi dan dibangunkan in-house bagi profil kualitatif dan kuantitatif herba yang terkenal di Asia Tenggara iaitu Eurycoma longifolia atau Tongkat Ali. Sensor biomimetik yang meniru lidah manusia, e-lidah digunakan untuk (1) profil potentiometrik sampel mentah dan ekstrak, (2) identifikasi variasi kandungan kimia bahagian berlainan pohon, peringkat kematangan, kumpulan(batches) dan keadah pengekstrakan dan (3) pengkelasan ekstrak menggunakan zat pelarut berlainan secara analisis kimometrik, E. longifolia . Zat meruap dari ekstrak dari pengeringan sembur dan sejuk beku telah dicirikan menggunakan e-hidung yang juga dibangunkan in-house. E-lidah terdiri daripada tatasusunan (array) beberapa sensor membran yang terdiri daripada polimer-lipid yang meniru sistem gustatori (deria rasa) manusia. Sistem tersebut terdiri daripada 8 sensor polimer-lipid tak-spesifik yang mempunyai kepemilihan bertindih separa dan kepekaan silang (cross sensitivity) terhadap campuran cecair kompleks sampel herba. Sensor akan memberikan signal potentiometrik di dalam larutan sampel. E-hidung terdiri daripada bahan pizoelektrik seperti kuarza, QCM (Hablur Kuarza Mikro-imbang) yang dilapisi dengan membran lipid-polimer dan bahan-bahan fasa pegun gas kromatografi. Penjerapan wap molekul pada membran akan dikenalpasti melalui perubahan frekuensi ayunan kuarza yang akan dikaitkan dengan jisim wap yang terjerap sebagai isyarat sensor. Bagi merealisasikan pendekatan organoleptik, hidu dan rasa yang dapat membantu peningkatan penilaian, klasifikasi dan keupayaan pengecaman sesuatu produk, pencantuman data iaitu teknik matematik yang menggabungkan dua atau lebih persepsi tiruan, dari analisis e-lidah dan e-hidung juga akan dibentangkan.