Sensor Development At Assumption University?

By

Dr. Tin Win

Department of Basic Science
Faculty of Engineering
Assumption University

ABSTRACT

Possible development of two or six tin-oxide MOS type gas sensors into ISO 9000 pro-active quality standard compliant oriental sauce testers and fermentation product process monitors are discussed, through their capability of sauce identification, which is comparable to the only two, much more costly commercial multi-sensor (55) instruments.

1. INTRODUCTION

An intense global concern on environment problems has stimulated interest in monitors capable of detecting and measuring various aspects of the environment Reviews, such as in reference [1] are being published frequently. Development of such monitoring systems has major commercial implications. For example, air pollution monitoring equipment is now worth US$340 million and is expected to grow to a value of over US$422 million by 1990. Gas sensors, which detect gases in the atmosphere are used in these equipment[2].

1.1. TYPES OF GAS SENSORS

Theoretically any transducer capable of converting responses to gases into electrical signals can be used as gas sensors. Many require reactions with gases when the gases get adsorbed on some surface. There are a number of types of gas sensors, of which **Metal Oxide Semiconductors (MOS)** and

Conducting Polymers (**CP**) are the two most popular.

Each has its own advantages. The CP types are selective, they respond to only selected gases and sensitive, they respond to minute amounts; but they do not last long and have to be replaced quite frequently. The MOS types are less selective, but are more hardy. Since these sensors rely on adsorption, temperature and humidity need to be controlled carefully.

1.2. INSTRUMENTS

Instruments normally include an array of gas sensors to detect gases, a pump to draw in air or gases, and a datalogger to collect and record data. After measuring the recorded data are entered into a spreadsheet, such as **MS Excel**. The responses from the sensor array form a "fingerprint" pattern. The pattern differences allow identification of various gases. The difference parameters are many and **Artificial Neural Net** (ANN) software, such as **Brainmaker** from California Scientific Software or statistical **MAP** functions, such as **cluster analysis** or **principal component analysis** have to be used.

AromaScan [3] and Alpha MOS Fox [4] multi-sensor (55 sensors) monitors are the only two commercial instruments available at elevated cost. For sauce identification purposes, they are not much better than two or six sensor testers.

1.3. APPLICATIONS

Two distinct types of instruments are being developed; one for detection and quantifying; and another for quick on-site or on-line testing. The former is intended for operations by trained technicians. The latter is intended for daily routine use by anyone. Hence they have to be small, portable and handheld if possible. These will detect variation, from a set standard, of volatile composition in **headspaces** (space above a solid or liquid sample in a container) of any material, such as food, wines, oil or air, which contains volatile components

These testers can therefore be used on-line during production processes. It in effect gives a method for continuous monitoring during production. Thus the small handheld testers are ideal for pro-active quality control, which is demanded by the ISO 9000 quality standard. Hence these types of testers will be in great demand in future.

Development of two MOS handheld gas monitors into oriental sauce testers is described below.

2. EXPERIMENTAL

2.1 THE MONITOR DESIGN

2.1.1 TWO SENSOR MONITOR

Two Taguchi tin-oxide MOS sensors, TGS 812 and TGS 824, from

Figaro, Osaka, Japan, were assembled in FIA (Flow Injection Analysis) mode. A pump which drew sample gases from headspaces at the rate of 1L per minute was used to flow sample gases over the sensor surfaces. The analog output voltage was converted via a 12-bit ADC that transmitted through an RS232C output to a Macintosh PowerBook 145B or a Macintosh LCII computer. Software, written in-house, was used for data acquisition and real-time voltage readings were displayed on the computer screen. Collected data were saved as text files, transferred to a spreadsheet, plotted out as graphs on the VDU and used for data analysis

2.1.2 SIX SENSOR MONITOR

Six Taguchi tin-oxide MOS sensors, TGS 880,825, 824, 822, 813, 800 were assembled in FIA mode, using a similar pump as above. The electrical outputs were recorded on a datalogger called Tattletale, which could optionally be connected to an Acer/Extensa 355 IBM PC computer, via a RS 232C cable, where responses were displayed in real time. The data were then processed as above. Tattletale provided sensor array options of 2,3,4,5,6 sensor combinations.

2.1.3 SAUCE SAMPLES

Sauce samples such as soy sauces, mushroom soy sauces, teriyaki sauces, tamari sauces, and fish sauces, from Thailand, Australia, USA, Singapore, Japan and Taiwan were examined. Sauces with high volatile contents were diluted 1:10 just before testing.

50 mL of sauce samples were taken in 100 mL volumetric flasks. The approximate 50 mL headspaces were stabilized in a humidity and temperature controlled room.

2.1.4 PROCEDURE

The monitor was switched on and the pump kept running for about twenty minutes, until background readings were stabilized. Then the sampling tubing was inserted into the headspace to a position about 5 cm above the sauce liquid. For the six sensor monitor, monitoring time was only ten seconds, whereas for the two sensor monitor, monitoring was done until a steady-state flat response was obtained.

For the two sensor monitor, the recorded data on Satod, were loaded onto a graphing program called Igor. The data were printed out as graphs. The flat steady-state response data were measured, entered into an Excel file, saved as text, and fed to the Brainmaker Artificial Neural Network, where Brainmaker (Net Training) files were created and an ANN was formed. Training parameters, such as learning rate, tolerance, number of hidden neurons and neuron transfer functions were set , and the ANN net was trained.

For the six sensor monitor, data from Tattletale was downloaded to the IBM PC onto the Txtools program and saved as text. The data were printed out as graphs. Peakheights were measured, entered into an Excel file, saved as text, fed to Brainmaker and processed as above.

The measuring processes were repeated on test sauce samples, and the data processed as before, up to the point of feeding data to Brainmaker. Running Fact files were then formed and fed to the trained ANN net, which identified the tested sauces.

3. RESULTS AND DISCUSSION

3.1 MONITORING METHOD

The peakheight measurement used with the six sensor monitor was quick, but conditions, such as headspace stabilization , monitoring time and time between measurements, needed strict control. The steady-state method took longer, minutes as compared to ten seconds, but was relatively tolerant of variations in the above conditions. Thus the latter method was most suitable for testers, which were really aimed for operations by anyone.

Peakheight and steady-state values had to be measured manually. This was a barrier to automation of the testing process. Development of such software was therefore desirable.

3.2 IDENTIFICATIONS

Efficient identification of five sauces by the two sensor tester was shown in figure 1. Identification certainity was around 90%, as shown by the column plots. Identification of more than five sauces required grouping the sauces into three sets based on their volatile contents, high, medium and low, as shown in table 1. Three different ANNs had to be used.

Such an arbitrary grouping was not necessary for the six sensor tester. Figure 2 showed identification of all fourteen sauces, shown in table 2. Thus technically it was more efficient than the two sensor tester. However, it must be remembered that sauce manufacturers would not produce more than two or three kinds of sauces. Hence the two sensor tester could be said to be of more practical importance.

3.3 POSSIBLE APPLICATIONS

One possible application area was quality control or quality assurance. Proactive quality standards like the ISO 9000, required continuous assessment all along the production stream, as opposed to the reactive standards which simply required checking the finished product output. Thus small, efficient on-line testers would be in great demand in the future.

Any variation from the norm would have sensor responses different from the standard values. Thus if these variations could be detected by the ANN trained net, then any sub-standard quality sample batch would be identified. Hypothetical variations of ± 0.5%, ±1%, ±2%, ±5%, ±7% and ± 10%, in the Cornwell's soy sauce test response data were fed into a three sensor array, of the six sensor tester, ANN trained net, for identification. Figure 3 showed distinct identification pattern differences starting from 1% response variation. The sharpest changes were in the Zu Miao component of the identifications. Thus this change could be used to set the required quality standard of Cornwell's soy sauce. Therefore the two and six sensor testers had potentials for being developed into an on-line tester for oriental sauce production. This possibility is being explored.

The two or six sensor tester could possibly be used to follow fermentation during soy sauce production and optimum production parameters could be determined. Work on similar lines had been done on Japanese *miso* (soybean paste) [5]. Lipid membranes were used as taste transducers in a multichannel taste sensor, an electronic tongue analogous to the electronic nose. Similar applications could be developed in wine and beer production.

3.4 ADVANTAGES OVER MULTI-SENSOR ARRAYS

The main advantages of the two or six sensor MOS array over multi-sensor MOS arrays were comparable identification capabilities at comparatively lower cost and the minimised error probability due to less peak or steady-state measurements. Thus in sauce identification, the two or six sensor tester, being much less costly, was preferable to the much more costly multi-sensor monitors. They also had a potential for development into an on-line quality assurance tester, for proactive, rather than reactive, conformity to standards, in accordance with ISO 9000 quality standards; and a soy sauce production monitor.

4. CONCLUSION

The two and six sensor testers when coupled with Brainmaker ANN software could efficiently identify oriental sauces at comparatively lower cost. Development into a procative on-line sauce production quality assurance tester, and general fermentation monitor was plausible. They were therefore preferable, at least for sauce manufacturers or wine, beer producers, to the much more sophisticated but costly multisensor monitors, such as AromaScan or Alpha MOS Fox.

Commercial development of quality assurance production on-line testers and fermentation monitors would be profitable. Software development for direct reading and tabulating of sensor response data would be the first step, as this would open the path to automating tester operations.

Assumption University has the potential for carrying out such a development program, provided funding is available. Assumption University will be in the forefront of sensor technology, not only in Thailand, but also in the world. Thus it will be worthwhile to search for funding sources.

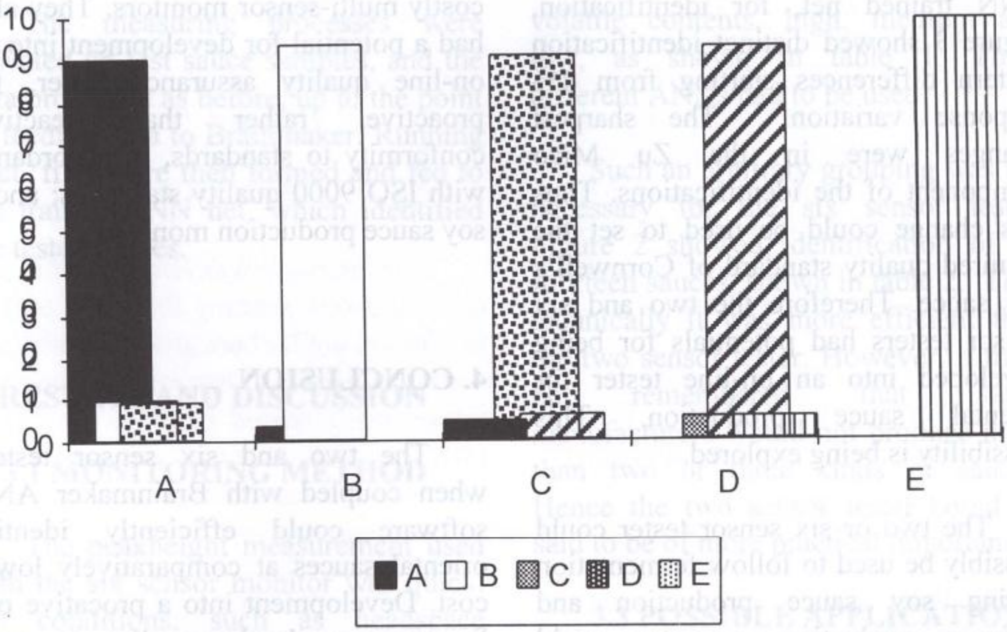

Figure 1: Identification of Five Sauces (Two-sensor Tester)

A = Pearl River Bridge Soy; B = Masterfoods Soy; C = Zu Miao Soy; D = Maggi Chilli Sauce; E = Maggi Hot Chilli Sauce

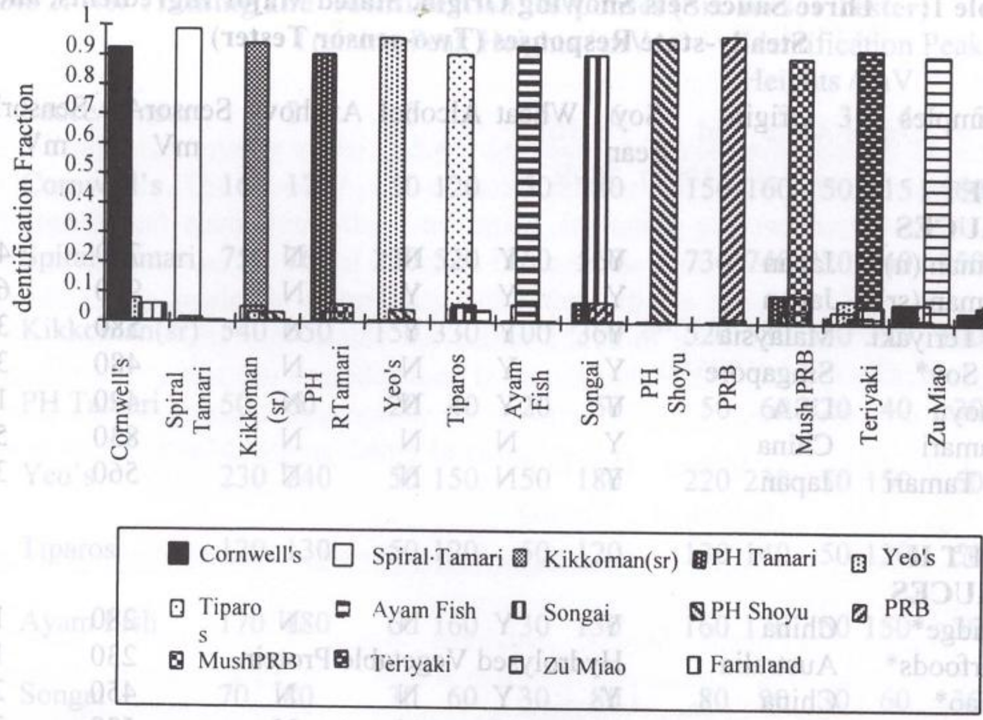

Figure 2. Identification of Fourteen Sauces (Six-sensor Tester)

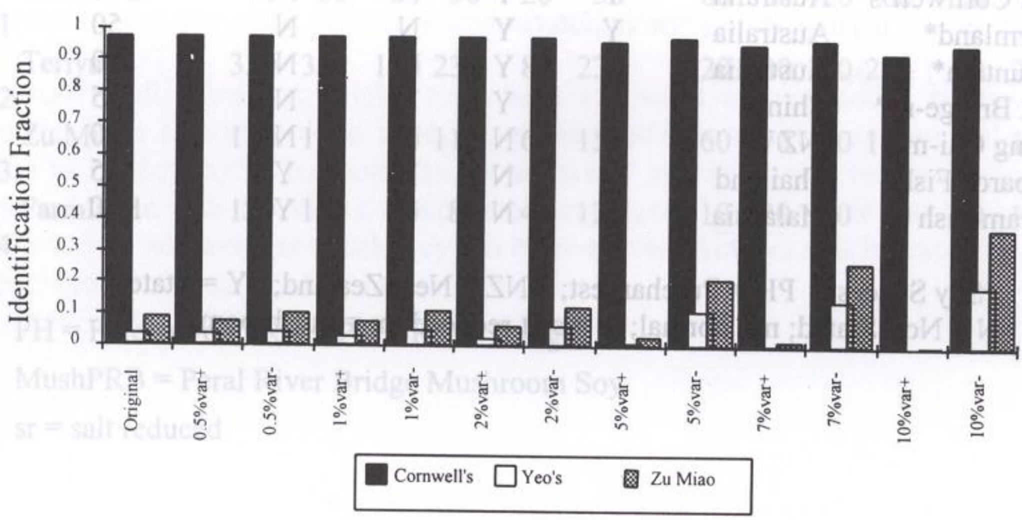

Figure 3. Hypothetical Variations of Cornwell's Sauce.
ISO 9000 Pro-active Quality Assurance Possiblity.

Table 1: Three Sauce Sets Showing Origin, Stated Major Ingredients, and Steady-state Responses (Two-sensor Tester)

Samples	Origin	Soy Bean	Wheat	Alcohol	Anchovy	SensorA/ mV	SensorB/ mV
SET I SAUCES							
Kikkoman (n)*	Japan	Y	Y	N	N	720	460
Kikkoman (sr)*	Japan	Y	Y	Y	N	990	620
Ayam Teriyaki	Malaysia	Y	Y	Y	N	580	320
Yeo's Soy*	Singapore	Y	Y	N	N	480	320
PH Shoyu	USA	Y	Y	N	N	420	190
PH Tamari	China	Y	N	N	N	830	500
Spiral Tamari	Japan	Y	N	N	N	560	340
SET II SAUCES							
PR Bridge*	China	Y	Y	N	N	280	170
Masterfoods*	Australia	Hydrolysed Vegetable Protein				230	160
Zu Miao*	China	Y	Y	N	N	450	260
Maggi chilli	Thailand	N	N	N	N	530	340
Mag.Hot chilli	Malaysia	N	Y	N	N	680	560
SET III SAUCES							
PH Cornwell's*	Australia	Y	Y	N	N	40	60
Farmland*	Australia	Y	Y	N	N	50	30
Fountain*	Australia	Y	Y	N	N	10	15
PR Bridge-m*	China	Y	Y	N	N	35	65
Song Gai-m*	NZ	Y	N	N	N	90	80
Tiparos Fish	Thailand	N	N	N	Y	15	35
Ayam Fish	Malaysia	N	N	N	Y	70	65

*Soy Sauces; PH = Pureharvest; NZ = New Zealand; Y = Stated; N = Not Stated; n = normal; sr = salt reduced; m = mushroom

Table 2: Net Training and Identification Responses (Six-sensor Tester)

		Training Peak Heights / mV						Identification Peak Heights / mV					
o.	Sauce/Sensor	1	2	3	4	5	6	1	2	3	4	5	6
	Cornwell's	160	170	50	120	50	180	150	160	50	115	60	180
	Spiral Tamari	750	760	230	520	160	560	730	740	220	540	150	50
	Kikkoman(sr)	540	550	150	330	100	360	520	530	150	320	100	350
	PH Tamari	50	60	20	40	20	50	50	60	20	40	20	50
	Yeo's	230	240	50	150	50	180	220	230	50	150	60	200
	Tiparos	120	130	50	120	50	120	130	140	50	120	50	130
	Ayam Fish	170	180	60	160	30	130	160	170	60	150	30	130
	Songai	70	80	30	60	30	80	80	90	30	60	30	80
	PH Shoyu	350	360	100	260	60	250	330	340	100	260	60	250
0	PRB	100	110	20	70	20	80	100	110	20	70	20	80
1	MushPRB	70	80	20	50	20	50	80	90	20	60	20	50
2	Teriyaki	320	330	100	230	80	230	320	330	100	220	80	220
3	Zu Miao	170	180	50	110	60	150	160	170	50	100	60	150
4	Farmland	120	130	30	80	40	120	110	120	30	70	50	110

PH = Pureharvest PRB = Pearl River Bridge

MushPRB = Peral River Bridge Mushroom Soy

sr = salt reduced

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Assumption University
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Tel. (662) 300-4543, (662) 300-4553
Ext. 1308, 1309, 1336
Fax : (662) 300-4552
E-mail: charmmonman@acm.org
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