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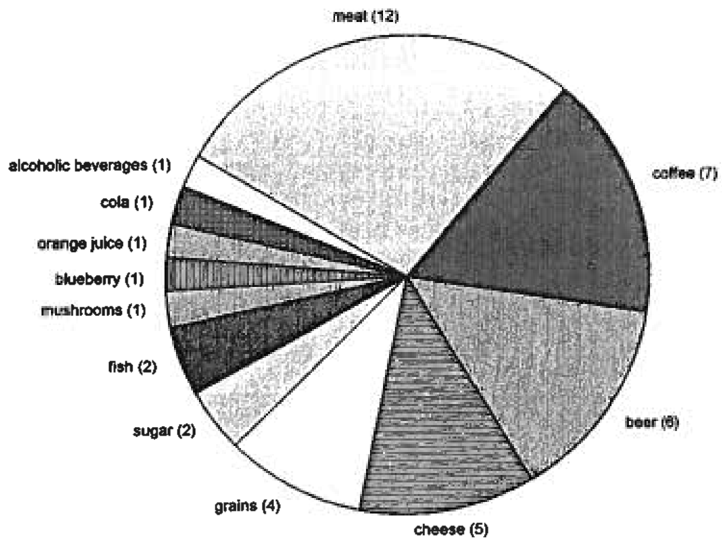

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'Electronic noses' and their applications in the food industry: A review

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The term 'electronic nose' appeared 15 years ago but research and dedicated applications of this instrument were only extended during the last four years with the first commercial systems. This article briefly presents the currently used sensor technologies and statistical data treatments, as well as the newest instruments of five main companies. A table summarises diverse applications with food products.

Keywords: artificial nose; electronic nose; food; gas sensor analysis; review

An 'electronic nose' is defined as "an instrument, which comprises an array of electronic chemical sensors with partial specificity and an appropriate pattern-recognition system, capable of recognising simple or complex odours" (Gardner and Bartlett, 1993). Various kinds of gas sensor are available on the market but only four technologies are currently used in commercialised 'electronic noses'. These cover three working mechanisms: (i) a change of resistance—metal oxide semiconductors (MOS) and conducting organic polymers (CP); (ii) a change of potential—metal oxide semiconductors field effect transistor (MOSFET); and (iii) a change of resonance frequency—piezoelectric crystals (bulk acoustic wave = BAW and surface acoustic wave = SAW) (Figures 1 and 2) (Sberveglieri, 1992). Others such as fibre-optic, electrochemical and bimetals sensors are still in the developmental stage for this kind of application but could be integrated in the next generation of 'electronic noses'. Whatever the sensor technology, all sensors have interactions with the gas to be measured, so that when volatile compounds flow over the sensor a series of physical and/or chemical interactions occurs. A dynamic equilibrium is set up as volatile compounds are constantly being adsorbed and desorbed at the sensor surface (Shiers, 1995).

These different sensors can be divided in two main classes: hot sensors (MOS, MOSFET) and cold sensors (CP, SAW, BAW). The former ones, working at high temperatures, are supposed to be more robust and less sensitive to moisture and so should offer the best ratio of drift and lifetime to sensitivity.

The raw responses generated by the sensors are analysed using different statistical methods (Gardner and Bartlett, 1992). The commercially available techniques fall into three main categories:

- graphical analyses: bar chart, profile plot, polar and offset polar plots;
- multivariate analyses: principal components analysis (PCA), canonical discriminant analysis (CDA), feature weighting (FW) and cluster analysis (CA);
- network analyses: artificial neural network (ANN) and radial basis function (RBF) (Hodgins, 1997; Holmberg, 1997).

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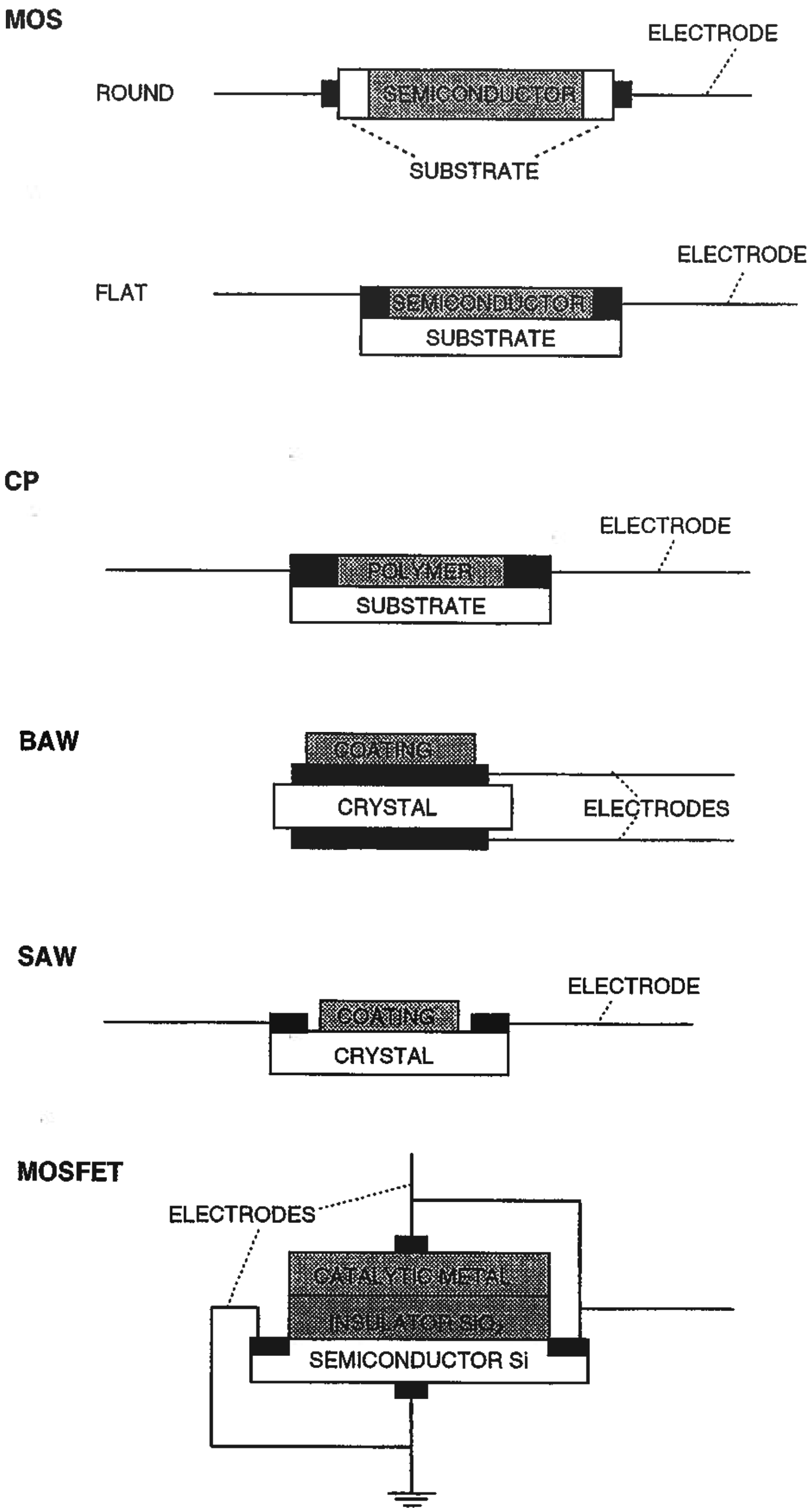

Fig. 1. Schematic designs of five different kinds of sensors. MOS = metal oxide semiconductor; CP = conducting polymer; BAW = bulk acoustic wave; SAW = surface acoustic wave; MOSFET = metal oxide semiconductor field effect.

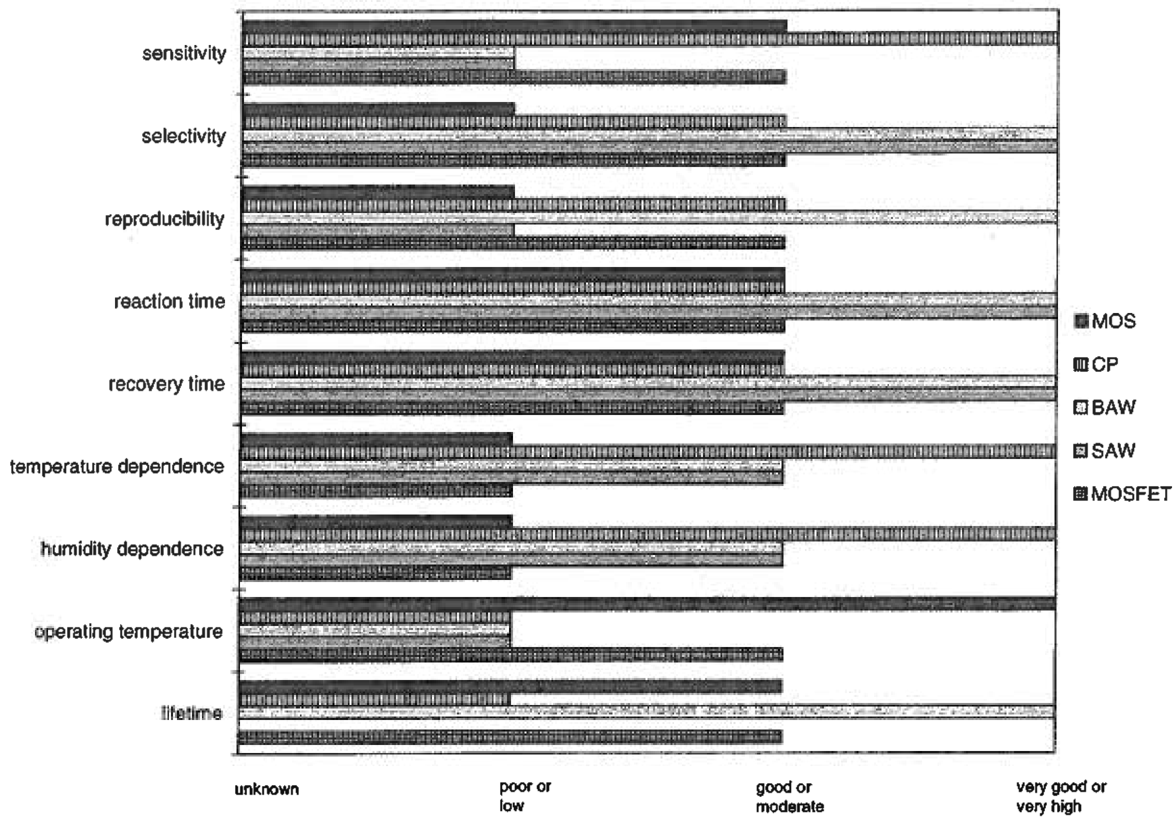

Fig. 2. Comparison of various sensor technologies. Abbreviations as in Figure 1.

The choice of method depends on the available data and the type of result that is required (Figure 3).

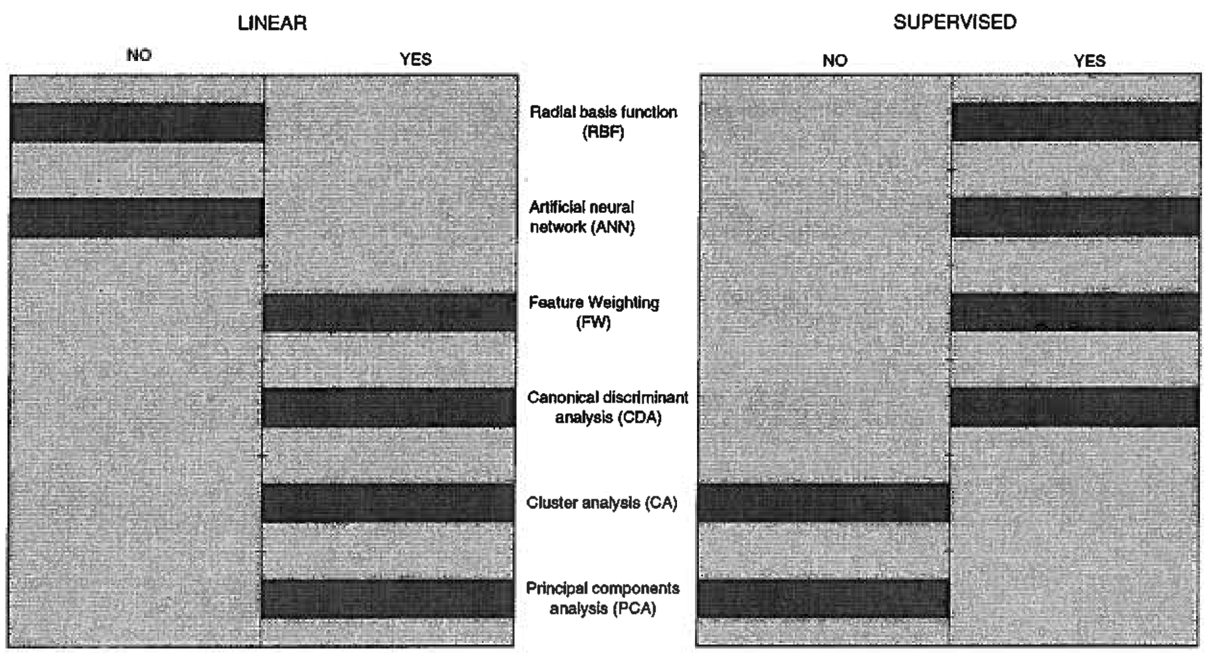

Fig. 3. Main statistical methods used in electronic noises.

Table 1. Latest version of commercially available electronic noses. MOS = metal oxide semiconductor; CP = conducting polymer; BAW = bulk acoustic wave; MOSFET = metal oxide semiconductor field effect; IR = infrared

Company	Neotronics	AromaScan	HKR	NST	Alpha MOS
Instrument	e-NOSE 5000	AromaScan A32/50S	QMB6	NST 3220	FOX 5000
Number of sensors	24	32	6	15	24
Sensor technology	CP-MOS	CP	BAW–MOS	MOSFET–MOS–IR	MOS–CP–BAW
Auto-sampler	Yes	Yes	Yes	Yes	Yes
Headspace generation	Static or dynamic	Static or dynamic	Static	Static	Static or dynamic
Sampling[1]	Dynamic	Dynamic	Dynamic	Dynamic	Dynamic
Measurement	Dynamic or semi-dynamic[2]	Dynamic	Semi-dynamic[2]	Dynamic	Dynamic

[1] The headspace is transported to the sensors by a carrier gas.
[2] The gas to be measured is stopped for a certain amount of time in the sensor chamber.

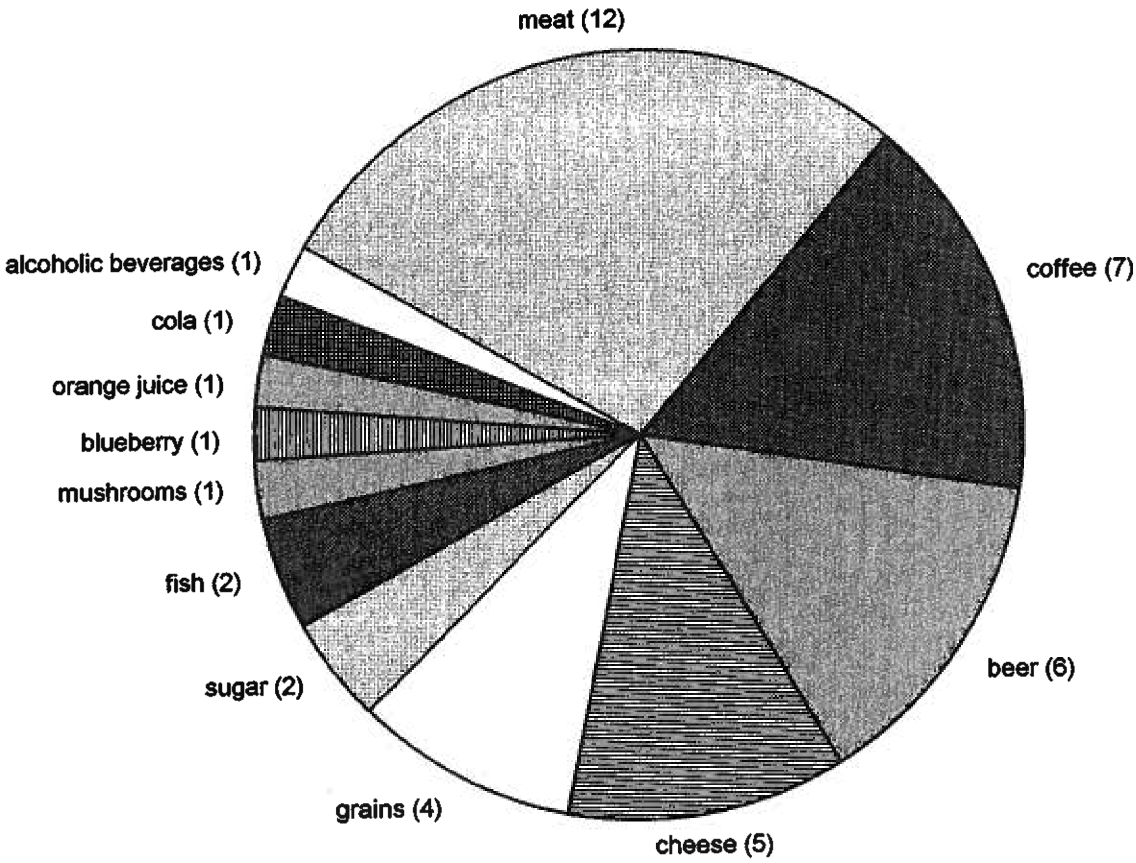

Fig. 4. Number of published papers on food application (1992–1997).

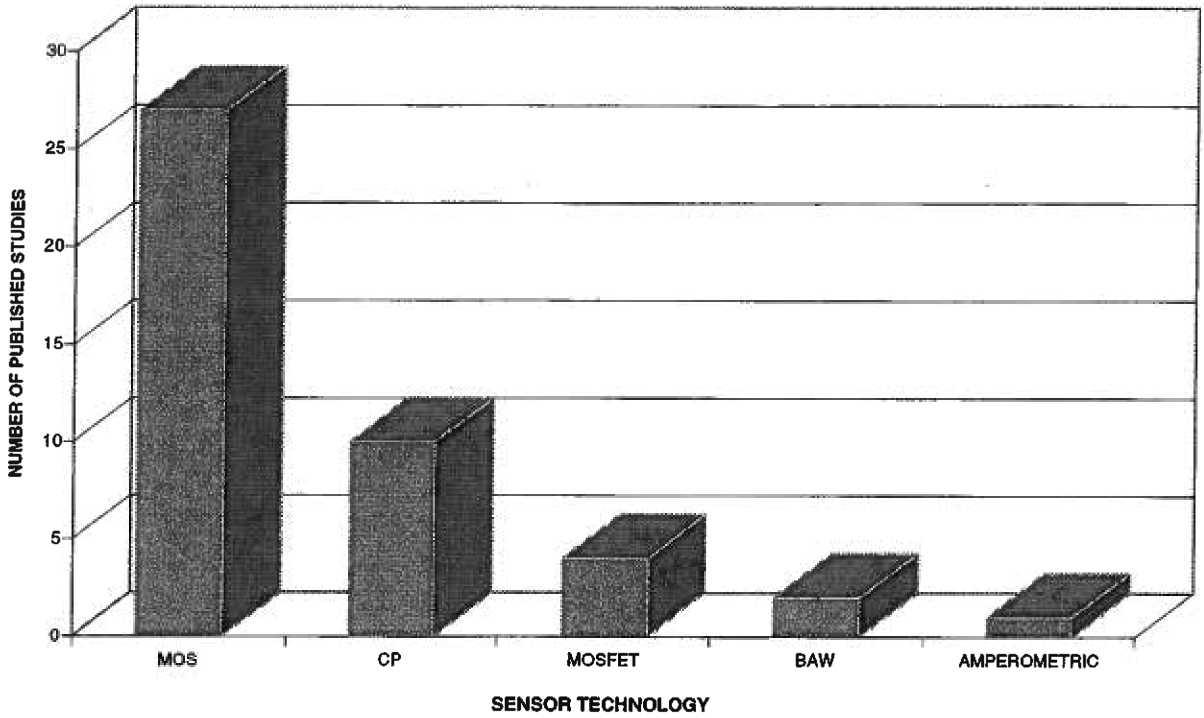

Fig. 5. Sensor technologies used in studies on food products. Abbreviations as in Figure 1.

Five main manufacturers of electronic noses, from four different countries, were found to be competing on the market. Two were English: Neotronics and AromaScan; one German: HKR; one Swedish: Nordic Sensor Technologies AB (NST); and one French: Alpha MOS. Each is specialised in a different sensor technology, which implies various instrument designs (Table 1).

The 'electronic noses' were designed to be used with numerous products (cars, food, packaging, cosmetics, etc.) in a broad range of applications, namely quality control of raw and manufactured products; process, freshness and maturity monitoring; shelf-life investigations; authenticity assessments of premium products; classification of scents and perfumes; microbial pathogen detection; and environmental studies. Although only a few ground studies have yet been published, most of these themes have probably been treated either by manufacturers of electronic noses in preliminary feasibility studies or by industrial researchers who have not published their work. Some studies were performed on packaging, tobacco, cosmetics or the environment, but until now, most of the research has been carried out on various food products (Figure 4). The MOS sensor technology has been far and away the most employed in these studies (Figure 5).

Most scientists working with an 'electronic nose' consider this instrument as an interesting tool for a rapid quality test in various food applications. However, before being used as a completely reliable, industrial instrument, it still needs a lot of improvements. Due to the difficulty of having a single instrument intended to be used with every possible application, the trend is to create a whole range of electronic noses dedicated to specific applications.

References

Gardner, JW, Bartlett, PN. (1992) Pattern recognition in odour sensing. In *Sensors and sensory systems for an electronic nose* (JW Gardner and PN Bartlett, eds). Kluwer Academic Publishers, Dordrecht, pp. 161–179.

Gardner, JW, Bartlett, PN. (1993) A brief history of electronic noses. *Sensors and Actuators B*. **18**(1–3), 211–220.

Hodgins, D. (1997) The electronic nose: Sensor array-based instruments that emulate the human nose. In *Techniques for analyzing food aroma*. (R. Marsili, ed.). Marcel Dekker Inc., New York, pp. 331–371.

Holmberg, M. (1997) *Data Evaluation for an Electronic Nose*. Doctoral thesis at the Department of Physics and Measurement Technology, Linköping University, Sweden.

Sberveglieri, G. (1992) *Gas sensors*. Kluwer Academic Publishers, Dordrecht.

Shiers, VP. (1995) Electronic nose technology—evaluations and developments for the food industry. *Food Ingredients Europe Conference*, Frankfurt.