DEVELOPMENT OF ENZYME ELECTRODES FOR MONITORING AND ANALYSIS OF FOOD ANALYTES IN THE FOOD INDUSTRY

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Introduction

Verifying the content of nutrients and detection of contaminants are some of the requirements to evaluate the quality of processed food products. Several techniques are being used for the verification but chromatography is the most common technique due to its ability to provide accurate results. In the food industry, there is a significant need to monitor the content of nutrients and detection of contaminants during the processing stage in order to control the amount of incoming raw materials or ingredients as well as to prevent contamination. There are two types of process control systems: manual and automatic. To incorporate chromatography technique in the automatic process control system is difficult and costly due to its limitation in the analysis procedures for system integration requirements. Therefore an alternative approach needs to be explored. Biological-based sensors or biosensors, have been successfully used in determining the concentration of some food substrates such as glucose, glutamine and lactate. These have attracted interest in developing a real-time monitoring system that can be incorporated in automatic food process control system. This study aimed to find the requirements for detection of biological activities using electronic-based signal processing, and subsequently develop a model of automatic process control system in food industry.

Materials and Methods

Consultations from the experts in food engineering and biotechnology are needed to find the relevant literature and to guide the conduction of nutrient analysis using chromatography. Results based on chromatography were used as the main references in calibrating the measurement for use in the development of biosensors. A biosensor consists of two components: a bio-receptor (enzyme or antibody) and a transducer. The architecture and the material of electrodes in the formation of transducer were determined to enable immobilisation of bio-receptor and to convert the target chemical reaction product into electrical signal. The design of electronic circuits was able to receive the correct signal, to convert the incoming analogue signal into digital data and, to interface the converted digital data with computer. Finally, software were developed to provide accurate measurement results and to generate appropriate control signals or instructions.

Results and Discussion

A prototype of computer-based instrumentation system that can analyse biological activities in real-time has been developed. The system consisted of biosensors, mixed analogue-digital signal processing circuit, RS232-based computer interface circuit and an executive software. Eight biosensors can be connected in parallel. If each sensor is dedicated to detect one type of nutrient then eight type of nutrients can be detected and analysed simultaneously. The advantage of using a biosensor is that each type of nutrient can only react with a specific type of bio-receptor e.g. glucose oxidase is a bio-receptor that can react with glucose only. Each sensor consists of three electrodes: working electrode, auxiliary electrode and reference electrode. The electrodes were fabricated using gold because of its high conductivity in order to avoid signal loss. The sensitivity of the sensor was inversely proportional to the size of working electrodes. The measurement technique that involves computer interfacing is controlled by software. The operations include input channel selection, sampling rate, analogue to digital conversion, data transfer to computer, unit conversion and generation of control signal. Since the operations are controlled digitally, high measurement accuracy can be achieved. Eight windows can be displayed simultaneously on the computer screen. Each window is dedicated to an analysis based on the responses from one biosensor. Analysis results can be displayed in the form of numerical and graphical. The software has been developed using a compiler called Visual Designer. This compiler is based on block oriented programming. Since the subroutines such as mathematical expressions, display commands and communication port attribution are represented in blocks, the software development time is short. By providing allowable margin of each nutrient concentration, a signal can be generated and fed back to the process equipment if the measured data is beyond the allowable margin. With this approach the process can be controlled automatically. Other advantages offered by the proposed system include flexibility on the type of nutrients to be monitored and analysed, portable realisation by storing the software in a ROM (Read-Only-Memory) chip and ability to incorporate the system with network facilities if there is a need for real-time remote monitoring applications. Miniaturisation of the hardware can be achieved by integrating the electronic components onto a single silicon chip or PLD (Programmable Logic Device).

Conclusions

The fundamental requirements for detection of biological activities using electronic-based signal processing have been identified. A model of automatic process control system based on the requirements has been successfully developed and can be applied in food industry. Results show that the system can verify the contents of food nutrients in real-time. Different type of nutrients can be monitored and analysed simultaneously by introducing multiple biosensors where each sensor is dedicated to detect a particular target analyte. The software is able to generated signals required for controlling the processing operations automatically.

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