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An intelligent system for egg quality classification based on visible-infrared transmittance spectroscopy

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A B S T R A C T

The potential of the visible infrared (Vis–IR) (400–1100 nm) transmittance method to assess the internal quality (freshness) of intact chicken egg during storage at a temperature of 30 ± 7 °C and 25 ± 4% relative humidity was investigated. Two hundred chicken egg samples were used for measuring freshness and spectra collection during egg storage (up to 25 days). Two correlation models, firstly between Haugh unit (HU) and storage time, and secondly between the yolk coefficient (YC) and storage time, were developed and yielded correlation coefficients (R^2) of 0.86 and 0.96, respectively. These models spanned the period for which egg quality decreased dramatically and are statistically significant ($P < 0.05$). In addition, to reduce the dimensionality of the spectra and extract effective wavelengths, two methods were developed based on principal component analysis (PCA) and a genetic algorithm (GA). The output of PCA and GA were also used comparatively to design an egg quality intelligent system. The result of the analyses indicated that identification ratio of GA with fast Fourier transform (FFT) preprocessing was superior to other methods, and that the quality classification rates of this method for one-day-old eggs are 100%. This study shows that identification of an egg's freshness using NIR spectroscopy with GA and artificial neural network (ANN) is reliable.

1. Introduction

Nowadays, the main worldwide tendency is to consume only high quality food products. In the egg industry, aspects of quality perception include egg size, shell quality and egg shape, but the most important is internal quality, and this is the main concern of this study [1].

The processing of poultry eggs for human consumption has four main steps: collecting, washing, grading and packaging. Of these the first two and the last steps have largely been automated; however, human grading of eggs is still required [1,2]. Therefore, the goal of automating the grading process continue is very important for quality assurance, to minimize

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costs and reduce the work load on graders, and to generally improve the quality control process. In addition, due to the several changes which occur in the internal constituents of shell eggs during storage [3], the non-destructive grading of eggs with respect to internal quality requires specialist equipment (such as Visible-Infra-Red spectroscopy) and human expertise, and therefore is very costly. Therefore, use of a computer-based 'intelligent system' to emulate the logic and reasoning processes that an expert egg-grader would do is very attractive.

The present research utilised the results of Vis–IR spectroscopy applied to shell eggs combined with mathematical pre-processing, pattern recognition and artificial intelligence technology to create an intelligent system. This intelligent system achieved egg quality classification based on egg internal quality during storage.

2. Literature review

Currently, many researches have been focused on egg quality examination. For example, different non-destructive techniques for automatically detecting cracks, dirt and blood spots have been investigated [4–6]. Though these criteria could be useful as exclusion criteria in an on-line system, they could not demonstrate the internal quality of eggs. Therefore, researcher's attention focuses on the development of non-invasive and non-destructive instrumental techniques such as infrared and front face fluorescence spectroscopy. The potential of visible-near transmission spectra for the assessment of egg freshness and the properties of egg white quality has been demonstrated by several studies [7–10].

Giunchi et al. [11] investigated the NIR reflectance for qualitative measurement of egg freshness according to the days of storage. Predictive models showed R^2 values up to 0.722, 0.789 and 0.676 for air cell height, thick albumen heights and Haugh unit, respectively.

Kemps et al. [12] investigated the feasibility of visible transmission spectroscopy as a non-destructive assessment of the freshness of an individual egg. A partial least squares (PLS1) model was built in order to predict Haugh unit [12] and pH of the albumen based on the transmission spectra. The correlation coefficients between the predicted values and the measured values were 0.842 and 0.867 for Haugh unit and pH of the albumen, respectively [12].

Studies carried out in order to set up techniques for online prediction of the days of storage and the assessment of the egg freshness parameters involved the use of an electronic nose-based (E-nose) system [13]. Results of this study showed that the E-nose could distinguish eggs of different storage time under cool-room and room-temperature storage by linear discriminant analysis, principal component analysis (PCA), back propagation neural network (BPNN), and genetic algorithm with BP neural network (GANN). Better prediction values were obtained by GANN than by BPNN. Relationships were established between the E-nose signal and egg quality indices (Haugh unit and yolk factor) and by quadratic polynomial step regression (QPSR). The prediction models for Haugh unit and yolk factor indicated a good prediction performance with correlation coefficient 0.91, and 0.93, respectively.

3. Intelligent system conception and development

Fig. 1 shows the general structure of the intelligent system conceived. The system consists of the following components: a knowledge-based resource, an inference engine, and an explanation facility.

In general, there are two approaches in collecting the domain knowledge. In the first approach, the knowledge is garnered by the knowledge engineer from the expert(s) through interviews and discussions. In the second approach, the knowledge is obtained from technical reports, results of simulations, optimization of models and case-studies, and this was the approach was used in this study.

In order to process the data and get the best results the following methods were used.

3.1. *Preprocessing of spectroscopic data*

The preprocessing of optical data can remove the noise caused by the system error and the random error [14]. The high dimension optical data was mixed with high frequency noise.

To obtain high signal-to-noise ratio (SNR) information from spectroscopic data, the preprocessing methods of multiplicative scatter correction (MSC) [15], 1st and 2nd derivative (D^1 and D^2, respectively), Fast Fourier transform (FFT) and standard normalized variate (SNV) were evaluated. Standard normal variate (SNV) can be applied for light scatter correction and reducing the changes of light path length [16]. The derivative treatment can remove the influence of baseline variation and make the noise of a variable moderately amplified [17].

3.2. *Multivariate calibration*

Many pattern recognition problems rely critically on efficient data representation. Therefore, it is desirable to extract measurements that are invariant or insensitive to the variations within each class of interest. The process of extracting such measurements is called feature extraction [18]. In this regard, genetic algorithm (GA) and principal component regression (PCR) were used.

3.2.1. *Principal components analysis (PCA)*

Principal component analysis (PCA) is a mathematical technique which has been used specifically for extracting information from correlation matrices [19]. Since the spectral data forms the array of correlated variables which contains overlapped information, this approach makes it possible to extract useful information from high-dimensional data. To choose the number of components the 'leave-one-out' cross-validation method is used [20]. The extracted principal components are used as the input variables for the classification model.

3.2.2. *Genetic algorithm (GA)*

The method of binary encoding with population sizes of 100 was used. The probability of crossover was 0.5. The random single mutation operator is important so that it can maintain the diversity of population and prevent the appearance of a maturate phenomenon too early. The probability of mutation was considered 0.1. The criterion of convergence judgment is