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Review Paper on Efficient Quality Inspection of Food Products Using Neural Network Classification

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Abstract

With the increasing competiveness in the field of food production growing at a faster pace across the globe, quality is one of the most desirable features that a product should possess. The ability to produce quality as well as safety food is the most prerequisite factors for both, national and international market. This paper explains the recently developed approaches and latest research efforts related to the assessment of the quality of different food products through comparison of multivariate techniques and examine the potential for their deployment. Here, there is a comparison of the abilities of nine different multivariate classification methods: linear discriminant analysis (LDA), quadratic discriminant analysis (QDA), regularized discriminant analysis (RDA), soft independent modeling of class analogy (SIMCA), partial least squares (PLS) classification, K-nearest neighbor (KNN), support vector machines (SVM), probabilistic neural network (PNN), and multilayer perceptron (ANN-MLP). The overall results sufficiently demonstrate the fact that the probabilistic neural network (PNN) method has the potential to determine the quality of various food products significantly with high accuracy.

Keywords: *Food quality inspection, artificial intelligence techniques, wavelet transform, probabilistic neural network (PNN) approaches*

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INTRODUCTION

The increased awareness and sophistication among the consumers has created more expectation for an improved quality in consumer food products. This in turn has stimulated the need for enhanced quality monitoring. Quality itself is defined as the sum of all those attributes, which leads to the production of a combination of products acceptable to the consumer. Quality being the subject of a large number of studies implies the degree of excellence of a product or its suitability for a particular use [1].

Quality is a human construct and comprises of many properties or characteristics. Quality of production encompasses sensory properties (appearance, texture, taste and aroma), nutritive values, chemical constituents, mechanical properties, functional properties and defects. The component attributes of quality vary with the context. The choice of what to measure, how to measure it, and what values are acceptable, are determined by the person or institution requiring the measurement. This is done with a consideration of the intended use of the product and of the measurement, available technology, economics and often tradition [2]. Since quality is one of the most critical factors influencing customer satisfaction and future behaviors, quality has been extensively researched within the service-marketing field. Providing appropriate level of service or food is often against customers' heightened expectations. This leads to lower customer satisfaction and lower loyalty behaviors [3]. The distribution of food differs from the distribution of other products in such a way that food products show continuous quality changes throughout the supply chain [4]. This happens all the way until final consumption. Hence, in the case of food distribution, quality, health, and safety are the key factors [5].

Large scale development in the field of manufacturing technology and system has enabled automation in product processing and quality control including processing methods and precision machines. Advances in manufacturing system included flexible manufacturing system and quality control system such as automation and robotics, inspection method, automatic gauging and sensing, on-line data acquisition, and automated monitoring and diagnosis system [6]. Most of the food industries have a qualitative evaluation of products which is strictly related to human perception of odours. Electronic odour sensing systems is a pronounced tool that complements or elaborates this important quality control function. The term "electronic nose" or "e-nose" describes an instrument consisting of an array of weakly specific or broad-spectrum chemical sensors. This is intended to mimic the human olfactory system, by converting sensor signals to data that are then analyzed with appropriate software [7].

LITERATURE REVIEW

Quality Inspection Techniques in Food Products using Neural Network Classification

Application of image analysis and computer vision system used in quality evaluation of products in the field of agricultural and food has become an essential technique used in image analysis and automated sorting and grading associated with computer vision system.

Computer vision, a rapid, economic, consistent and objective inspection technique, has expanded into many diverse industries. Its speed and accuracy has satisfied the rising production and quality requirements. This aids the development of totally automated processes. This non-destructive method of inspection is applied in the agricultural and food industry. This is inclusive of the inspection of quality and grading of fruit and vegetable. It is also implemented successfully in the analysis of grain characteristics and in the evaluation of foods such as potato chips, meats, cheese and pizza [8]. A hyper spectral imaging system in the near infrared (NIR) region (900–1700 nm) was developed by ElMasrya *et al.* to assess the quality of cooked turkey hams [9]. It used different ingredients and processing parameters. Hyper spectral images were acquired for ham slices. Their origin was from separate quality grades and then their spectral data was extracted. Spectral data was analyzed using principal component analysis. This (PCA) helped to reduce the high dimensionality of the data and to select some important wavelengths. Out of 241 wavelengths, only eight wavelengths (980, 1061, 1141, 1174, 1215, 1325, 1436 and 1641 nm) were selected as the optimum wavelengths. This was used for the classification and characterization of turkey hams. The data analysis shows the possibility to separate different quality turkey hams with few numbers of wavelengths based on their chemical composition.

Artificial neural network (ANN) classifier was implemented by Dębska *et al.* for numerous quality inspection and grading tasks of diverse food products [10]. ANN is a good pattern classifier because of its ability to learn patterns that are not linearly separable. They also have concepts dealing with uncertainty, noise and random events. For example,
The ANN was utilized as a part of the order demonstrates considering the pertinent components of beer. Tests of a similar brand of beer with differing producing dates, beginning from various assembling parcels, have been spoken to in the multidimensional space by information vectors. This was a get together of 12 components (% of liquor, pH, % of CO2 etc.). The order was performed for two subsets. The initially included specimens of good quality beer and the other contained examples of unsuitable quality. ANN procedures permits segregation between characteristics of beer tests with up to 100% of right orders.

An electronic nose in light of a variety of six metal oxide semiconductor sensors was utilized as a part of mix with artificial neural network (ANN) strategy [11]. This was utilized to order pecorino cheeses as per their aging time and assembling systems. For this reason, electronic nose signs were dealt with and tried. Especially, four unique elements extraction calculations were contrasted and a principal component analysis (PCA) was used to reduce the dimensionality of informational

collection (information comprised of 900 information focuses per sensor). All the ANN models (with various pre-treatment information) have distinctive abilities to foresee the pecorino cheeses classifications.
Table 1 presents various quality inspection techniques in food products using neural network classification.

Automated Processing of Food Products Based on Computer Vision System

Liu *et al.* have described the basic taxonomy of the methods [12]. Their respective advantages and disadvantages were also taken into account. Special attention was paid to recent developments in wavelength selection techniques for HIS. This was so in the field of food quality and safety evaluations. Typical commonly used methods in HSI, such as partial least squares regression, stepwise regression and spectrum analysis, were explained in detail. Some sophisticated methods, such as successive projections algorithm, uninformative variable elimination, simulated annealing, artificial neural network and genetic algorithm methods were also discussed.

Costa *et al.* have studied the main applications of shape analysis on agricultural products such as relationships between shape and: (1) genetic; (2) conformity and condition ratios; (3) products characterization; (4) product sorting and finally, (5) clone selection [13]. A new automated shape processing system was proposed. This seems to be useful for both scientific and industrial purposes, there by forming the base of a common language for the scientific community.

Narendra *et al.* have presented the recent development and application of image analysis and computer vision systems [14]. This was used to sort and grade products in the field of agriculture and food. More over basic concepts and technologies associated with computer vision, a tool used in image analysis and automated sorting and grading was also highlighted.

Liming *et al.* designed the automated strawberry grading system [15]. This was chiefly based on three characteristics: shape, size and color. The system efficiently helped to obtain the shape characteristic by drawing the lines and then class with K-means clustering method for the strawberry image. The color of the strawberry adopts the dominant color method, and the size was described by the largest fruit diameter. The strawberry automated grading system could use namely one, two or three characteristics to grade the strawberry into three or four grades. In order to solve these multidimensional problems, the multi-attribute decision making theory was adopted in this system.

Table 1: *Quality Inspection Techniques in Food Products Using Neural Network Classification.*

Author Name and Year	Method	Function	Pros and cons
Narendra and Hareesh 2010 [8]	Image processing and image analysis	Computer vision constructs explicit and meaningful descriptions of physical objects from images	Computer vision inspections of food products are more consistent, efficient and cost effective. Also, with the advantages of superior speed accuracy and computer vision
ElMasry *et al.* 2011 [9]	NIR hyperspectral imaging system	The following technique provides useful information about the quality of food products being examined and the effects of different processing regimes	❖ Non-destructive technique. ❖ Clear and accurate data.
Debska *et al.* 2011 [10]	Data mining techniques (ANN, SVM and multiple regression MR)	ANN techniques allowed the discrimination between qualities of beer samples with up to 100% of correct classifications	Data accuracy
Cevoli *et al.* 2011 [11]	Artificial neural network (ANN) method with GC–MS volatile and electronic nose analysis	The method was capable of classifying pecorino cheese according to their ripening time and manufacturing techniques using MOS sensors	Provides 100% classification performance

The system applied a conveyer belt, a camera, an image box, two photoelectrical sensors, a leading screw driven by a motor, a gripper, two limit switches and so on. The system control was done by the single-chip-microcomputer (SCM) and a computer.

Girolami *et al.* [38], 2013 have investigated the limits of the colorimeter and a technique of image. This was used in the evaluation of the color of beef, pork, and chicken. The Minolta CR-400 colorimeter and a computer vision system (CVS) was also employed to measure colorimetric characteristics. In order to evaluate the chromatic fidelity of the image of the sample displayed on the monitor, a similarity test was carried out using a trained panel.

Artificial vision frameworks are capable apparatuses utilized for the programmed assessment of products of the soil. Run of the mill targets uses of these frameworks in corporate reviewing, quality estimation from outside parameters or interior elements, checking of natural product forms amid capacity or assessment of trial medicines. The abilities of a simulated vision framework is considerably more than the constrained human limit of assessing long haul forms equitably or to acknowledge occasions that occur outside the noticeable electromagnetic range. Utilization of the ultraviolet or close infrared spectra investigates deformities or components that the human eye can't see. Hyperspectral systems give data about individual segments or harm. This can be seen just at specific wavelengths and can be utilized as an apparatus to grow new PC vision frameworks adjusted to specific targets. With the assistance of in-line evaluating frameworks, colossal measures of organic product or vegetables can be reviewed separately. This gives insights about the clump. When all is said in done, counterfeit frameworks substitute human review, and additionally enhance its abilities [14].

A summary of automated processing of food products based on computer vision system has been presented in Table 2.

Automated Grading System in Food Products

Dubosclard *et al.* have proposed a technique for an automatic method for visual grading [16]. This was designed to solve the industrial problem of evaluation of seed lots. The sample was thrown in bulk onto a tray placed in a chamber used to acquire color image. An image processing method was developed to separate and characterize each seed. The approach adopted the segmentation step based on the use of marked point processes and active contour. This paves the way of tackling the problem by a technique of energy minimization.

Arivazhagan *et al.* have proposed a strategy in view of PC vision procedures [17]. It was utilized to perceive an organic product that was dependable on four essential elements, which describe the question: power, shading, shape and surface. The paper proposed a productive combination of shading and surface components for organic product

Table 2: *Automated Processing of Food Products Based on Computer Vision System.*

Author Name and Year	Method	Function	Pros and Cons
Costa *et al*. 2011 [13]	Artificial Neural Network	ANN method quantifies the variation in the shape of fruits are particularly useful as nonlinear regression tools	Significantly performs arbitrary non-linear mappings in patterns of information.
Narendra *et al*. 2010 [14]	Computer vision and image analysis	A computer vision system consists of two basic components, which are image acquisition: illumination and image capture device (camera) and image analysis: an image capture board (frame grabber)	❖ The technique is incredibly vigorous. ❖ Non-destructive cost-effective technique ❖ Less time-consuming, and highly consistent
Cubero *et al*. 2010 [4]	Hyperspectral image analysis	Hyperspectral systems provide information about individual components or damage that can be perceived only at particular wavelengths and can be used as a tool to develop new computer vision systems adapted to particular objectives	Assess features like color, size, shape, texture and presence of damage of food products with high speed and accuracy

acknowledgment where the base separation classifier based upon the factual did the acknowledgment and co-event highlights got from the wavelet transformed sub-bands.

Fadilah *et al.* have developed a readiness characterization of oil palm crisp natural product bundles [18]. This was done (FFBs) amid gathering to guarantee that they are collected amid ideal stage for greatest oil generation. The paper exhibited the utilization of shading vision for computerized readiness order of oil palm FFB. Pictures of oil palm FFBs of sort DxP Yangambi were gathered and broke down. This was done utilizing computerized picture handling systems. The shading components were further separated from those pictures and utilized as the contributions for artificial neural network (ANN) learning. The execution of the ANN for readiness arrangement of oil palm FFB was examined misusing two strategies: preparing ANN with full elements and preparing ANN with decreased elements in light of the principal component analysis (PCA) information diminishment strategy.

Pre-Processing Segmentation of Image in Food Products

Duchesne *et al.* have developed methods and applications of multivariate image analysis [19]. These methods were developed for use in the process industries. It presented a general framework for the methods and their applications and discussed them under image analysis methods. Here, only spectral features of the images, such as multivariate image analysis (MIA), and multivariate image regression (MIR), and those that use textural features and combinations of textural and spectral features were put to use. The emphasis was on applications like monitoring, prediction and control, and on those aspects of the methods that make them compatible.

Panagou *et al.* have introduced a multispectral imaging system [20]. It is used for the evaluation and monitoring of aerobically packaged beef filet spoilage at different storage temperatures (0, 4, 8, 12, and 16°C). Spectral data in the visible and short wave near infrared area (405–970 nm) were collected from the surface of meat samples and correlated with microbiological data (log counts), for total viable counts (TVCs). Qualitative analysis were further (PLS-DA) employed for the discrimination of meat samples in three microbiological quality classes based on the values of total viable counts. Furthermore, PLS regression models were developed to provide quantitative estimations of microbial counts during meat storage. In both the cases, model validation was implemented with independent experiments. They were stored at intermediate temperatures (2 and 10°C) using different batches of meat.

Montalban *et al.* have analyzed the images collected using either few spectral channels (sometimes called multispectral images) or, most recently, data treatments that deal with hyperspectral images [21]. Here, the spectral direction is exploited in its full extension. Pioneering data treatments in image analysis were applied to simple images. This was used mainly for defect detection, segmentation and classification. New fields brought in with the introduction of chemometrics on image analysis are exploratory image analysis, multivariate statistical process control (monitoring), multivariate image regression or image resolution.

Wu *et al.* have presented the fundamental and application side of a hyperspectral imaging technique [22]. The basic principles and theoretical aspects of this technique, including the processing methods for data analysis, and the main features of instruments were presented. This was followed by a general overview of applications in quality determination for numerous food products to illustrate the applicability of this technique in the food industry. This was also used for sample classification and grading, defect and disease detection, distribution visualization of chemical attributes in chemical images, and evaluations of the overall quality of meat, fruits, vegetables, and other food products.

Moghaddam *et al.* have presented late utilizations of hyper ghostly imaging in quality and wellbeing review of nuts and grains [22]. They included audit of arrangement, structures expectation, surface examination, and location

of varietal pollutions, harms, and contaminations.

Khoshroo *et al.* have proposed arrangement of four Iranian wheat [23]. This was done utilizing morphological components and fake neural systems. After the readiness of tests, 164 pictures of grains were obtained for every cultivar in a lighting chamber. Ten morphological components were separated from pictures utilizing picture preparing procedures and for ordering wheat assortments, different topologies of artificial neural network (ANN) with various number of neurons in the shrouded layers were created. The nine imperative morphological elements extricated from pictures were utilized as the contribution for created ANN.

Mollazade *et al.* have explored quality evaluating of raisins [24]. This was done utilizing picture handling and information mining based classifiers. The pictures from four unique classes of raisins (green, green with tail, dark, and dark with tail) were procured utilizing a color CCD camera. After pre-processing and division of pictures, 44 highlights including 36 hues and eight shape elements were removed. Connection based element determination was utilized for the choice of best components for evaluating the raisins. Among them, seven components were observed to be predominant. Keeping in mind the end goal to group raisins, four unique information-mining-based systems including artificial neural networks (ANNs), support vector machines (SVMs), decision trees (DTs) and Bayesian networks (BNs) were examined.

Gill *et al.* have described a technique used to discriminate between four different grades of made black tea [25]. Here, textural features were used based on grey tone spatial dependencies. The statistical features were computed from the tea images and wavelet decomposed sub band images. The multi-layer perceptron (MLP) technique was used for the purpose of data classification.

Boukar *et al.* have designed a CFA (Color Filter Array) image processing system [26]. This was used to measure water absorption capacity (WAC) of bean grains with high precision in short time intervals (10 min). The relationships between the CFA image features, extracted from raw images captured by CCD (charge coupled device) camera, and the measured WAC were also established. The calibration models using multiple linear regression (MLR) were further developed to predict WAC [27].

Wavelet Analysis of Signals in Agriculture and Food Quality Inspection

Pu *et al.* have built up the utilization of wavelet investigation to near-infrared (NIR) hyper ghostly imaging information [28]. This was utilized for the arrangement of sheep muscles. An assortment of basic wavelet changes was researched to distinguish the best wavelet highlights for the order of sheep muscles. The fifth-order Daubechies wavelet ("db5") was imagined as the best wavelet work for deterioration of sheep unearthly flag. Elements of wavelet coefficients extricated from db5 wavelet at the fifth deterioration level were then utilized as the contributions of least squares support vector machine (LS-SVM) for creating order models and principal component analysis (PCA) was utilized for dimensionality decrease. In view of unique, first subordinate, second subsidiary, smoothing, standard normal variate (SNV), and multiplicative scatter correction (MSC) ghastly information order execution of LS-SVM classifiers pair with wavelet change and PCA was contrasted and the LS-SVM models. Then, the general right arrangement execution for the preparation and test sets utilizing mix with wavelet guess and detail coefficients in fifth deterioration scale and PCA was found.

Deng *et al.* have focused on the Fourier frequency analysis of a vibration-based response [29]. The paper proposed a new detection methodology for eggshell cracks. Here, a continuous wavelet transform and a support vector machine (SVM) technique was made use of. The proposed methodology consists of an experimental system and a data processing system. The experimental system was used to generate the impact force and to measure the acoustic signal, and the data processing system extracted timely signal features. This was used for the classification of the signals based on an SVM algorithm that is presented herein. The wavelet change was acquainted with conquer the disadvantages of

the traditional Fourier investigation and to discover new break delicate components in view of the neighborhood time and recurrence data of the flag. By breaking down the vitality conveyance of the wavelet change coefficients for split and in place eggs, a few wavelet-based elements were extricated. These components incorporate the first resonance scale (FS), the s-coordinate (SC) and the corrected t-coordinate (TC) of the centroid for the time-scale area, and the weighted standard deviation (WD). These components, and also the distinctive blends of it, were utilized to build the SVM classifiers. The characterization impacts of the best single-, two-, and three-highlight SVM classifiers and the four-include SVM classifier are given.

Jackman *et al.* have developed a method to discriminate between various grades of pork and turkey ham exploiting the color and wavelet texture features [30]. Image analysis methods were developed for predicting the palatability of beef. This was applied rapidly to identify the ham grade. With high quality digital images of 50–94 slices per ham, it was possible to identify the grayscale. It best expressed the differences between the various ham grades. The best 10 discriminating image features were found with the help of a genetic algorithm.

Munoz *et al.* have presented and discussed the application of multivariate wavelet texture analysis (MWTA) as it was applied to three different types of pharmaceutical materials: (a) tablet cores, (b) wet granules and (c) controlled release tablets [31]. The application of MWTA was initially proposed as a quantitative replacement to the human visual judgment of the textural appearance of the different materials. In all cases, the metrics obtained with MWTA agrees with visual assessment on the progression of textural features. Here, the features that were stressed are erosion and surface roughness. It also demonstrates that MWTA is represented as a useful tool to increase the understanding of the manufacturing process. This is because it provides diagnostics to relate process parameters with textural features of the material that are difficult or costly to measure. MWTA was also presented as a potential tool for real-time release for those cases where the textural features proved to provide sufficient accurate predictions of the final product performance.

Hsieh *et al.* have developed an integrated system where wavelet transforms and recurrent neural network (RNN) based on artificial bee colony (ABC) algorithm (called ABC-RNN) were combined for stock price forecasting [32]. The system comprises of three stages: First, the wavelet transform using the Haar wavelet was applied to decompose the stock price time series. This eliminates the noise. Secondly, the RNN, which has a simple architecture and uses numerous fundamental and technical indicators, was applied to construct the input features chosen via stepwise regression-correlation selection (SRCS). Thirdly, the artificial bee colony algorithm (ABC) was utilized to optimize the RNN weights and biases under a parameter space design.

Kiani *et al.* have weighed the advantages of image processing to automatically detect and localize the crops and to remove all other undesired plants growing within rows and between two crops [33]. Wavelet transformation of digital images discriminated several spatial orientations. This was very effective in analyzing the information content of images. In this study, wavelet analysis was used to extract appropriate features for classification. The mask was calculated for each sub-band of wavelet transform and then, energy, entropy, contrast, homogeneity and inertia features were extracted from each sub-band. Finally, these features were fed into a multi-layer perceptron neural network to compartmentalize corn and weeds from each other that is commonly found in corn farms.

Li *et al.* have introduced a shrewd technique for the acknowledgment of various sorts of Chinese renowned tea [34]. This depends on multi-phantom imaging system. Two sorts of highlight extraction techniques including dim level co-event lattice and wavelet transform (WT) were received for mining normal for multi-spectral picture. At that point, multi-class minimum square bolster vector machine models were embraced for the grouping of

multi-otherworldly picture. This is little been utilized as a part of this area. In the meantime, the receiver operating characteristic (ROC) bend examination was utilized to assess the execution of multi-spectral imaging classifier. In order to explore the structure of the wavelet textural features (WTFs), principal component analysis (PCA) was performed based on all the WTFs, and finally, the most important features were detected through loading weight analysis of PCA.

Mohammadpour *et al.* have proposed continuous wavelet transform as well as first and second derivative spectrophotometry methods for simultaneous quantitative analysis of triamterene and hydrochlorothiazide [35]. Here, the time-consuming extraction step was done away with. In the wavelet transform method, different wavelet families were tested and subsequently coiflets wavelet family (coif1) and reverse biorthogonal wavelet family (rbio 2.8) were selected. This was applied under the optimal conditions for simultaneous analysis.

The two above mentioned methods were based upon the use of the continuous wavelet and derivative transforms of the spectra and measurement at zero-crossing wavelengths. Validation of the developed methods was confirmed by analyzing various synthetic mixtures of the investigated drugs.

MULTIVARIATE CLASSIFICATION METHODS FOR FOOD QUALITY INSPECTION

Linear Discriminant Analysis (LDA)

Among the successful techniques used for data classification, linear discriminant analysis (LDA) is a commonly used one [36]. Linear discriminant analysis (LDA) is used to find the linear combination of features which separates the best of two or more classes of object or event. The resulting combinations may either be used as a linear classifier, or more commonly in dimensionality reduction before later classification. This method maximizes the ratio of between-class variance to the within-class variance in any particular data set thereby guaranteeing maximal separation. LDA is used to find the linear combination of features, which best separates two or more classes of object or event. The resulting combinations may be used as a linear classifier. The number of principal components (PCs) determines the performance of the LDA discrimination model. In this study, the number of PCs was optimized by cross-validation in developing LDA model. The optimal number of PCs was decided according to the highest discrimination rates by cross-validation [37].

Quadratic Discriminant Analysis (QDA)

In quadratic discriminant analysis, it cannot be assumed that the covariance of each of the classes is identical. When there is true assumption, the best possible test for the hypothesis is a given measurement from a given class. This is the likelihood ratio test.

Regularized Discriminant Analysis (RDA)

Regularized discriminant analysis (RDA) is a combination of both LDA and QDA. RDA introduces a double type of bias in the estimation of the covariance matrices of each class. This is done with the aim of stabilizing the prediction in the case of a deficient estimation of their elements. This is a very frequent problem encountered with real data due to the fact that estimations of the matrices are very sensitive to the presence of different data.

Soft Independent Modeling of Class Analogy (SIMCA)

Soft independent modeling of class analogy (SIMCA) is a strategy utilized for directed information grouping. This requires a preparation information collection comprising of tests (or protests) with an arrangement of qualities and their class participation. The expression "delicate" alludes to the reality; the classifier can recognize tests having a place with different classes and need not really deliver an order of tests into non-covering classes. To fabricate the grouping models, the examples having a place with each class should be broken down utilizing principal components analysis (PCA). For a given class, the subsequent model portrays a line, plane or hyper plane. As each demonstrated class is concerned, the mean orthogonal separation of preparing information tests from the line, plane or hyper plane (ascertained as the remaining standard deviation) is utilized to decide a basic separation for arrangement.

Partial Least Squares (PLS) Regression and Classification

Partial least squares (PLS) regression can be called an extension of the multiple linear regression models. PLS method has variant uses in multivariate analysis of spectral data. The main goal of PLS usage is calibration model building, but this technique can also be applied for classification purposes.

K-Nearest Neighbor (KNN)

K-nearest neighbors (KNN) is a linear and non-parametric supervised pattern recognition method. An unknown sample in prediction set is classified according to the majority of its K-nearest neighbors in training set. Parameter K greatly influences, to a large extent, the identification rate of KNN model. Moreover, the optimal value of K is determined in the KNN calibration process. Parameter K value is chosen according to the subsequent KNN classification. The optimal results are measured by a minimum prediction error. The prediction errors for a given set of K values are estimated by cross validation, and the value of K that gives the highest prediction rate is selected. Meanwhile, the number of principal component factors (PCs) also should be optimized [36].

K-Nearest neighbor (KNN) method was first introduced by Fix and Hodges. In this method, after distance (Euclidean or other) assigning distance (Euclidean or other) between all points in a data set, the data points, K-closest neighbors (K being the number of neighbors), are found by analyzing (sorting) the distance matrix. The K-closest data points are then analyzed to determine the most common class label among the set ("voted" KNN).

The most common class label is then assigned to the data point being analyzed. This is done along with other variants of KNN ("weighted" KNN). In these methods, different neighbors have different "weight"; this has the ability to influence on class of sample according to their distances from the sample. For KNN classifier, it is necessary to have a training set which is neither too small, yet with a good discriminating distance. KNN performance is best in multi-class simultaneous problem solving. There exists an optimal choice for the value of the parameter K, which brings in the best performance of the classifier. This value of K is often approximately close to $\sqrt{N}$ [37].

Support vector machines have been developed by Vapnik. Support vector machines (SVM) are based on some "beautifully simple ideas". But, they provide a clear intuition of learning from examples. SVM also shows high performance in practical applications. In very simple terms, an SVM corresponds to a linear method in a very high dimensional feature. This is nonlinearly related to the input space. Even though we think of it as a linear algorithm in a high dimensional feature space, practically, it does not involve any computations in that high dimensional space. By using kernels, all necessary computations are performed directly in the input space. Support vector machines map input vectors to a higher dimensional space where a maximal separating hyper plane is constructed. Two parallel hyper planes are constructed on each side of the hyper plane that separates the data. This maximizes the distance between the two parallel hyper planes. The assumption is that the larger the margin or distance between these parallel hyper planes, the better the generalization error of the classifier.

Support Vector Machines (SVM)

The ideology of multilayer perceptron (MLP) usage for classification problem is similar to that of PLS classification. The main dissimilarity between MLP and PLS is the ability of MLP in solving nonlinear problems [36].

Probabilistic Neural Network (PNN)

The probabilistic neural network (PNN) was developed by Specht. The probabilistic neural network provides a general solution to pattern classification problems. This is done by following an approach developed in statistics, called Bayesian classifiers. PNN uses a supervised training set to develop distribution functions within a pattern layer. These functions, in the recall mode, estimate the likelihood of an input feature vector being part of a learned category, or class. The learned patterns can also be combined, or weighted, with a priori probability, also called the relative frequency, of each category to

determine the most likely class for a given input vector.

Multilayer Perceptron (MLP)

For KNN classifier, it is important to have a training set which is neither too small, but that has a good discriminating distance. KNN performance is well in multi-class simultaneous problem solving. There exists an optimal choice for the value of the parameter K. This brings in the best performance of the classifier. This value of K comes approximately close to √N.

Artificial Neural Networks (ANN) Model

Considering the fact that the linear model does not provide a complete solution to the classification problem, non-linear approach such as artificial neural networks (ANN) was used in this work. Artificial neural networks (ANN) are well known as a classification algorithm, and their application in solutions to classification problem of NIR spectra data, is reported. In developing ANN model, some parameters to a certain extent influence the performance of final model. These parameters include the number of neurons in the hidden layer, scale functions, learning rate, momentum factor, and initial weight. In this work, the classical back propagation artificial neural network (BP-ANN) with 3-layers topology construction was used in the development of the discrimination model. The parameters of the BP-ANN model were optimized by cross-validation as follows: the number of neurons in the hidden layer was set as 5, the learning rate and momentum factor were set as 0.1, the initial weight was set as 0.3, and the scale function was set as 'tanh' function. Selection of the appropriate number of PCs in developing a BP-ANN model is crucial [37].

Artificial Chemistry Optimization

Artificial chemistry (AChem) is a computational paradigm used for search, optimization, and machine learning. In this paradigm, the artificial molecules represent machine or data and the interactions among these molecules are driven by an algorithm. The duality of the molecule to represent either a machine (or operator) or data (or operand) is what that enables a molecule to process other molecules or be processed. This dual property of molecules enables one to implicitly define a constructive computational procedure. Here, the procedure adopted is by using the dynamics of chemical reaction as a metaphor to solve complex optimization problems. The capacity of AChem to simultaneously find solutions to different problems makes it a potent solution to find the best ANN structure for the classification problem [37].

Processing Images for Inputs to ANN

A simple edge-detection algorithm was used for identifying and extracting the images. This is achieved by removing their respective backgrounds. The extraction process includes the red, green, and blue (RGB) spectral patterns of the background-less image thereby confirming that only the RGB patterns of the produce were recorded. Then, the RGB patterns were normalized by scaling each RGB value with the number of pixels of the product image. Thus, the RGB patterns have values that range from 0 to 1.4. Then the normalized RGB patterns were stored in a file together with the image's classification [38].

Optimization of Classifiers

When we make a comparison of different classification models, their best results should be obtained. The result of model usage depends on the model parameters. We have made use of wide ranges of models' parameters to achieve the best results. The optimal number of principal components (PC) or the optimal level of spectra averaging was located for soft independent modeling of class analogy (SIMCA) method. For PLS classification, the class (one of N) of each sample was coded by N binary strings. Different types of K-nearest neighbor (KNN) method (voted and weighted by different weighting functions) were utilized to get the best result. Different types of kernel functions (and corresponding parameters) were checked for optimization of SVM table 3 classification model.

Optimal PNN spread value was found. Artificial neural network (ANN) analysis of spectral data was also performed with multilayer perceptron (MLP). Similar to PLS analysis, each class was coded by N binary strings. A three-layer MLP (structure: PC–NN–N) with input, hidden, and output layers was used. Each weight of the bond that

Table 3: *Building Parameters for Support Vector Machine (SVM) Classification Model.*

Kernel	Formula	Cost Parameter C
Linear	$Y(s_p, s_q) = s_p s_q + 1$	C=0.001–100
Polynomial	$Y(s_p, s_q) = (s_p s_q + 1)^z$	C=0.001–100
Gaussian	$Y(s_p, s_q) = \exp \frac{\left(\left\|s_p - s_q\right\|\right)^2}{\left(\sigma^2\right)}$	C=0.005–50

Table 4: *Training Parameters of Multilayer Perceptron (MLP).*

	Product Used
Algorithm	Constant learning rate
Minimized error function	Mean squared error (MSE)
Learning	Supervised
Initialization method	Random
Transfer functions Input layer Hidden layer Output layer	 – Hyperbolic tangent (tanh) Hyperbolic tangent (tanh)
Learning rate	0.001
Maximal number of epoch	100,000
Early stopping	5-Fold cross-validation
Number of training iterations	250
Number of input neurons	1–25
Number of hidden neurons	1–25

connects hidden and input units or output and hidden units was trained by means of back propagation. The prediction of the class of individual samples was performed using N predicted output scores.

Training parameters for multilayer perceptron are shown in Table 4.

Model Efficiency Estimation

To characterize prediction ability (efficiency) of created classification model, the error of cross-validation (E) was used E=**E=** $\frac{N_o - N_{right}}{N_o}$

where,

Nright refer to the number of rightly classified samples; and N0 is the total number of samples in validation set.

RESULT AND DISCUSSION

Implementation of Software

MATLAB (2013, b) was used as standard software for classification methods realization. Different kinds of toolboxes were used.

The methods can be segregated into the following groups (according to the error of classification) namely: highly effective methods, methods of medium effectiveness, and methods of low effectiveness.

Table 5: *Classification of Model Efficiency.*

Models	$\frac{N_{right}}{N_o}$, **Where, Nright=Number of Rightly Classified Samples; N0=the Total Number of Samples in Validation Set**	$\mathbf{E} = \frac{N_o - N_{right}}{N_o}$
LDA	30/30	0%
QDA	28/30	0.06%
RDA	29/30	0.03%
SIMCA	25/30	0.16%
N-PLS	26/30	0.13%
MLP	22/30	0.26%
KNN	21/30	0.3%
SVM	24/30	0.2%
PNN	20/30	0.33%

The methods presented above show that nine multivariate methods used in this study can be separated into three groups, according to their classification accuracy.

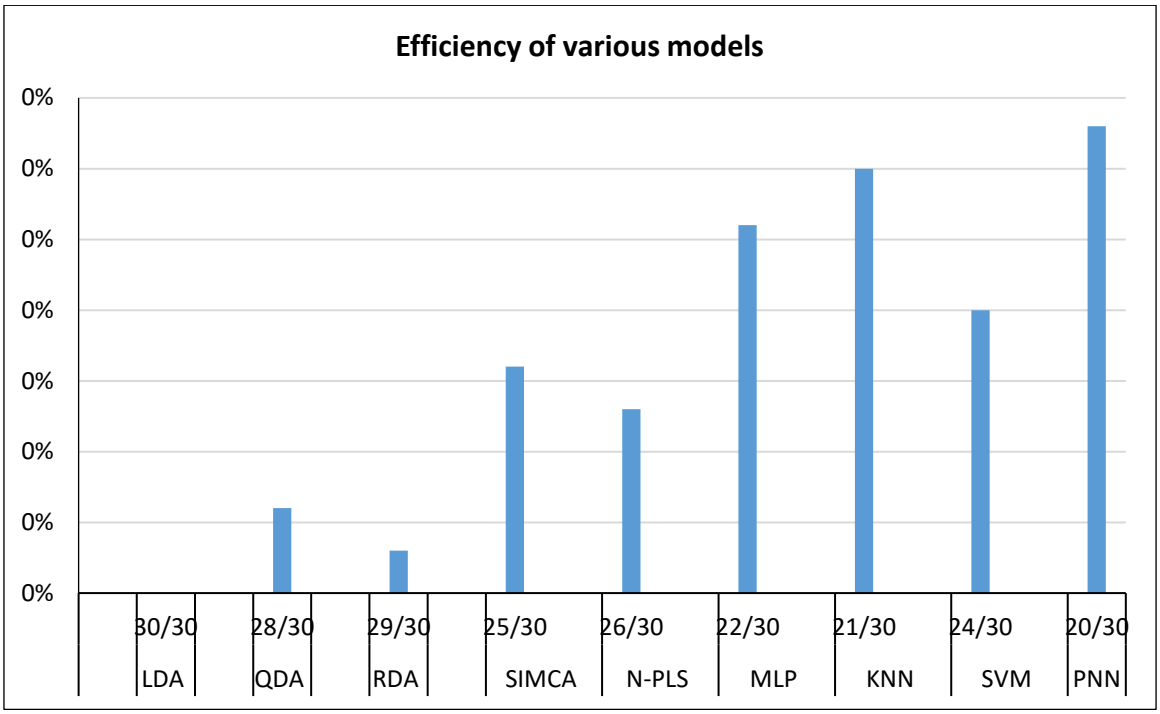

Fig. 1: *Graphical Representation of Efficiency for Various Models.*

The first group ("highly accurate methods") includes KNN, SVM, and PNN methods; the second group ("methods of medium effectiveness") consists of MLP and PLS models; the third group ("methods of low effectiveness") includes SIMCA and discriminant analysis methods (LDA, RDA, and QDA). With respect to its effectiveness the classification methods can be arranged in the following order: PNN≥KNN>ANN-MLP≥SVM>SIMCA≥N-PLS>QDA≈LDA≈QDA (Figure 1 and Table 5).

CONCLUSIONS

After our examination of different approaches to evaluate the quality of food products, we can conclude that: The probabilistic neural network (PNN) method is the most effective way amongst the various multivariate models. This method can be recommended for food industrial inspection process. K-Nearest neighbor (KNN) and support vector machines (SVM) classifiers have also shown adequate results.

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