Artificial vision and embedded systems as alternative tools for evaluating beef meat freshness

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Abstract— **Beef meat is a high nutritious product as it is filled with proteins, vitamins, and many other nutrients that have many beneficial health effects. Global demand of meat are still increasing. Thus ensuring high quality and maintaining the freshness of meat has become a main concern of manufacturers, distributors and sellers in order to avoid economic loss. Imaging methods such as artificial vision have been recently utilized to visually assess beef meat based on color, shape, size, surface texture features. This paper reports a synthesis of our recent researches about beef meat freshness based on color and texture features using the artificial vison technique.**

Keywords—artificial vision, embeded system, portable system, beef meat freshness.

I. INTRODUCTION

Beef meat is a high nutritious product as it is filled with proteins, vitamins, and many other nutrients that have many beneficial health effects [1]. Global demand for meat has increased by 70 million tons in 1961 and 283 million tons in 2011 [2]. Thus ensuring high quality and maintaining the freshness of meat has become a main concern of manufacturers, distributors and sellers in order to avoid economic loss.

During transportation and conservation, meat tends to spoil. Spoilage is defined as complex dynamic process owing to the reactions of enzymes tissue and chemical reactions such as oxidation and it is often accompanied with changes in color, smell, and texture [3]. Therefore, it is imperative to controle and evaluate meat freshness before making them available to consumers.

In brief, several techniques are used for assessing beef meat freshness. In one hand, traditional techniques such as microbiological analysis are destructive, laborious and not suitable for real-time assessment. On the other hand, imaging methods have been recently utilized to visually assess beef meat based on color, shape, size, surface texture features. Artificial vision is one such method. It is non-destructive, reproductive, fast and suitable for real-time assessment.

Artificial vison, named also machine vision has been used to obtain and analyze the actual scene image by means of computers that get the data or control the process [2]. Though, as this technique is based on computer system for data processing, it can easily be affected by processor speed and computer stability. The limitation of hardware arithmetic speed affects the real-time performance of the system.

Therefore, it was necessary to develop of a portable device that can be rapid, reproductive, inexpensive and easy to use for beef meat freshness evaluation .

In this paper, we present a synthesis of our recent researches about the assessment of beef meat freshness using artificial vision technique.

The reminder of this paper is organized as follows. Section 2 gives an overview of the materiel and methods used. Section 3 presents the obtained results. Finally, a conclusion is provided in section 4.

II. MATERIAL AND METHODS

A. Meat samples preparation

Beef meat samples were purchased from different providers from the market of the city of Beni Mellal (Morocco). The samples were transported under refrigeration to the laboratory. They were placed in plastic boxes and kept under cold storage at 4 ± 1°C for nine days. The choice of 4± 1°C temperature storage refers to the temperature storage of meat in grocery stores [4].

B. Embedded system description

The proposed embedded system contains four principal systems: the illumination system, the processing system, the image acquisition system and the display system.

The illumination system contains fluorescent lamps. The processing system contains an EVM6678 evaluation module platform. The acquisition system contains GigEPRO camera series and the display system use a pc for the results display. Fig.1 illustrates the proposed system. Interested readers are addressed to [5]. The embedded system is characterized by its portability, rapidity and it can be used in real time and on-site.

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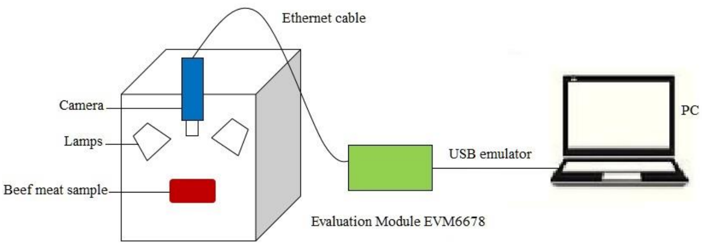


Fig. 1. Structure of the device hardware [6]

C. *Image processing using color features*

Color is one of the most important quality traits of meat that the consumers check before purchase. In the customer's views, freshness is related to bright red in red meats [7]. Therefore, in order to measure changes of color in beef meat surface, parameters of beef meat HSI images captured during nine days were used to build the classification models. Mean, variance, standard deviation and interquartile range features were calculated from a window of (200x200) pixels from each image. The transformation from RGB to HSI is given in [8].

D. *Image processing using texture features*

To extract texture features, the saturation images of beef meat samples were decomposed using the fast wavelet transform. The wavelet transform allows a digital image to be decomposed by a wavelet mother into sub-band in the horizontal and vertical directions [6]. Low and high pass filters are applied to the image along rows and columns separately. This yield to three detailed sub-images: horizontal high-pass sub-image, vertical high-pass sub-image, and diagonal high-pass sub-image and one approximate low-pass sub-image. The symlet mother wavelet was used at the 6th order and at two decomposition levels. At each decomposition level, 4 texture parameters have been calculated i.e the mean, standard deviation, energy and entropy of each sub-image, and the values were then standardized. More details can be found in [6].

Gray level co-occurrence matrix (GLCM) method was used to characterize meat texture surface [9]. Haralick parameters such as contrast, energy, entropy, and homogeneity were extracted from the saturation images and used to form the training model. The distance between two pixels was set to 1 d= 1 and $\boldsymbol{\theta} \epsilon$ [0, 45, 90, 135].

E. *Principal Component Analysis (PCA)*

PCA is a well-known unsupervised linear method describing dataset without a priori knowledge of the data structure and which is successfully used in meat freshness applications. PCA can be used for feature extraction, dimension reduction, classification and prediction. PCA transforms original feature vectors from large space to a small subspace with lower dimensions by creating new variables called principal components (PCs) [4].

F. *PCA predict*

PCA predict method is deduced from PCA algorithm. It permits to predict the class of unknown samples based on the model build by PCA. Interested readers are addressed to [5]

G. *Support Vector Machines (SVM)*

SVM is a supervised learning algorithm based on statistical learning theory. It has been widely used since its introduction by Cortes and Vapnik [10]. It is considered one of the most powerful classification engines due to its mathematical background. SVMs were originally designed for binary classification. Since in this application meat freshness classification and identification is a multi-class problem, a combination of binary classifiers is required. In fact, there are two types of approaches for multiclass SVMs. One is by constructing and combining several binary classifiers (one-against-one or one-against-all methods), while the other is by directly considering all data in one optimization formulation.

H. *Probabilistic Neural Network (PNN)*

Neural networks are often used in classification in a supervised way since classes are mentioned in advance in the learning phase. It was based on the concept of utilizing a nonparametric estimator for obtaining multivariate probability density estimates. The most used for classification problems are the Radial Basic Functions (RBF) networks whose architecture is that of (Multiple Layer Perceptron: MLP) and a Gaussian activation function. PNN is one of them. Proposed by Specht [11], PNN is presented as an implementation of the Bayes decision rule as a neural network, based on maximum probability classifiers. A typical PNN is composed of an input layer, a layer of patterns or target classes (hidden layer) and an output layer.

I. *Linear Discriminant Analysis (LDA)method*

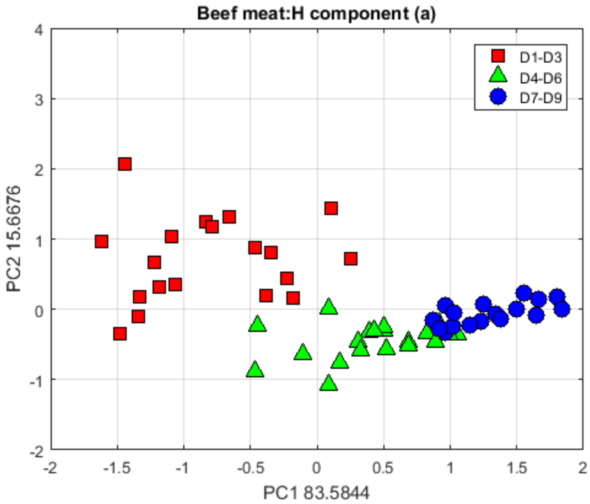
LDA as a supervised pattern recognition method utilized for predictive technical analysis. Initially introduced by Fisher and Mahalanobis [12], It aims for explaining and predicting the membership of an individual to a predefined class (group) based on his indicators measured using predictive variables. It is also used for dimension reduction of a dataset and compressing the information into interpretable variables, called latent variables.

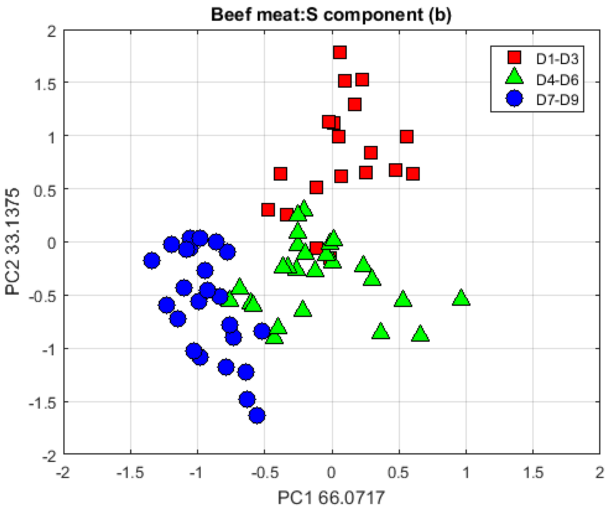
III. RESULTS AND DISCUSSION

A. *PCA using color datasets*

PCA was performed first in order to provide partial visualization of color datasets in a reduced dimension and second to determine the capability of the proposed system to recognize either the meat samples are fresh or not. The projection result of PCA permits to visualize groups of samples that have similar properties, which could indicate if they are fresh or spoiled. Fig. 2 presents the color dataset projection by PCA of HSI beef meat images. It can be concluded form the figure that the saturation channel can be reliable to classify beef meat freshness according to days of cold storage. Furthermore, we noticed from fig.2.a three groups distinct. The scatters marked by red are samples that have undergone three days of cold storage, the scatters marked by green are samples that have been stored for six days of cold storage and the scatters marked by blue are samples that have been stored for nine days of cold storage. According to previous microbiological researches [13], the scores marked by red are fresh, scores marked by green are semi-fresh and scores marked by blue are spoiled. In addition, the hue and intensity channels have failed to give satisfactory results due to the overlap between different groups (fig.2.b) and (fig.2.c). From these results, we conclude that the proposed system can classify clearly beef meat samples according to days of cold storage based on color and the saturation channel.

Compared to previous researches, beef meat freshness was assessed using nondestructive techniques such as electronic tongue [14], electronic nose [13], and machine vision [15]. In these studies authors have discriminate successfully the shelf life of beef meat according to days of cold storage. The difference is in the techniques and the methods employed.





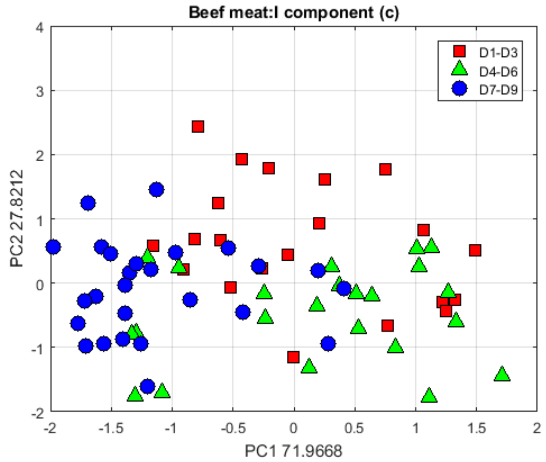


Fig.2. PCA scores plot of the number of storage days based on: (a) H component, (b) S component, (c) and I component [5]

B. *PCA predict using color datasets*

Fig. 3 illustrates the obtained results using PCA predict and the saturation channel. In fact 16 unknown samples were projected on the existing samples that form the training set. These results show that the proposed system predict successfully the unknown samples according to the days of cold storage.

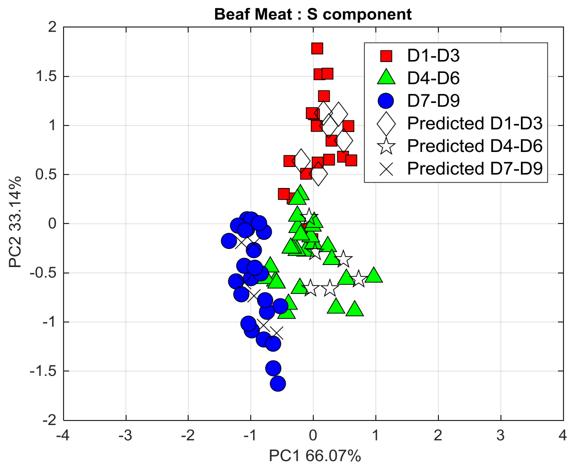


Fig 3. Projection of the second set of measurements on the PCA model built using the first set of measurements of S component [5]

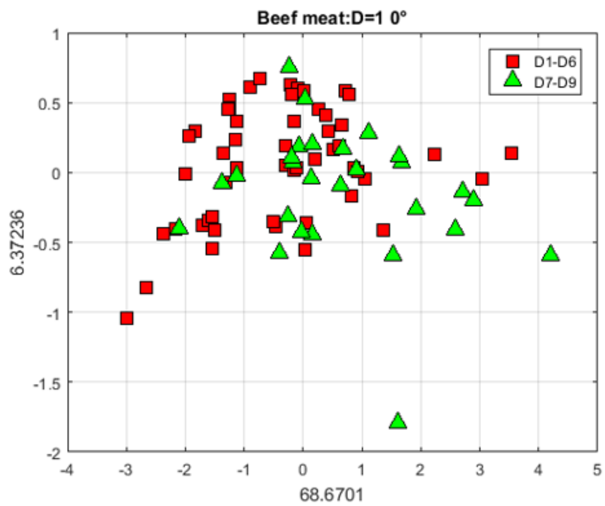
C. *PCA using GLCM texture datasets*

Fig. 4 shows the data projection using GLCM and saturation channel. The distance between two pixels was set to 1 d=1 using different direction $\boldsymbol{\theta} \epsilon$ [0, 45, 90, 135]. It can be noticed from the fig. 4.a big overlap between all samples. The same observation goes for fig. 4.b, fig. 4.c and fig. 4.d. These results show that the proposed system has failed to classify samples according to the days of cold storage using GLCM as a tool to extract texture feature.

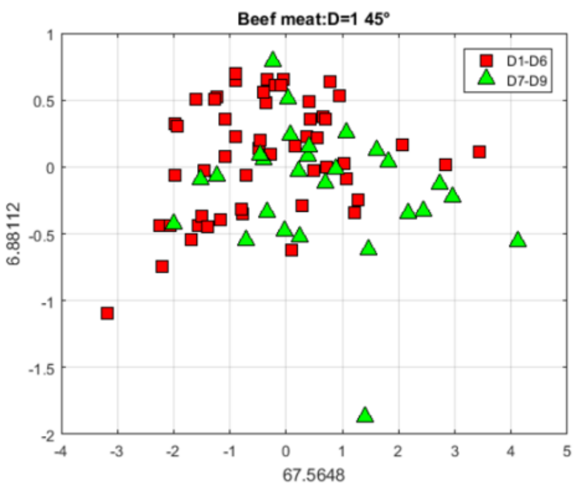
D. *PCA using wavelet texture datasets*

Fig. 5 presents the obtained results. From this figure, we noticed two clear groups. The group marked by red scatters presents samples that have undergone six days of cold storage. The group marked by green scatters presents samples that have undergone nine days of cold storage. According to previous microbiological studies, the samples stored six days under 4°C are fresh and the samples stored more than six days are spoiled. Compared to GLCM, the wavelet transform gives the best results. From these results, we can conclude that the proposed system discriminate successfully fresh samples and spoiled samples based on texture features using wavelet transform and PCA method.

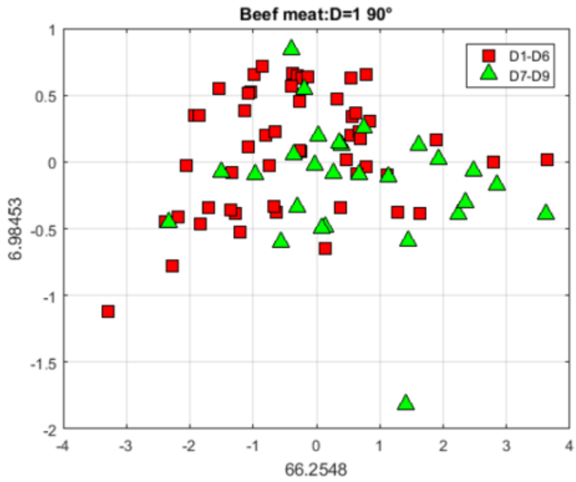
Machine vision was employed to characterise the surface of beef meat using texture features and wavelet transform. From several studies [16] texture was an effective indicator of meat eating qualities like palability, tendenrness and favor. However [17] was the closest study to our research, it reported the freshness of porc meat using texture features by GLCM and light scattering technique.



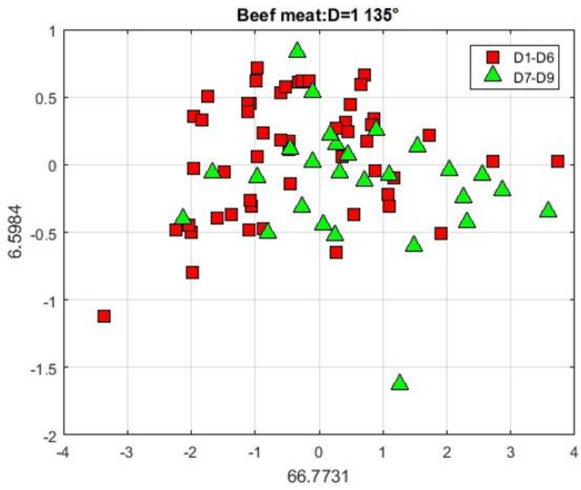
(a)



(b)



(c)



(d)

Fig.4. PCA scores plot of the number of storage days based on GLCM and S component for D=1: (a) $\boldsymbol{\theta}$=0°, (b) $\boldsymbol{\theta}$=45°, (c) $\boldsymbol{\theta}$=90, (d) = $\boldsymbol{\theta}$=135°

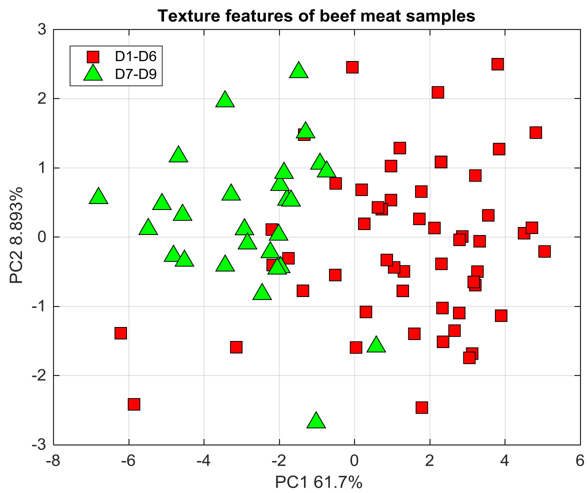


Fig.5. The projection of texture features of beef meat samples using PCA method and S component [6]

E. PCA using wavelet texture dataset and color dataset

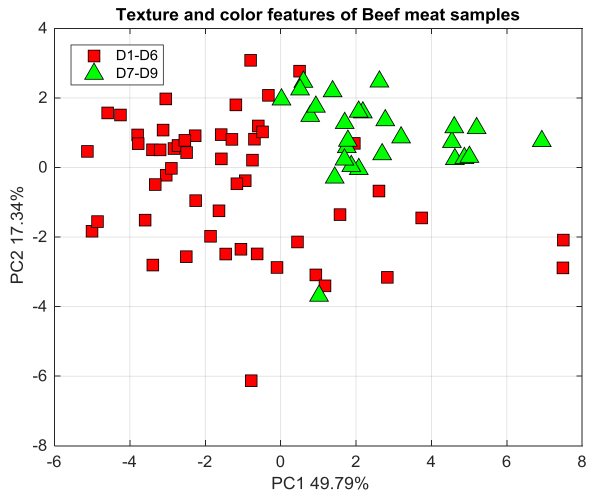
Artificial vision technique have been successfully used to classify and predict the freshness of beef meat samples based only on color or only on texture surface changes. Thus, we associated color datasets with texture dataset to classify and predict the freshness of meat beef samples. Fig. 6.a presents the projection results obtained from PCA method. Two different groups appeared. The red scatters present samples that have undergone 6 days of cold storage and the green scatters present samples that have undergone 9 days of cold storage. From these results, we can conclude that the proposed system discriminate successfully fresh samples and spoiled samples based not only on color features or on texture features but also based on color associated with texture features.

To accomplish the study, it was necessary to demonstrate the stability and the reproducibility of the proposed system. Consequently, a new dataset was established respecting the same conditions of the first experiment mentioned in II.A. The new measurements of texture associated with color features were projected onto the already existing PCA model of texture associated with color features. The new samples appear correctly distributed according to their stage of conservation (Fig. 6.b). These results prove that the system leads to reproducible results and that it can be used as a screening tool to assess the freshness of beef meat.

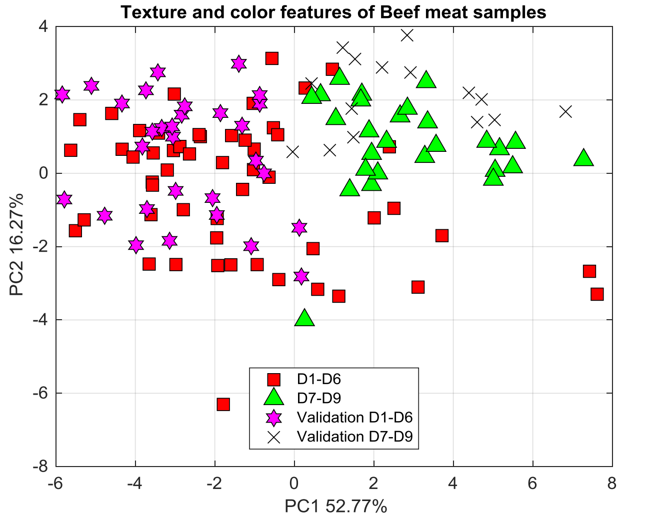
F. Prediction using supervised methods

1. SVM

In order to classify and identify beef meat samples into the three classes obtained by PCA analysis, the SVM multiclass method was employed. Results obtained from Matlab show a 100% success rate in the classification and identification of measurements within the three classes given by PCA. [13] has used the electronic nose system and SVM algorithm to classify beef meat samples freshness based on desktop system. The accuracy rate of the classification was 98.81% [15] has investigate whether the artificial vision technology and Fuzzy ARTMAP neural network running on desktop system was able to assess beef meat freshness. Results show a classification rate of 95.24%.



(a)



(b)

Fig.6. The projection of color associated with texture features of beef meat samples using PCA method and S component (a), projection of color associated with texture features of the existing and the new measurements (b) [6]

2. PNN

PNN is used to classify beef meat samples into fresh or spoiled, and to predict the freshness of new samples based on color, texture and color associated with texture features. Table 1 shows the confusion matrix of classification and identification of samples using color, texture, color associated with texture features and PNN. A classification rate about 86.41% within the two classes given by PCA and an identification rate about 85.18% was obtained from color features. Moreover, a classification rate about 91.36% was obtained from the texture dataset and 82.71% for the identification rate. Finally, a 93.83% classification rate was obtained from the texture associated with color dataset and an identification rate about 87.65%.These results show that color associated with texture features give the best rate in term of the classification and the identification of beef meat freshness than both texture and color features.

TABLE I. CONFUSION MATRIX OF CLASSIFICATION AND IDENTIFICATION OF SAMPLES USING COLOR, TEXTURE, COLOR ASSOCIATED WITH TEXTURE FEATURES AND PNN

		Predicted (fresh)	Predicted (spoiled)
Color	True (fresh)	45 (c) 47 (id)	9 (c) 7 (id)
	True (spoiled)	2 (c) 7 (id)	25(c) 20 (id)
Texture	True (fresh)	53(c) 44 (id)	1(c) 10 (id)
	True (spoiled)	6 (c) 4 (id)	6 (c) 4 (id)

Color associated with texture	True (fresh)	53(c) 50 (id)	1(c) 4 (id)
	True (spoiled)	4 (c) 6 (id)	23 (c) 21 (id)

3. LDA

As for PNN, LDA was used to classify and identify the freshness of beef meat samples. Table 2 shows the obtained results from the confusion matrix. In fact, a classification rate about 81.48% and an identification rate about 66.67% was obtained from color features. Moreover, a classification rate about 76.54% was obtained from the texture dataset and 66.67% for the identification rate. Finally, A 82.72% classification rate was obtained from the texture associated with color dataset and an identification rate about 80.25%. These results show that the PNN algorithm leads to the best classification and identification rates using color, texture and texture associated with color. Moreover, color associated with texture features gives the best classification and identification rates and consequently it can be used to assess beef meat freshness using the proposed system.

TABLE II. CONFUSION MATRIX OF CLASSIFICATION AND IDENTIFICATION OF SAMPLES USING COLOR, TEXTURE, COLOR ASSOCIATED WITH TEXTURE FEATURES AND LDA.

		Predicted (fresh)	Predicted (spoiled)
Color	True (fresh)	46 (c) 47 (id)	8 (c) 7 (id)
	True (spoiled)	7 (c) 27 (id)	20(c) 0 (id)
Texture	True (fresh)	27(c) 47 (id)	27(c) 7 (id)
	True (spoiled)	11 (c) 27 (id)	16 (c) 0 (id)
Color associated with texture	True (fresh)	44 (c) 44 (id)	10 (c) 10 (id)
	True (spoiled)	4 (c) 6 (id)	23 (c) 21 (id)

IV. CONCLUSION

In this paper, we reported a synthesis of our recent researches. We proposed a portable instrument based on artificial vision and embedded systems. Results show that the instrument was able to classify and predict successfully the freshness and the spoilage of beef meat samples. Thus, it can be used in real-time and in site. To conclude, artificial vision is a reliable technique, and it has shown its efficiency in much application related to meat assessment. However, it still has some limitations. In fact, it permits to detect external features, but not internal characteristics. Also, for embedded system, there still some challenges in the optimization of the existing processing algorithms and the development of novel ones suitable for processors. This is highly required in order to permit the material miniaturization and the real time assessment of meat quality.

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