Development of a Prototype for the Quality Control of Bovine Meat Determined by its Organoleptic Characteristics, based on an Automatic Inspection System for Artificial Vision

Portero P., Mena B., Gavilanes J.

***Abstract*— Abstract— The world beef market is in full growth and with unsatisfied demands and prices up and these depend very much on their quality when arriving at the final consumer, while the national market, our country also has a future potential in the meat industry. In the present investigation is to evaluate the sensory characteristics of color and texture by means of the presence of a bovine meat sample in the system whose final result will be the acceptance or negation of its organoleptic quality. The system is constituted by a transport band in charge of taking the sample to a capsule where both the Lighting System (LS) and the Computer Vision System (CVS) are located, and when leaving there it will be automatically classified by an actuator, guaranteeing less manipulation and estimation of time by human intervention throughout the process while providing greater security to the final consumer about the meat that is entering their home.**

Index terms— Artificial intelligence, automation systems, quality control, color space, organoleptic characteristics.

I. INTRODUCTION

Since the middle of the twentieth century the consumption of beef has been increasing, because people consider it as an essential product for their food, for this reason their production has increased, bringing with it factors that can affect their quality, so the industry (Blandino, 2005) within its project "The Beef Industry in Central America: Situation and Perspectives" defines quality as "the whole characteristics of a product or service that meets the explicit or implicit wishes of the consumer. "

However, at present the tool that allows to evaluate characteristics of quality as the color and the texture of quantitative way using a simple digital image that generates a non-destructive, fast, precise, objective evaluation and that avoids the human inspection that in many occasions tends to be expensive and imprecise, are the Computer Vision Systems (SVC) as it allows to replace human manipulation using the robust algorithms used in image processing [1]. Consequently, this has led several researchers to perform work involving SVCs, such as the Advanced Engineering Research and Development Center (CIDIA), which in 2008 developed a Meat Sorting Device that determines the quality of beef through the use of industrial digital cameras evaluating the color, the thickness of the subcutaneous meat and the marbling.

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II. QUALITY CONTROL IN THE MEAT INDUSTRY

Quality control in the meat industry, and especially in beef, was born in 1996 from the appearance of European cases on Bovine Spongiform Encephalopathy and the correlation that existed between this disease and humans. the main markets for this product, demanded systems and tools that would satisfy the safety of food and meat in particular to protect the safety of its consumers.

III. ARTIFICIAL VISION VS. HUMAN VISION

The human being in tiny amounts of time has the capacity to acquire, process and assimilate information from the outside world, which may or may not be visible in its entirety and in varying lighting conditions [3], but the industry constantly uses the quality control and most are the employees who take care of it.

Where these processes usually have several hours of duration, so the individual tends to become tired or distracted generating erroneous results in the evaluation [4].

In contrast, with Artificial Vision (AV) and with less or equal assimilation times can be emulated variety of elemental vision processes obtaining a minimum of error. Concluding that AV systems can be an important factor in the economic development of human considering that even in several actions its improvement is necessary [3].

IV. COMPUTER VISION MEASYSTEM

A CVS is technically divided into two systems: the perceptual system and the actuation system. The first consists of lighting systems, image capture and signal acquisition in the computer. The second uses a processing algorithm that provides information that helps us in making decisions and that follows a system of action responsible for making judgments on the outside of the system [5].

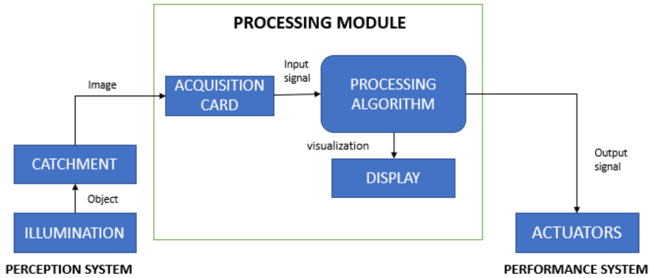


Fig. 1 Technical composition of an Artificial Vision System

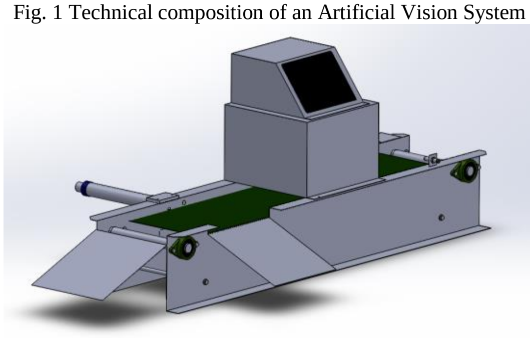


Fig. 2 Structure design

V. DEVELOPMENT AND IMPLEMENTATION

Due to the fact of working with a food product and that the quality of this depends partly on the little or much manipulation that suffers, it has been considered to use a conveyor belt for the whole process its material is of stainless steel and is constituted by sensors, actuators and the SVA.

The control of the devices and the processing of the algorithm of the SVA is realized through a Raspberry Pi 3B (RPi), using the library of Open CV that allows the processing of images in real time, with more than 500 functions.

Figure 4 describes the operation of the system. Where, the initial sensors determine the existence of the product to start with the conveyor belt until arriving at the capsule, where, it will be integrated the SI and a sensor that allow to execute the algorithm of vision, once finished the analysis with the algorithm is executed again the conveyor belt to a sorting point where it will pass only the qualified product, otherwise it will be rejected to another location by the cylinder drive.

An essential part of a good SVA is the SI, due to the work done with color and texture differentiations, the lateral lighting technique has been selected, which allows highlighting of reliefs, edges, fissures and textures.

For the design, two lamps (L1 and L2) of 6W, 6000K with an external 20 ° angle were considered, to obtain a better distribution of light in the encapsulation of the vision system. Figure 5.

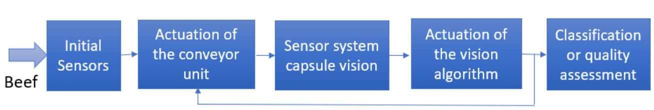


Fig. 3 Block diagram of prototype operation

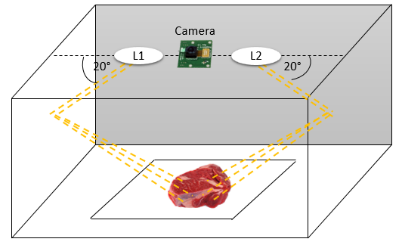


Fig. 4 LS Desing

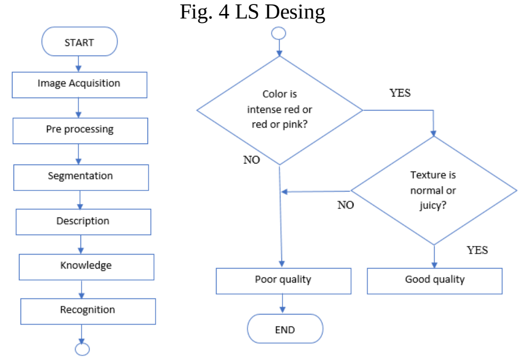


Fig. 5 AV Algorithm Flowchart

The SVA is based on the obtaining of organoleptic parameters of quality specifically of color and texture, using the CIELab and HSL color spaces, where the former uses the methodology (AMSA, 1992) together with the sensorial methodology allowing to obtain the characteristic of the color in an objective way based on the parameters a, b and L [6] while the second allows to obtain the brightness of the sample through the parameter L. For the characterization of the texture was taken as a guide the parameters extracted from the Department of Agriculture of the United States (USDA) and color was taken as a guide the meat color patterns developed by the Faculty of Veterinary Medicine and Animal Science of the National Autonomous University of Mexico (UNAM). However, beef scores and grades were classified into 5 scales. (Table V); information extracted from the document of the meat processing module of Ing. Tania Parra MSc. Magister in Livestock Industries Mention Industries of the Meat and teacher of meat processes of the Polytechnic School of Chimborazo.

The methodology used for the development of the vision algorithm is appreciated in the block diagram in Figure 6 and the function of each of the stages is detailed below.

A. *Image Acquisition*

Technique that consists in digitizing the signal delivered by the camera of the RPi.

Let an image be a two-dimensional function f (x, y), the digitization consists of decomposing this function into an MxN matrix, which is no more than a grid of pixels

Fig. 6 Original (Left) and image scanning (Right)

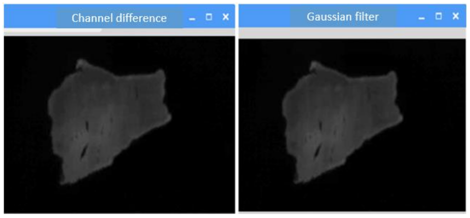


Fig. 7 Channel difference (left), Gaussian filter (right)

B. Pre processing

Once the Acquisition is made, the pre-processing is performed to obtain an improvement of the digitized image.

The RGB image is converted to grayscale, followed by this the Gaussian Filter is applied in order to eliminate the noise that occurs during the capture, producing a smoother or smoother more uniform through the image than the filter of the half.

C. Segmentation

Next, the segmentation process in charge of decomposing the image into regions is executed, in order to extract only the section that constitutes the area of the sample. From the binarization of the image.

Binarization consists of zeroing all the pixels smaller than a threshold value and one of those equal or greater, the final image being constituted by a set of ones and zeros, which is nothing more than the representation of the black and white image.The threshold in most cases is fixed, contrary to this study in which the color of the samples is continuously changed, for that reason uses the OTSU thresholding technique, which obtains a binary image (black and white) by means of an automatic threshold from a grayscale or bimodal image.

To find the value of the threshold, Otsu makes use of the histogram of a bimodal image obtaining an approximate one half of the two peaks representing the color black and white respectively. The automatic threshold value proves to be very useful for this segmentation, however, within the analysis of the images it has been considered to perform a variation (add a constant to the final threshold value) of the final value, allowing to eliminate fragments that are not of interest to image.

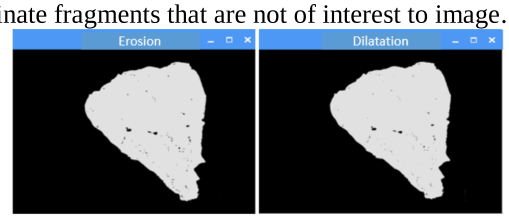


Fig Morphological operations

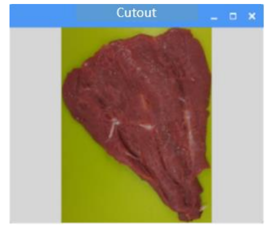


Fig. 10 Crop an image

Following this step morphological operations are executed, which are those in charge of exalting the geometry and shape of the objects, it is fundamental to use them prior to the extraction of characteristics [3]. For this case erosion is used followed by dilation.

Erosion removes pixels at the borders of the image, makes it smaller and dilation adds pixels at the borders of the image, makes it larger. These operations have been implemented in the event that veins are present, torn at the edges of the sample.

The last step of the segmentation is to extract or to cut the section of interest determining by means of the functions of OpenCV the coordinates of the pixels that conform the outline of the sample.

D. Description

Five scales have been taken into account both in color and texture as can be seen in the following tables.

E. Knowledge

The parameters of color and texture are obtained for later evaluation and to determine if the meat is of good or poor quality. To know the color variations that the image presents the conversion of RGB color space to CIELAB is performed which is a chromatic model frequently used to better describe the colors perceived by the human eye as it does not depend on any device resulting more objective to constantly describe more precisely the same color.

OpenCV through the use of its functions allows to obtain the maximum and minimum values of each parameter corresponding to the resulting color space. The color parameters representing each color are shown below.

TABLE I
COLOR SCALE CONSIDERED

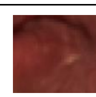
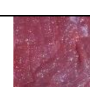
Very intense red	Intense Red	Red	Pink	Very light pink
				

TABLE II
TEXTURES SCALE CONSIDERED

Very Juicy	Juicy	Normal	Dry	Very Dry
				

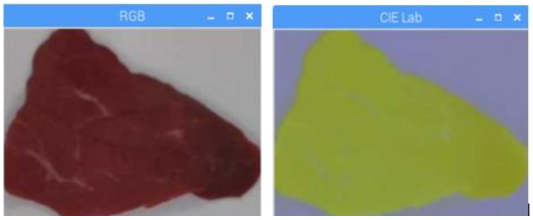


Fig. 11 RGB image (left), CIELab image (right)

TABLE III
DESCRIPTION OF CIELAB PARAMETERS

Colors	CIE LAB PARAMETERS					
	Minimum Values			Maximun Values		
	L	A	B	L	a	B
Very intense red	19	136	131	38	145	137
Intense red	36	143	133	57	155	137
Red	43	152	136	97	159	142
Pink	59	156	132	99	166	149
Very light pink	45	145	133	78	157	142

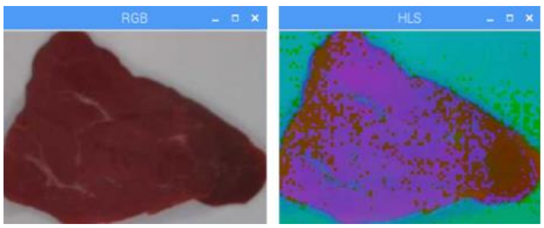


Fig. 12 RGB image (left), HLS image (right)

To determine the colors that will represent the juiciness within the texture algorithm, HLS is used because it allows to have a better appreciation of the brightness. In this case allows to differentiate the amount of water on the meat, as they will vary their values depending on how juicy or dry this is.

The texture parameters are obtained in the same way as the color parameters.

F. *Recognition*

Beef does not present a uniform color in its entirety, that is why the color algorithm is responsible for segmenting the meat by its color from very intense red to very light pink.

The segmentation is done by means of a mask, this being a binary image where its pixels are placed to one as long as the value of each of the pixels of the CIELab space are within the preset range for each color. The multiplication between the matrix of the mask and the matrix of the CIELab color space is then performed, resulting in an image containing only one color, which belongs to the 5 working scales.

TABLE IV
DESCRIPTION OF HLS PARAMETER

HLS PARAMETERS					
Minimum Values			Maximun Values		
H	L	S	H	L	S
175	54	51	180	121	149

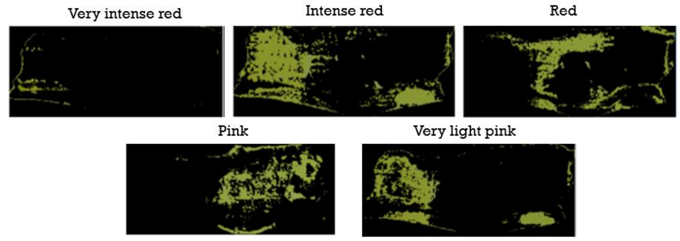


Fig. 13 Color filters on an image

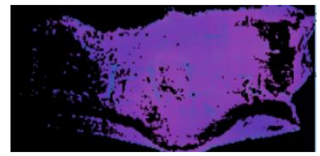


Fig. 14 Representation of juiciness

Meat color determination is performed by comparing between the areas of the resulting 5 images, and color will be defined by the image having the largest area.

As for the texture, the same procedure is executed as for the color, but only once and the juiciness will be determined by comparing the total area of the sample with the area of the image resulting from the multiplication between the mask and the HLS image.

And the quality will depend on the percentage yielded (Very dry: 30%, dry: 45%, normal: 50%, juicy: 55%, very juicy: 70%). To know if meat is juicy or not, the pixels of the mask add juiciness and compared with the total area of the meat.

G. *Make decisions*

The quality of the meat is considered according to its color and texture by means of the following conditions:

- RFN: Red meat, firm and juicy.
- PSE: Pale flesh, soft and juicy.
- DFD: Dark, firm and dry meat.

Where the first RFN describes quality meat and is the desirable condition for its ability to retain water, for its bright red color and for its firm texture. The two remaining conditions were considered to be of poor quality.

Within the algorithm, to comply with these conditions the colors that are accepted are: intense red, red and pink and for juicy and normal texture

VI. TESTS AND RESULTS

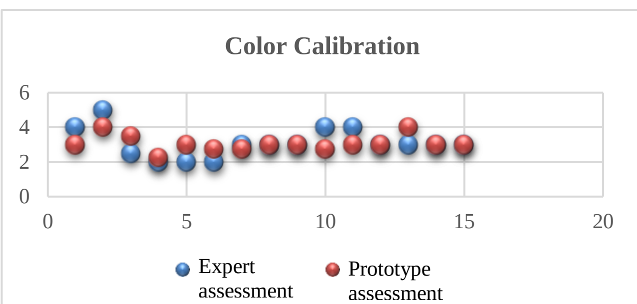
A comparative analysis of the machine is carried out with respect to a human sensory evaluation panel, to evaluate times, color variations and texture of each sample. For this purpose, 5 semi-expert judges were selected, who evaluated the characteristics of 15 samples in two replicates, scoring in 5 ranks (Table 5), based on the sensorial methodology where the weights of each judge were weighted by each sample to tabulate the data. While for the time it is considered the joint commitment of each judge for the 30 samples valued reaching an average time of 01:09:56.

TABLE V
SCALES OF COLOR AND TEXTURE AND ITS WEIGHTING

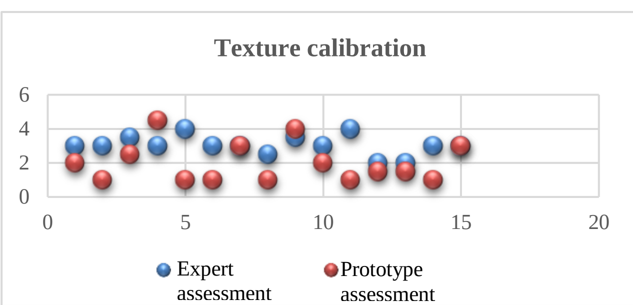
WEIGHTING	COLOR	TEXTURE
5	Very intense red	Very Juicy
4	Intense red	Juicy
3	Red	Normal
2	Pink	Dry
1	Very light pink	Very Dry

It should be added that the evaluation carried out by the prototype used the same samples and previous repetitions, taking as a guide the methodology (AMSA, 1992) and the sensory methodology from which only the values of the CIELab parameters of the color pattern will be taken. While for the texture the percentage levels of the L parameter of the HLS color space shown in the total area of the sample were taken.

After a proper calibration of parameters, better results were obtained as can be seen in the following graphs. For the analysis of this study, the t-dependent test for paired samples was used because it is desired to observe the behavior of the prototype against the recovery performed by the judges taking into account that the sample has been evaluated twice and that it is desired to verify significant differences in the behavior of the prototype. Using the SPSS statistical software, we finally obtained a correlation significance of 0.595 in color without significant differences, while for the texture a correlation significance of 0.77 was obtained, there being a significant difference between the two valuations.



Gráf. 1 Color calibration



Gráf. 2 Texture calibrarion

VII. CONCLUSIONS

This device has provided an objective non-invasive method for assessing color and texture of meat, in intervals shorter times with respect to a panel of selected sensory judges for evaluating these organoleptic characteristics of beef, substituting this panel evaluation by a single user, responsible for management and interpretation of results easily, thanks to the friendly interface incorporated

VIII. FUTURE WORKS

This device has provided a non-invasive objective method for assessing color and texture of the meat, in smaller time intervals with respect to a panel of sensorial judges generating a saving of approximately 67% and with an 18.384% error in the evaluation. Being able to replace the evaluating panel by a single user, the same one that is in charge of the handling and interpretation of the results of a simple way, thanks to the friendly interface incorporated.

The implemented system proved to be optimal. However, being a prototype has a range of error that can be corrected by future research.

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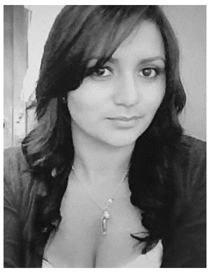

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