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Research Article

Predict the quality and safety of chicken sausage through computer vision technology

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Abstract

The aim of this study was to test the ability of image technology to predict quality and safety of chicken sausage. Chicken sausages were chosen for image capture. Traits evaluated were color indexes (L*, a*, b*), pH, drip loss, cooking loss, dry matter, moisture, crude protein, ether extract, ash, thiobarbituric acid reactive substances (TBARS), peroxide value (POV), free fatty acid (FFA), total coliform count (TCC), total yeast and mold count (TYMC) and total viable count (TVC). Images were analyzed using the software Matlab (R2015a). Conventional analytical technology i.e., proximate, bio-chemical and microbiological analyses were followed for reference value. Calibration and prediction model were fitted using The Unscrambler X software. Results of this work show that image technology may be a useful tool for prediction of meat quality traits in the laboratory and meat processing industries. The L* value from imaging analysis had medium correlation with a* (r=0.28), b* (r=0.29), pH (r=0.31). A medium correlation found in CP (0.29) with 'a*' value obtained from imaging analysis. In this experiment we found lower calibration and prediction accuracy in a*, crude protein and ether extract value. From this study it may be recapitulated that image technology has a potentiality to replace analytical technology for meat laboratory and processing units.

Introduction

Meat is the most essential product in the human diet and greatly prized by the consumer, mainly due to its valuable nutrients such as protein, fat, vitamin and micronutrients, all of which are responsible for good human health (Disha et al, 2020). Since it affects their profitability, meat quality has recently become a matter of interest to stakeholders in the meat business as well as consumers concerned about their health (Hocquette and Chatellier, 2011). Meat is rich in biologically significant macronutrients and micronutrients, all of which are necessary for greater overall human health (Hashem et al., 2021). Quality and safety of meat and meat products are usually defined by physical, chemical and biological attributes. With the current growing need for low production cost and high efficiency, the meat processing industry is facing with a number of challenges, including maintenance of high-quality standards and assurance of food safety while avoiding liability issues. Meeting these challenges has become crucial in regards to grading meat products for different markets. Consumer demand for higher-quality meat products has increased as a result of the improvement of living standards, and meat quality differentiation is seen as a crucial element in market success (Sun et al., 2016; Bithi et al., 2020; Hashem et al., 2022a, 2022b). Traditionally, assessment of quality and safety involves human visual inspection, in addition to chemical or biological determination experiments which are tedious, time-consuming, destructive and sometimes environmentally unfriendly. In Bangladesh, traditional measurement techniques are still widely used for raw and processed meat quality and safety estimation. Meat processing companies and suppliers need accurate, fast, real-time, low-cost and non-chemical detection technologies in order to optimize quality assure safety of meat to enable them to satisfy different market's need, thereby raising their competitiveness and expanding their market share. Imaging analysis, non-destructive method, is interesting for the assessment of meat quality in the recent years. As a rapid and non-destructive technique, imaging technique has received huge attention throughout the world for measuring quality attributes and safety parameters for agricultural products including meat and meat products (Rahman et al., 2020). The superiority of the imaging technique compared to traditional analysis methods is that they allow displaying distribution of the analyzed properties (Turgut et al., 2014). Fatih et al. (2016) used computer vision system for color measurement in meat. Researchers used imaging technology for assessing water holding capacity in meat (Qiao et al., 2007; Monroy et al., 2010; El Masry et al., 2011). Imaging analysis, using a digital camera, is presently used only for assessing the external appearance of the meat. However, these assumptions may be possible because one previous research reported that frozen breast meat with low water-holding capacity had flatter in shape during extended storage time (Lee et al., 2008). Direct measurements are inconvenient and time-consuming when used in the continuous processing of meat. Thus, imaging analysis with a digital camera may provide an alternative method for assessing the quality attributes by determining the conformation parameters and color. Several high-performance techniques for determining the quality characteristics of meat, such as the hyperspectral imaging technique (Qiao et al., 2007),

near-infrared (NIR) hyperspectral imaging (El Masry et al., 2011), and nuclear magnetic resonance (NMR) (Bertram et al., 2001), have been used. However, these techniques require costly equipment, whereas imaging analysis using a digital camera is inexpensive. The application of machine vision during the analysis of digital images is limited to the recognition and extraction of exterior image attributes or quality elements such as color, size, and surface structure (Chmiel et al., 2012; Penman, 2001; Zhang et al., 2015). This experiment aimed to establish a correlation between the chemical composition of chicken sausage and its image value and finally to assess the effectiveness of image technology in predicting the safety and quality of chicken sausage. Further research would be required to confirm any causal relationships and to fully understand the underlying mechanisms behind any observed correlations.

Materials and Methods

Chicken sausage was purchased from superstore at Mymensingh town. Total number of sausages was 40. Samples were vacuum-packed and analyzed for meat quality after a refrigeration period of 24 hours at 4 °C. Color index (CIE, 1976) was measured using Minolta colorimeter (model CR-400, Konica Minolta Inc, Tokyo, Japan) that set to 8 mm aperture, D65 illuminant and 10˚ observer angle. The pH values of the sample were determined using HANNA meat pH meter. Moisture, ether extract, ash and protein were determined according to AOAC (2005). Drip loss was calculated as difference between the sample weight at 24 h and that after hanging. Cooking losses was determined using procedures suggested by ASPA (1996). Three types of biochemical analysis were followed. Microbiological analyses of the samples were performed by Ikhlas et al. (2012). Images of the sample were captured using a digital camera (Canon, model Ixus 190). An image processing software (Matlab R2015a) was applied for image analysis. For cross-validation analysis the software unscrambler X was used.

Sample preparation

After 24 h samples were removed from the refrigerator and then kept it in a tray for about 10–12 minutes to allow moisture to appear on sausage surface. Then the surface of the samples was soaked gently with the help of blotting paper which subsequently used for better color value estimation.

Image acquisition

Image acquisition of the sample was performed with the help of imaging system (Computer Vision System, Fig1.) developed locally following the information reported by Iqbal et al. (2010) and Valous et al. (2009). The main components of the developed system are: an illumination source, a color digital camera (Canon IXUS, Model No. 190, Tokyo, Japan), and a computer-supported with an image acquisition software package (Matlab 2015a, The Mathworks, Natick, MA, USA). Images of the samples were captured using the camera of imaging system and were stored in the computer for further processing. An image processing software (Matlab 2015a, The Mathworks, USA) was applied for image analysis.

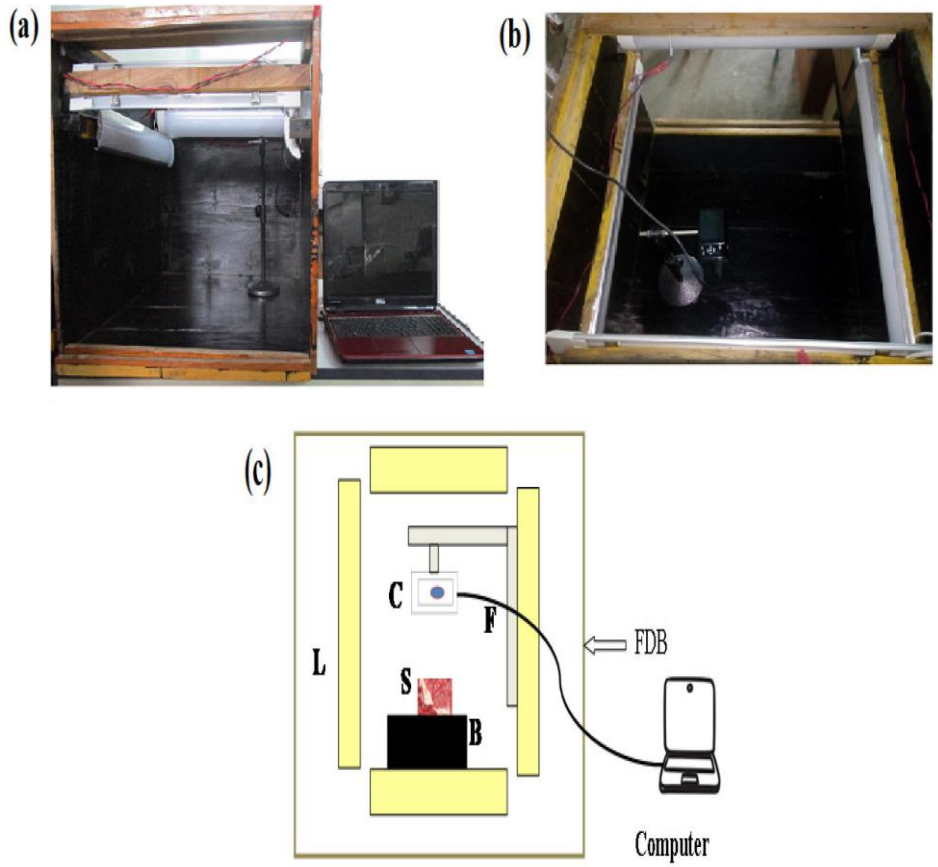

Fig 1. Computer vision system developed in the Laboratory: (a) front view; (b) top view and (c) schematic diagram with its components. L, light sources; C, camera; S, sample; B, black background; F, attachment for camera; FDB, frame with dark box.

Surface color evaluation

The surface color of the samples was measured in terms of L* (lightness), a* (redness) and b* (yellowness) values using a Chroma meter (CR-400, Konica Minolta, Osaka, Japan) following the guidelines provided by Commission International de l'Eclairage (CIE) system (CIE, 1976).

Physico-chemical analysis

pH value recording

The pH value in sausage was measured by meat pH meter (Model no. HI99163, Hanna Instruments, Woonsocket, RI, USA). The pH meter was adjusted with pH 7.01 buffer solution before the measurement. The electrodes were rinsed with cleaning solution after use.

Cooking loss (CL) measurement

Approximately 30 g sausage sample was taken in a poly bag and heated it in water bath until the temperature rises to 71°C in sample. Sausage with 71°C was taken out from the water bath and soaked it with tissue paper. Weight loss of the sample was measured during cooking beef.

Proximate analysis

Moisture, protein, fat, and ash was determined as per the standard procedures of association of official analytical chemists (AOAC, 2005).

Biochemical analysis

Three types of biochemical analysis were carried out in this study: (i) thiobarbituric acid reactive substance (TBARS), (ii) free fatty acid (FFA) and (iii) peroxide value (POV) measurement. Three types of analysis are discussed below:

Thiobarbituric acid values (TBARS) measurement

Lipid oxidation was assessed in triplicate using the 2-thiobarbituric acid (TBA) method described by Schmedes et al. (1989). Samples (5 g) was blended with 25 ml of 20% trichloroacetic acid solution (200 g/l of tricholoroacetic acid in 135 ml/l phosphoric acid solution) in a homogenizer (IKA) for 30 seconds. The homogenized sample was filtered with Whatman filter paper number 1 and 2 ml of the filtrate was added to 2 ml of 0.02 M aqueous TBA solution (3 g/l) in a test tube. The test tube was incubated at 100°C for 30 minutes and cooled with tap water. The absorbance was measured at 532 nm using a UV-VIS spectrophotometer (UV-1200, Shimadzu, Kyoto, Japan). The TBA value was expressed as mgmalondialdehyde (MDA) per kilogram of sample.

Peroxide value (POV) analysis (meq/kg)

POV was determined according to Sallam et al. (2004). The sample (3 g) was weighed in a 250-mL glass stopper Erlenmeyer flask and heated in a water bath at 60°C for 3 min to melt the fat, then thoroughly agitate for 3 min with 30 mL acetic acid-chloroform solution (3:2 v/v) to dissolve the fat. The sample was filtered under vacuum through Whatman filter paper number 1 to remove meat particles. Saturated potassium iodide solution (0.5 ml) was added to filtrate and continue with addition of starch solution. The titration was allowed to run against standard solution of sodium thiosulfate (25/1).

Free fatty acid (%) analysis

FFA value was determined according to Rukunudin et al. (1998). 5 g sample was dissolved with 30 ml chloroform using a homogenizer (IKA T25 digital Ultra-Turrax, IKA, Königswinter, Germany) at 10,000 rpm for 1 min. The sample was filtered under vacuum through Whatman filter paper number 1 to remove meat particles. After five drops of 1% ethanolic phenolphthalein was added as indicator to filtrate, the solution was titrated with 0.01N ethanolic potassium hydroxide.

Microbiological analysis

Microbiological analysis was determined by the procedure of Ikhlas et al. (2012).

Enumeration of total viable count (TVC)

For the determination of total bacterial counts, 0.1 ml of each ten-fold dilution was transferred and spread on triplicate PCA agar using a sterile pipette for each dilution. The diluted samples were spread as quickly as possible on the surface of the plate with a sterile glass spreader. One sterile spreader was used for each plate. The plates were then kept in an incubator at 35°C for 24–48 h. After incubation, 30–300 colonies were counted with the aid of a colony counter. The average number of colonies in a particular dilution was multiplied by the dilution factor to obtain the TVC. The results of the total bacterial count expressed as the number of organism of colony forming units per gram (CFU/g) of sample.

Enumeration of total coliform count (TCC)

For the determination of TCCs, 0.1 ml of each ten-fold dilution was transferred and spread on triplicate Mac Conkey agar using a sterile pipette for each dilution. The diluted samples were spread as quickly as possible on the surface of the plate with a sterile glass spreader. One sterile spreader was used for each plate. The plates were then kept in an incubator at 35°C for 24–48 h. After incubation, 30–300 colonies were counted with the aid of a colony counter. The average number of colonies in a particular dilution was multiplied by the dilution factor to obtain the TCC. The results of the total bacterial count expressed as the number of organism of colony forming units per gram (CFU/g) of sample.

Enumeration of total yeast-mold count (TYMC)

For the determination of total yeast and mold counts, 0.1 mL of each ten-fold dilution was transferred and spread on triplicate PDA agar using a sterile pipette for each dilution. The diluted samples were spread as quickly as possible on the surface of the plate with a sterile glass spreader. One sterile spreader was used for each plate. The plates were then kept in an incubator at 25°C for 48–72 h. After incubation, 30–300 colonies were counted with the aid of a colony counter. The average number of colonies

in a particular dilution was multiplied by the dilution factor to obtain the yeast and mold count. The results of the yeast and mold count were expressed as the number of organism of colony forming units per gram (CFU/g) of sample.

Statistical analysis

Calibration and prediction model were fitted using The Unscrambler X software.

Results and Discussion

Color value estimation

Color measurement is more important for the visual impression of the meat than an actual quality parameter. Color is usually measured in the CIE L*a*b* scale where L* denotes the lightness, a* the redness and b* the yellowness. The color values obtained from image analysis in sausage were 61.99±3.98, -0.16±0.7, 10.9±2.01 for L*, a*, b* respectively (Table 1). The L*, a*, b* values from direct measurement using colorimeter were 67.33±3.68, 6.72±6.72 and 20.96±1.45 respectively and shown in Table 1. Where Fatih et al. (2016) found 48.90, 24.21 and 12.31 for L*, a*, b* respectively from image analysis and 46.73±1.01, 21.94±1.24 and 13.11±1.00 for L*, a*, b* respectively from direct measurement and Kamruzzaman et al. (2016) stated L*, a*, b* values for beef were 47.25±5.19, 15.81±2.25 and 7.56±3.29 respectively. The L* and a* values obtained from colorimeter by Weglarz (2010) were 37.40±1.38 and 13.44±2.07 respectively that are almost similar to the findings of the present study.

Physicochemical properties

The descriptive statistic of pH, DL and CL are shown in Table 1. Measurements of pH have proven to be an important analytical measurement for meat. The pH found in the study was 6.51±0.36.

Proximate components

Dry matter, moisture, crude protein, fat and ash content of the sample has been shown in Table 1. The values were 26.16±2.3, 73.84±2.3, 20.42±1.64, 3.3±0.76, 1.7±0.39 for dry matter, moisture, crude protein, fat, and ash, respectively. These findings are in close agreement with those reported by De Marchi et al. (2007).

Biochemical properties

The oxidative stability of meat depends upon the balance of anti and pro-oxidants and the composition of these oxidation substrates (Bertelsen et al., 2000). Average TBARS, POV and FFA value of chicken sausage longissimus dorsi were found 0.13±0.01, 1.15±0.13 and 0.02±0.01 respectively (Table 1) where researchers found almost same values in fresh beef from hind limb of bull. The biochemical traits measured in this experiment were lower than the limit (TBARS: <0.6 mg MDA/kg, POV: <6 meq/kg and FFA<1.2) for rancidity.

Microbiological analysis

Microbiological traits measured by the laboratory method are presented in Table 1. The average values with standard deviations were 4.99±0.11, 5.85±0.12 and 7.64±0.12 for TCC, TYMC, and TVC respectively. The TCC and TYMC value were higher than results of Murshed et al. (2016). The possible cause of this variation in microbial load might be due to the differences sanitary condition in the production line.

Table 1. Statistical summary for quality traits of chicken sausage using imaging technology and laboratory technology

Traits		No. of sample	Range	Mean	SD	CV%
Image Analysis Data	L*	40	50.39-67.86	61.99	3.98	6.42
	a*	40	-1.02-2.15	-0.16	0.7	-425.84
	b*	40	7.74-15.96	10.9	2.01	18.42
Direct Measurement Data	L*	40	56.38-70.09	67.33	3.68	5.46
	a*	40	4.64-7.81	6.72	0.78	11.55
	b*	40	17.13-23.33	20.96	1.45	6.92
	pH	40	5.53-6.8	6.51	0.36	5.54
	DM%	40	20.15-29.62	26.16	2.3	8.81
	Moisture%	40	70.38-79.85	73.84	2.3	3.12
	CP%	40	17.94-24.87	20.42	1.64	8.04
	EE%	40	1.11-4.05	3.3	0.76	23.15
	Ash%	40	0.42-2.05	1.7	0.39	22.94
	TBARS	40	0.1-0.16	0.13	0.01	10.74
	POV	40	0.95-1.45	1.15	0.13	11.21
	FFA	40	0.01-0.05	0.02	0.01	37.36
	TCC	40	4.4-5.09	4.99	0.11	2.17
	TYMC	40	5.25-5.97	5.85	0.12	2.12
	TVC	40	7.04-7.82	7.64	0.12	1.53

L*, the lightness; a*, the redness; b*, the yellowness; n, sample size; CV, co-efficient of variation; DL, drip loss; CL, cooking loss; DM, dry matter; CP, crude protein; EE, ether extract; TBARS, thiobarbituric acid reactive substance; POV, peroxide value; FFA, free fatty acid; TCC, total coliform count; TYMC, total yeast-mould count; TVC, total viable count.

Correlation between computer vision technology and conventional analytical technology

Correlation between image data and reference data of chicken sausage is presented in Table 2. The L* value from imaging analysis had medium correlation with a* (0.28), b* (0.29), pH (0.31), TBARS (0.3) and POV (0.33). A medium correlation found in CP (0.29) with 'a*' value obtained from imaging analysis. The 'b' value resulted from imaging analysis, had medium correlation with moisture (0.37) and CP (0.42) measured by analytical method.

Table 2. Correlation between image data and reference data for quality assessment in chicken sausage.

Image data / Reference data	L*	a*	b*
L*	0.25	-0.07	-0.4
a*	0.28	-0.05	-0.42
b*	0.29	-0.12	-0.37
pH	0.31	-0.13	-0.43
DM	0.15	0.06	-0.37
Moisture	-0.15	-0.06	0.37
CP	-0.49	0.29	0.42
EE	0.25	-0.03	-0.41
Ash	0.22	-0.06	-0.41
TBARS	0.3	-0.08	-0.25
POV	0.33	-0.21	0.17
FFA	0.13	-0.23	-0.4
TCC	0.21	-0.07	-0.17
TYMC	0.21	-0.09	-0.21
TVC	0.13	-0.02	-0.14

L*, the lightness; a*, the redness; b*, the yellowness; DL, drip loss; CL, cooking loss; DM, dry matter; CP, crude protein; EE, ether extract; TBARS, thiobarbituric acid reactive substance; POV, peroxide value; FFA, free fatty acid; TCC, total coliform count; TYMC, total yeast-mould count; TVC, total viable count.

The ability of image technology to predict quality parameters in chicken sausage

It is known that the coefficient of determination (r^2) indicates the accuracy of model, varying from 0 to1. Table 3 presents the results of calibration and prediction of color, pH, dry matter, crude protein, Ash, TBARS, POV and FFA content of the sausage samples using image data. The ability of imaging technology to predict quality trait in chicken sausage which is determined by calculating R^2 value and RMSE that presented in table 3. In this experiment we found lower calibration and prediction accuracy in a*, crude protein and ether extract value. Other parameter showed very low prediction accuracy which is negligible.

Table 3. Accuracy of imaging technology for the determination of quality traits in chicken sausage

Parameter	Calibration		Validation	
	r^2C	RMSEC	r^2P	RMSEP
L*	0.3	3.04	0.07	3.5
a*	0.4	0.6	0.22	0.68
b*	0.26	1.23	0.06	1.39
pH	0.33	0.29	0.12	0.33
DM	0.34	1.85	0.15	2.09
Moisture	0.34	1.85	0.15	2.02
CP	0.39	1.27	0.24	1.41
EE	0.37	0.6	0.18	0.68
Ash	0.29	0.33	0.06	0.37
TBARS	0.24	0.01	0.06	0.01
POV	0.21	0.11	0.004	0.13
FFA	0.18	0.01	0.03	0.01

L*, the lightness; a*, the redness; b*, the yellowness; DL, drip loss; DM, dry matter; CP, crude protein; POV, per-oxide value; n, number of samples; r^2C, coefficient of determination of calibration; RMSEC, root mean square error of calibration; r^2P, coefficient of determination of prediction; RMSEP, root mean square error of prediction.

Conclusions

The aim of this study was to evaluate the imaging system's capability to predict meat quality traits in meat processing industries. The samples underwent analysis for color, physicochemical, proximate, biochemical, and microbiological values using conventional analytical methods. Imaging technology was standardized, and the correlation coefficient between imaging data and analytical data was determined. The chicken sausage sample showed a medium correlation between image data and reference data. The accuracy of the imaging technology was assessed through calibration and validation models. The statistical model used showed that the imaging technology had the potential to replace the time-consuming, expensive, and hazardous analytical technology for determining meat chemical properties. However, more trials and samples are required to develop robust models and obtain higher predictive values for the studied parameters in the future.

Conflicts of Interest

The authors declare that there are no potential conflicts of interests.

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