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Laser and Colorimetric Analysis Techniques for Quality Assessment of Some Imported Frozen Meat Cuts

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Abstract: A total of 48 frozen cattle meat samples from four primal cuts (12 for each) representing common retail cuts in the local market in Egypt (Ribs, Shoulder, Round and Hind shank) were collected to investigate their chemical and physical attributes and determine the feasibility of using visible Laser and colorimetric properties as machine vision in quality assessment of meat. Fat percentages were significantly ($P<0.05$) decreased while, there were significant ($p<0.05$) but slight increase in all of moisture content percentages, the protein percentages, the collagen percentages, the ash percentages and finally pH values for ribs, shoulder, round and hind shank, respectively. Both of the shear force values and water holding capacity were significantly increased ($p<0.05$) while, cooking loss% were significantly ($P<0.05$) decreased for ribs, shoulder, round and hind shank, respectively. There were significantly ($P< 0.05$) decreased in values of the light intensity from 37.91, 37.02, 36.32 and 35.62 and the saturation from19.6, 18.16, 16.93 and 14.19 for ribs, shoulder, round and hind shank, respectively. Meanwhile, the hue degrees were significantly increased from 70.8, 72.14, 76.3 and 79.52 degree for ribs, shoulder, round and hind shank, respectively. Values of reflection intensity with helium-neon laser as source of light for meat cuts were significantly decreased from 66.528, 54.371, 45.823 and 35.114 Lux meanwhile, the absorption intensity was significantly increased from 883.471, 895.628, 904.211 and 914.885 Lux for ribs, shoulder, round and hind shank, respectively. The reflection intensity values were able to predict with high accuracy both of the chemical properties of meat cuts (R^2= 0.8338- 0.9932) and the physical properties of meat cuts (R^2= 0.9430, 0.9831 and 0.8354) for water holding capacity, cooking loss and shear force, respectively. This study supports that visible Laser technique and colorimetric analysis can be useful tools in the meat analysis for quality prediction and monitoring.

Key words: Laser · Colorimetric analysis · Quality, Meat Cuts · Chemical Analysis · Physical Properties · Colorimetric Properties

INTRODUCTION

Quality is one of the most important goals of the meat industry. Meat quality is difficult to be defined because it is a combination of microbiological, nutritional, technological and organoleptic components [1]. At the consumer level, the quality of meat is influenced by appearance, palatability, nutritional value, safety and wholesomeness. The factors affecting the appearance of meat include lean meat, fat color, meat texture, firmness and composition [2]. While, factors affecting the palatability of meat are tenderness, flavor (Taste and aroma) and juiciness. Hence, it becomes necessary to move focus from the aggregate "quality" to investigate individual components of meat quality, such as visual aspects (e.g. the colour of lean) or eating quality (Tenderness, juiciness and flavor), which in turn are affected by chemical composition of the meat [3]. Conventionally, there are two manual methods available for measuring the quality attributes, human inspectors and instrumental measurements. The defects associated

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with the above two manual methods, low-efficiency, inconsistency and variability, requiring an improved and automatic quality inspecting method. Invention of a non-invasive method of assessing meat quality would allow for classification of cuts into quality categories, removal of poor quality product from discerning markets and objective substantiation to guarantee product quality [4].

Many methods have been used in beef cattle to predict meat quality attributes, such as near infrared (NIR) spectroscopy [5,6]. Moreover, visual assessment of fatness and conformation[7], ultrasound scanning in live animals [8]or video-image analysis (VIA) of carcasses [9]and live animals [10]have been used as a means of assessing carcass characteristics at slaughter. Birth *et al.* [11] showed that spatial measurements of scatteringof LASER light are related to meat quality.

The aim of this research is using the techniques of visible laser and colorimetric analysis as the machine vision for measuring the quality of some imported frozen meat cuts of cattle according to their chemical and physical characteristics to improve the quality for handling and processing of meat cuts and to obtain speed and accurate measurements parameters of meat quality for meat cuts of cattle.

MATERIALS AND METHODS

Meat Samples Preparation: A total 48 frozen cattle meat samples were obtained from the local markets in Cairo, Egypt. The samples were abscised from four primal cuts (12 for each) representing common retail cuts in the local market in Egypt (Ribs, shoulder, round and hind shank). The samples were collected and prepared by trimming off external fat and connective tissues. The frozen cattle meat samples were kept in sealed plastic bags at -18°C till the investigations.

Investigations: All measurements were done on 3 replicates per sample. The investigations included:

Chemical Analysis

Moisture Content, Protein, Fat and Collagen (%): Meat chemical analysis was performed using Food Scan™ Pro meat analyzer (*Foss analytical A/S, Model 78810 and denmark*). According to the manufacturer's instructions about 50 - 100 gm of raw meat samples were minced and put in the meat analyzer cup. The cup was inserted into the meat analyzer for scanning sample with infrared to determine the chemical components.

- Ash % [12]
- Measurement of pH value[13]

Physical Characteristics:

- Water Holding Capacity [14]
- Cooking loss % [15]
- Shearing force [16]

Optical Properties: The optical properties were done at the Laboratory of Laser Application in Agriculture Engineering at National Institute of Laser Enhanced Science (NILES), Cairo University. The samples were thawed overnight in a refrigerator and then left for an hour at ambient temperature before being scanned. Spectra were taken by reflectance in a Helium-Neon (He-Ne) laser system in the visible light with wavelength 632.8 nm which used in the present work as a light source.

Meat Color Properties: Meat color was measured using Chroma meter (*Konica minolta, model CR 410, Japan*). Color was expressed using the CIE L*, a* and b* color system [17].Hue angle was calculated as [Tan^{-1} (b*/a*)] and chroma or saturation index was calculated as [(a*2 + b*2)0.5][18].

Statistical Analysis: All data were analyzed using Statistical Analysis System [19]. Comparisons between samples within each analysis were tested. Significance was determined by the F-test and least square means procedure. Main effects were considered significance at $P \leq 0.05$.

RESULTS AND DISCUSSION

Chemical Properties of Cattle Meat Cuts: Mean values of some chemical properties for the cattle meat cuts (Table1) pointed out the presence of significant differences ($P < 0.05$) between the different meat cuts whereas the fat percentages were significantly decreased from 1.67, 1.55, 1.33 and0.82 % for ribs, shoulder, round and hind shank, respectively. However, there were significant ($p < 0.05$) but slight increase in all of moisture content percentages from 74.55, 74.93, 75.35 and 75.75%; the protein percentages from 20.34, 21.25, 21.48 and 21.75 %; collagen percentages from 0.93, 1.39, 1.52 and 1.77 %; slight increase but not significant ($p < 0.05$) in ash percentages from 1.06, 1.19, 1.25 and1.28 % and finally significant

Table 1: Mean values of chemical analysis for the imported frozen cattle meat cuts

	Number of samples	Moisture %	Protein %	Fat %	Collagen %	Ash %	pH
Ribs	12	74.55[a]	20.34[a]	1.67[a]	0.93[a]	1.06[a]	5.5[a]
Shoulder	12	74.93[a,b]	21.25[a,b]	1.55[a]	1.39[a,b]	1.19[a]	5.59[a]
Round	12	75.35[b,c]	21.48[b]	1.33[a,b]	1.52[b]	1.25[a]	5.65[a,b]
Shank	12	75.75[c]	21.75[b]	0.82[b]	1.77[b]	1.28[a]	6.02[b]

a-c: Means with different superscript within the same column differ significantly at P<0.05.

Table 2: Mean values of physical analysis for the imported frozen cattle meat cuts

	Number of samples	Shear force, N	Cooking loss %	Water holding capacity %
Ribs	12	4.82[a]	51.88[a]	26.18[a]
Shoulder	12	5.26[b]	49.65[b]	29.07[b]
Round	12	6.25[c]	46.44[c]	31.43[c]
Hind shank	12	9.31[d]	43.66[d]	37.7[d]

a-d: Means with different superscript within the same column differ significantly at P<0.05.

(p<0.05) but slight increase pH values from 5.5, 5.59, 5.65 and 6.02 for ribs, shoulder, round and hind shank, respectively. These differences on pH could be due to the unequal activity of each muscle, so lower values could be related to higher concentration of glycogen and less activity.

Similar results were obtained by Cecchi *et al.* [20] who found that a strong negative correlation between moisture and fat content of beef muscle. The meat with high fat content would have lower amounts of protein and water. The moisture content of meat is about 3.5 to 3.7 times the amount of protein present[21]. It is possible to observe lower moisture, ash, crude protein for the meat without fat thickness, while fat contents were higher for the meat with fat thickness [22]. Moreover, it could be noted that the variation on chemical composition of the two cuts occurred due to the moisture content variation. Lawrie [23]suggested that both rate and extent post- mortem fall of pH values are influenced by intrinsic factors such as species, type of muscle and variability between animals as well as extrinsic factors as environmental temperature and cooling rates. Lawrence and Fowler [24] found that collagen content was similar among classes, suggesting that the amount of this type of connective tissue is not dependent of the age of the animals.

Physical Properties of Cattle Meat Cuts: Table 2 illustrated that the mean values of some physical characteristics for the cattle meat cuts. Data showed a significant (p<0.05) increase in both of the shear force values i.e. increase of tenderness, from 4.82, 5.20, 6.25 and 9.31 N and the water holding capacity percentages from 26.18, 29.07, 31.43 and 37.7% for ribs, shoulder, round and hind shank, respectively. The cooking loss percentages were significantly (p<0.05) decreased from 51.88, 49.65, 46.44 and 43.66 % for ribs, shoulder, round and hind shank, respectively due to their ability to hold up water during cooking.

These results are in agreement with those obtained by McIntyre [25] who referred to the tenderness affected by muscle pH. He stated that tenderness decreases as pH rises and is toughest in a pH range of about 5.90-6.10. Katsaras and Peetz [26] observed that lower cooking loss, the more tender the meat. Such observation may explain why beef samples were more tender than that of buffalo which in turn was tender than that of camel. If the pH values of meat is raised above 5.4 (An increase in the net negative charge), the charges repel each other. The protein space and water holding capacity (WHC) increases after normal rigor mortis development meat has a pH of about 5.5 and therefore has the lowest Water holding capacity (WHC) possible [21].

Optical Properties of Cattle Meat Cuts: Table 3 illustrated that the mean values of optical properties for meat cuts of the cattle such as reflection and absorption intensities. It noticed that the measured values of reflection intensity with helium-neon laser as source of light for meat cuts were significantly (P< 0.05) decreased from 66.528, 54.371, 45.823 and 35.114 Lux for Ribs, shoulder, round and hind shank, respectively. Meanwhile, the absorption intensity was significantly (P< 0.05) increased from 883.471, 895.628, 904.211 and 914.885 Lux for Ribs, shoulder, round and hind shank, respectively.

Laser scanning of meat was introduced by Birth *et al.* [11], based on the analysis of light scattering illuminating the upper surface of a slice of muscle with a helium-neon laser. The muscles are generally opaque and will absorb, reflect or scatter incident light,

Table 3: Mean values of optical and colorimetric properties for the imported frozen cattle meat cuts

		Optical properties of the cattle meat cuts		Color properties of the cattle meat cuts		
	Number of samples	Reflection (Lux)	Absorption, (Lux)	Light intensity value (L)	Saturation value	Hue degree
Ribs	12	66.528[a]	883.471[a]	37.91[a]	19.60[a]	70.81[a]
Shoulder	12	54.371[b]	895.628[b]	37.02[b]	18.16[b]	72.14[b]
Round	12	45.823[c]	904.211[c]	36.32[c]	16.93[c]	76.31[c]
Hind shank	12	35.114[d]	914.885[d]	35.62[d]	14.19[d]	79.52[d]

a-d: Means with different superscript within the same column differ significantly at P<0.05.

but generally do not transmit much light. Reflectance measurements are affected by muscle structure, surface moisture and fat content and pigment concentrations [27].There is a strong relationship between spectra and chemical composition, which represents good quantitative information that the spectra change. According to chemical composition and that with an appropriate data management the chemical features could be elucidated [28].

Colorimetric Properties of Cattle Meat Cuts: Table 3 also showed the mean values of color properties of meat cuts of the cattle as light intensity values (L*), saturation values and the hue degrees. There were significantly (P< 0.05) decreased in values of the light intensity values (L*) from 37.91, 37.02, 36.32 and 35.62 and the saturation from19.6, 18.16, 16.93 and 14.19 for ribs, shoulder, round and hind shank, respectively. Meanwhile, the hue degrees were significantly (P< 0.05) increased from 70.8, 72.14, 76.3 and 79.52 degree for ribs, shoulder, round and hind shank, respectively.

Therefore, the color properties were gradually changed from light red, pink, rose and dark red for ribs, shoulder, round and hind shank, respectively. So, the ribs meat sample was lighter red than the others, while the hind shank sample was the darkest red. Young *et al.* [29] reported that although meat colour is a poor guide to eating quality, most consumers make purchase decisions based on display colour. Consumers discriminate against meat that is not red and bright, considering it is old or of poor quality. The color plays a very important part in quality evaluation, as it is one of the main appearance attributes that determine the purchase decisions on meat. Color has been correlated to sensory score, pH value, storage time and temperature and so on. Some meat cuts do not have discoloration but rather an irregular color than what is typically associated with cuts from that species. Most color irregularities are related to the water-holding properties of the muscle [30].

Effect of Chemical Properties on Optical Properties of Cattle Meat Cuts: Figure 1 pointed out that the relationship among the (Reflection intensity) with (Moisture content, protein, fat, collagen, ash percentages and pH values) of cattle meat cuts. Coefficient of determination (R^2) was ranged between 0.8338 - 0.9932 that indicates, there were a strong relationship among them. Where the highest coefficient of determination (R^2) was that of moisture content and the lowest was that of pH values.

That means, by increasing of moisture content, protein percentages, collagen percentages, Ash and pH values of meat samples the reflection intensity was decreased, so the ribs of meat sample has more reflection intensity than shoulder and round meat sample respectively, while the hind shank of meat sample was the lowest reflection intensity. Figure 2 showed that the relationship among (The absorption intensity) of meat samples with (Moisture content, protein, fat, collagen, ash percentages and pH values) of cattle meat cuts. Coefficient of determination (R^2) was ranged between 0.833 - 0.9932 that indicates, there were a strong relationship among them. Where the highest coefficient of determination (R^2) was that of moisture content and the lowest was that of pH values.

That means by increasing of moisture content, protein percentages, collagen percentages, Ash and pH values of meat samples, the absorption intensity of meat samples was increased, so the ribs of meat sample has less absorption intensity than shoulder and round meat samples respectively, while the hind shank of meat sample has the most amount on absorption intensity. In this consideration, meat with a high pH appears dark while meat with a low pH appears pale. Warriss [31] explained that, the high pH results in relatively little denaturation of proteins, water is tightly bound and little or no exudates is formed. This is because there is little or no shrinkage of the myofilament lattice and the differences in refractive index of the myofibrils and sarcoplasm are reduced. The muscles absorbed light making the meat appear darker. Light scattering may be

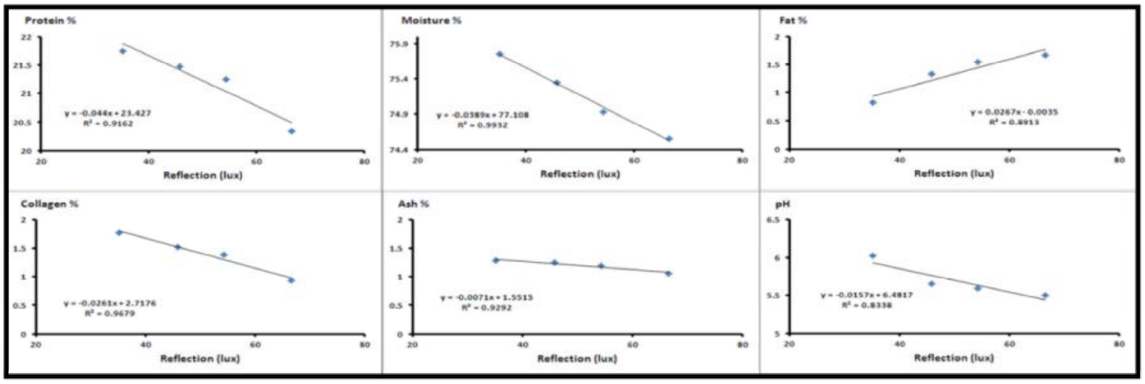

Fig. 1: Relationship between reflection intensity and chemical properties of imported frozen cattle meat cuts

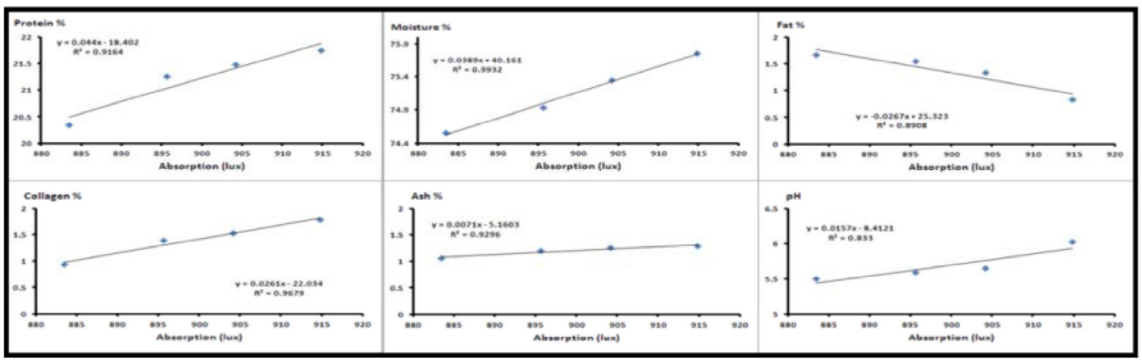

Fig. 2: Relationship between absorption intensity and chemical properties of imported frozen cattle meat cuts

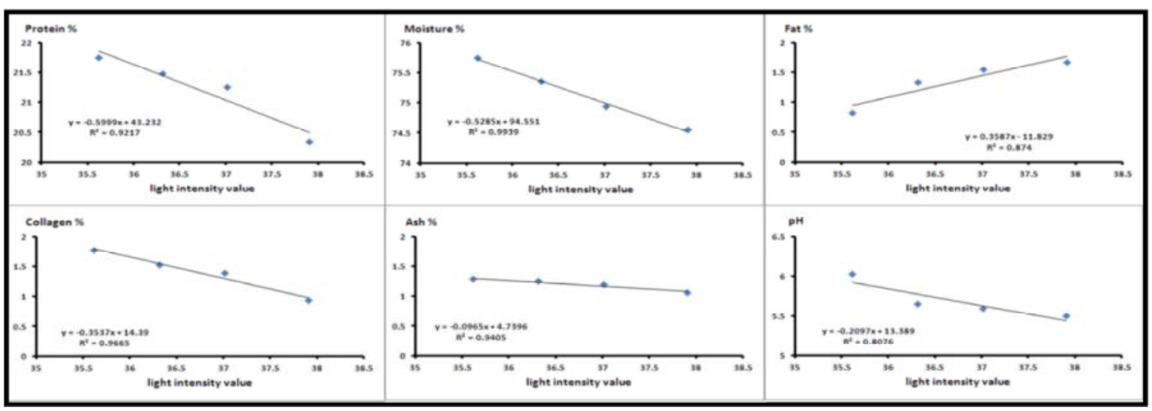

Fig. 3: Relationship between light intensity values (L*) and chemical properties of imported frozen cattle meat cuts
R^2: coefficient of determination

measured on-line for the direct prediction of the appearance of the meat, for either PSE or DFD [32], or as an indirect way of measuring other pH-related properties such as water-holding capacity [33].

Effect of Chemical Properties on Colorimetric Properties of Cattle Meat Cuts: Data in Figure 3-5 illustrated the effect of chemical properties on colorimetric properties of cattle meat cuts. The relationship between light intensity values (L*) and chemical properties (Fig.3) indicated that the coefficient of determination (R^2) was ranged between 0.8076 - 0.9939.That means there was a strong relationship among them. Where the highest coefficient of determination (R^2) was that of moisture content and the lowest was that of pH values. However, the relationship between saturation values and chemical properties (Fig.4) pointed out the coefficient of determination (R^2)

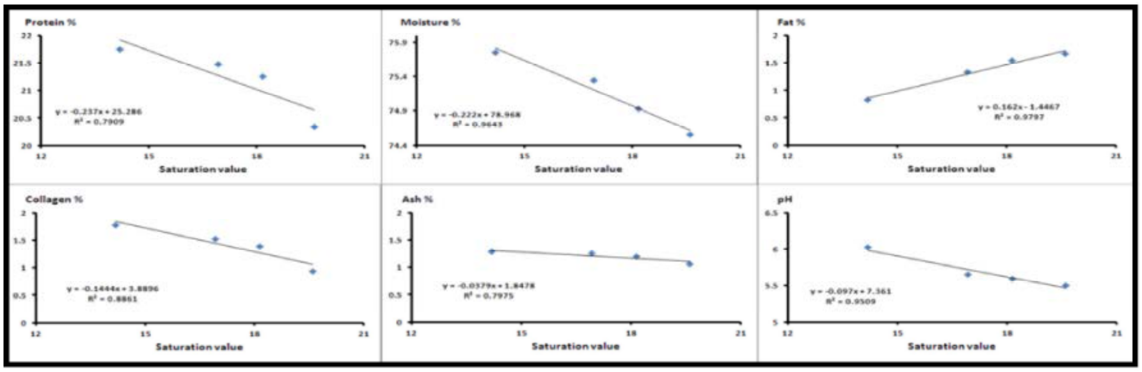

Fig. 4: Relationship Between Saturation Values And Chemical Properties Of Imported Frozen Cattle Meat Cuts

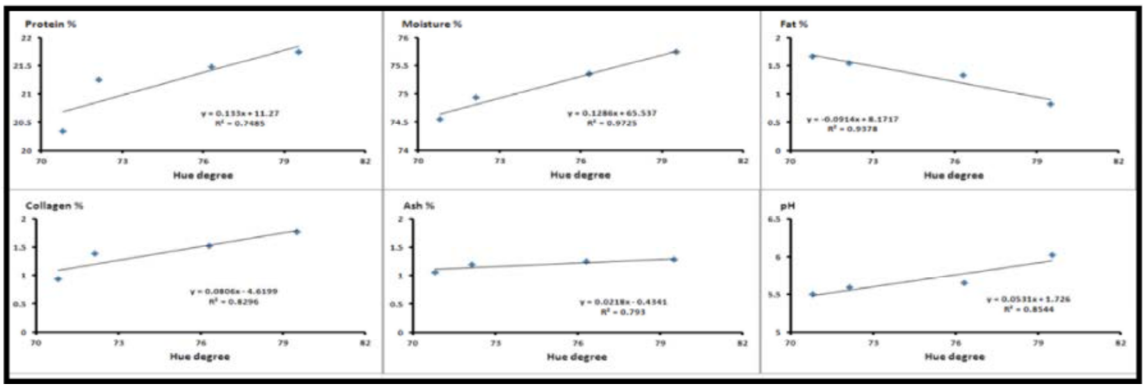

Fig. 5: Relationship between hue degrees and chemical properties of imported frozen cattle meat cuts

was ranged between 0.7909 - 0.9797 that emphasizes, there was a strong relationship among them. Where the highest coefficient of determination (R^2) was that of Fat percentages and the lowest was that of protein percentages. Finally, the relationship between hue degrees and chemical properties (Fig.5) pointed out the coefficient of determination (R^2) was ranged between 0.7485 - 0.9725 that indicates, there was a median relationship among them. Where the highest coefficient of determination (R^2) was that of moisture content and the lowest was that of protein percentages.

It was clear that by increasing moisture content, protein percentages, collagen percentages, Ash and pH values of meat sample the lightness and saturation values of meat color were decreased while the hue degree of meat samples color were increased. However, the decreases in fat percentages resulted in decrease in both (Light intensity and saturation values) of meat color and increase in the hue degree of meat samples.

Effect of Physical Characteristics on Optical Properties of Cattle Meat Cuts: Figure 6 pointed out that the relationship between the reflection intensity

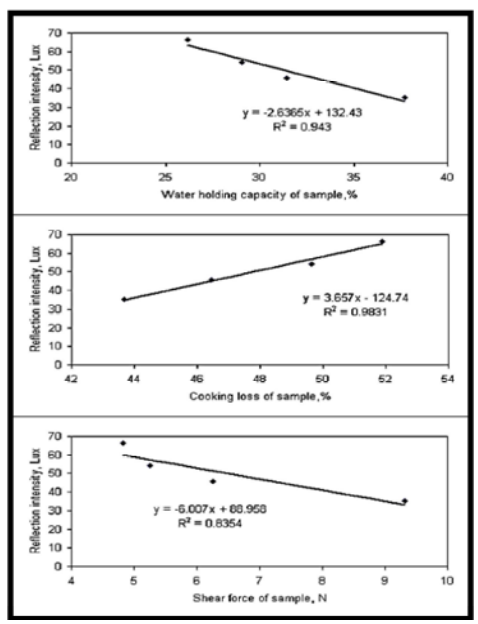

Fig. 6: Relationship between reflection intensity and physical properties of imported frozen cattle meat cuts

R^2: coefficient of determination

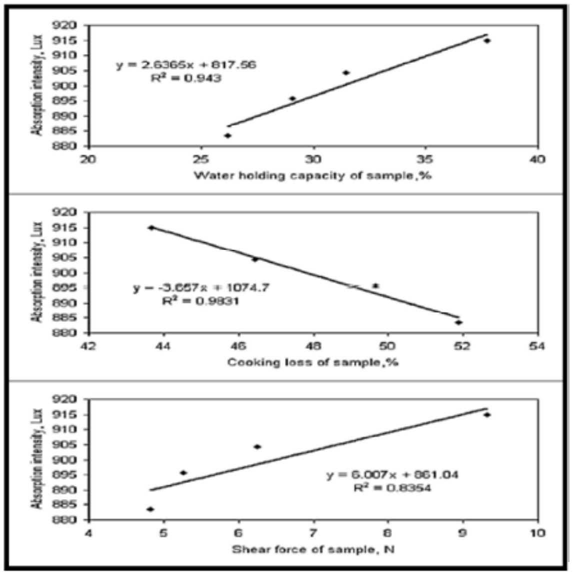

Fig. 7: Relationship between absorption intensity and physical properties of imported frozen cattle meat cuts

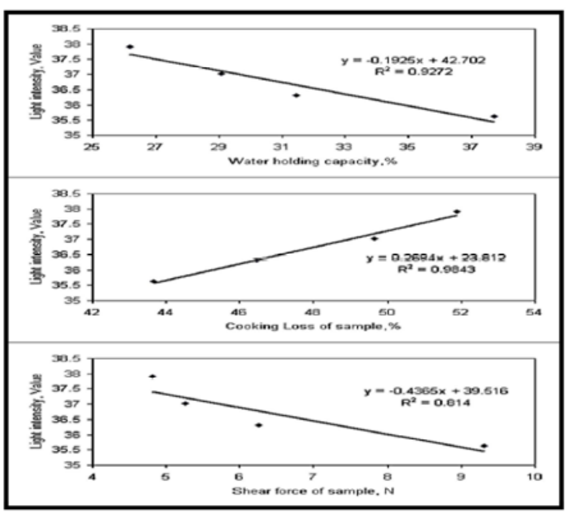

Fig. 8: Relationship between light intensity values (L*) and physical properties of imported frozen cattle meat cuts

with physical properties of cattle meat cuts. Coefficient of determination (R^2) of physical characteristics and reflection intensity of cattle meat cuts were 0.9430, 0.9831and 0.8354for water holding capacity, cooking loss and shear force, respectively. That indicates there was a strong relationship among them. Jaud *et al.* [34] reported that the usual method for predicting WHC on-line is to exploit a correlation of WHC with pH and, indirectly, with light scattering.

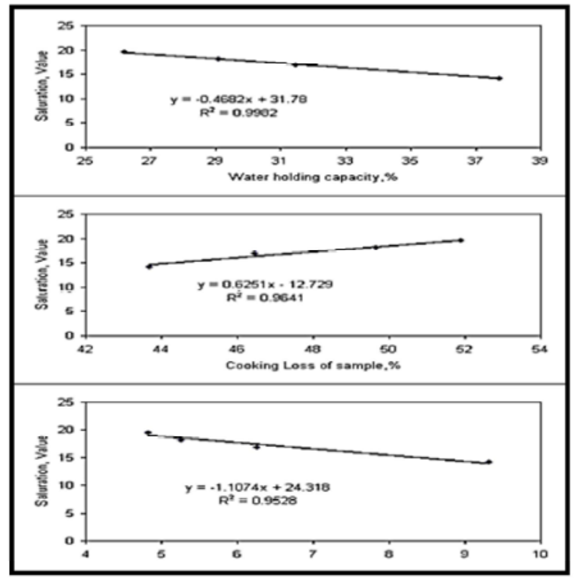

Fig. 9: Relationship between saturation values and physical properties of imported frozen cattle meat cuts.

R^2: coefficient of determination

Regarding the relationship between the absorption intensity with physical properties of cattle meat cuts (Fig.7) the coefficient of determination (R^2) were 0.9430, 0.9831and 0.8354 for water holding capacity, cooking loss and shear force, respectively. That indicates there was a strong relationship among them.

Effect of Physical Characteristics on Colorimetric Properties of Cattle Meat Cuts: Data in Figure 8-10 illustrated the effect of physical properties on colorimetric properties of cattle meat cuts. Coefficient of determination (R^2) of physical characteristics and light intensity values of cattle meat cuts (Fig.8) were 0.9272, 0.9843 and 0.8140 for water holding capacity, cooking loss and shear force, respectively. That emphasizes there was a strong relationship among them.

Coefficient of determination (R^2) of physical characteristics and saturation values of cattle meat cuts (Fig.9) were 0.9982, 0.9641 and 0.9528 for water holding capacity, cooking loss and shear force, respectively. That emphasizes there was a strong relationship among them. Coefficient of determination (R^2) of physical characteristics and hue degrees of cattle meat cuts (Fig.10) were 0.9398, 0.9862 and 0.8950 for water holding capacity, cooking loss and shear force, respectively. That emphasizes there was a strong relationship among them.

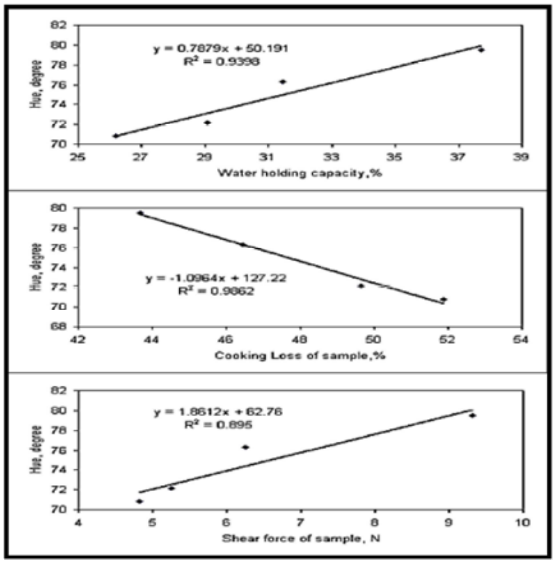

Fig. 10: Relationship between hue degrees and physical properties of imported frozen cattle meat cuts

CONCLUSION

There is a need to look for modern and innovative methods for rapid and easy evaluation of the food quality. Based on the results obtained in the present study it could be concluded that using visible LASER light technique and colorimetric analysis has the feasibility to correlate and predict chemical and physical characteristics of imported frozen cattle meat cuts. It is possible to make rapid, nondestructive and accurate cattle meat quality evaluation using these techniques. Further studies should evaluate the quality prediction ability of laser techniques on different meat products.

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