PHYSICAL PROPERTY MODELING OF RIB EYE BEEF CATTLE USING MULTIPLE REGRESSION ANALYSIS

S. Kerdpiboon[1*], P. Supaphon[1], S. Kaewsa-ard[1], Y. Peuchkamut[1] and A. Swetwiwathana[1]

[1]Faculty of Agro-Industry, King Mongkut's Institute of Technology Ladkrabang, Ladkrabang, Bangkok, 10520, Thailand
[*]Corresponding author email: kksoraya@kmitl.ac.th

Abstract – The purposes of this research were to predict physical property of rib eye steak of Thai beef cattle from surface image data (presented in terms of percentage of protein, IM-P and fat, IM-F) using multiple regression analysis. Rib eye steak was divided into premium, medium and slight levels. Each level of rib eye steak represented color, cooking loss, water holding capacity and firmness with significantly different (P≤0.05). IM-P and IM-F were used as independent variables to predict physical properties of rib eye steak using multiple regression analysis. The model could predict the physical properties of rib eye steak with R^2 higher than 0.79 in all cases.

Key Words – multiple regression, physical property, rib eye steak

I. INTRODUCTION

Beef steak has been graded according to the qualities of beef such as marbling and maturity. However, factors affecting an acceptance of beef steak consisted of physical properties, especially for color, texture and water holding capacity. Sources of beef cattle which are breeding in Thailand consist mainly of Pon Yang Kham beef cattle and Kamphaeng Saen beef cattle. These brands have been graded according to The standard of Thailand classified beef grading according to ACFS (Agricultural Commodity and Food Standards). ACFS grades beef cut using mainly of marbling and maturity of beef. Besides, marbling score assessment of beef cut in Thailand was decided from human and it is not easy to relate with other properties.

The properties such as color, texture, protein amount in beef affected the qualities and influenced consumers for choosing beef cut. Rapid techniques and tools to measure or predict these properties displayed the advantage for panel and consumer. Image analysis technique is one of non destructive technique could be used to describe the quality of beef cut. Image analysis was successful in correlation marbling and textural properties and relation of the properties to palatability and tenderness of cooked meats [1], to predict texture of food [2] to determine physical properties of food undergoing drying [3], for example. Using of image analysis to relate physical properties of Thai beef cattle is useful and could compare the qualities of beef with other countries. In addition, techniques used to develop the model prediction of food are interested. Multiple regression analysis is one of good techniques applied in many researches [4,5]. Shiranita et al. [6] applied multiple regression analysis and neural network in grading of meat from marbling score and image processing. This research analyzed numerical data from surface images of Thai beef steak achieved from Kamphaeng Saen beef cattle and relate this numerical data with physical properties using multiple regression analysis.

II. MATERIALS AND METHODS

Preparation of rib eye steak

Rib eye steak from Kamphaeng Saen beef cattle, Thailand dividing into 3 levels according to marbling level and maturity evaluated by farmer, butcher officer and trained panels was purchased. Rib eye steak thickness was 0.5-2 inches. Steak was packed in vacuum and chilled at 4°C during transportation to the lab. Storage time of rib eye beef after slaughter until finish properties determination was less than 48 hr. Ten samples of each level of rib eye steak were used. Experimental was done in triplicate.

Image acquired

Experimental set up of images was presented in Fig. 1. Rib eye steak was placed in a black box ($61 \times 61 \times 61$ cm^3). The height of the camera tripod was 18 cm and distance between camera and beef was 15 cm. Two light-emitting diode (LED) lamps with a 5 watt bulb size of 70 x 116 mm^2 were placed approximately 20.5 cm in the front of this adaptor as a light source. Rib eye steak images were captured using a Nikon camera (D3100, Japan). Ten rib eye steak in each level were used as sample. Experimental was done in triplicate.

Fig. 2: Image analysis set up

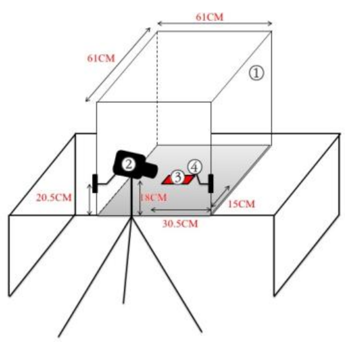

Image processing

Sirloin beef images were captured and cropped with image size of 512×512 pixels according to Supaphon et al. [7]. Images were captured in RGB format with 24 bits per pixel. Image in RGB format were changed in black and white format (BW) using intensity of 165. Pixels represented intensity between 0 to 164 were grouped in dark zone (represented protein part), while pixels represented intensity between 165 to 255 was grouped in white zone (represented fat part). Numbers of pixel calculated from images were presented percentage of protein (IM-P) and fat (IM-F). Data was calculated using MATLAB 7 Software (The Mathworks, Natick, MA) image processing toolbox.

Color measurements

Sample was measured color using Chroma meter a Model of Minolta CR-400 (Minolta, CR-400, Japan). Color was represented average in terms of L^*, a^* and b^*according to the procedure of Ramirez et al.[8]. Experimental was done in triplicate.

Texture analysis

Firmness (N) of sample was obtained by cutting cubes of $2 \times 2 \times 1$ cm^3 and measured using knife blade probe of TA-XT Plus (Stable Micro System, Surrey, England) according to Ramirez et al. [8].

Cooking loss

Sample was cut to$3 \times 3 \times 3$ cm^3 packed in polyethylene bags and heated at 75˚C for 30 min in water bath. After heating, samples were removed and cooled at 25˚C for 30 min [9]. Percentage of cooking loss was calculated using equation (1).

$$\%\,Cooking\ loss = \frac{(w_1 - w_2)}{w_1} \times 100 \qquad (1)$$

w_1 = weight of sample before heating
w_2 = weight of sample after heating

Water holding capacity (WHC)

Sample weights of 10 g were placed in a bag and heated at 90˚C for 10 min in water bath. After heating, samples were cooled at room temperature (25˚C), wrapped in filter paper and centrifuged at 9000 rpm for 10 min at 4˚C. The filter paper was removed and the sample weights were recorded according to the method of Hughes et al. [10]. The following value was calculated for percentage of water holding capacity calculated by (2) and (3).

$$\%WHC = 1 - \frac{T}{M} \times 100 \qquad (2)$$

$$\%WHC = 1 - \frac{(B-A)}{M} \times 100 \qquad (3)$$

T = total fluid loss
B = weight of sample before analyze
A = weight of sample after centrifugation
M = total water content in sample

Physical property modeling

Multiple regression analysis was applied to predict physical property from numerical data of surface images. IM-P and IM-F were used as independent variables, while physical property data was used as dependent variables. Data set was divided into prediction set of 30% and calibration set of 70%. Correlation coefficient of prediction (R_p^2), standard error of prediction (SEP), correlation coefficient of calibration (R_c^2) and standard error of calibration (SEC) were represented. The selected equations used in the research were chosen on the basis of highest multiple correlation coefficients (R^2). The equations were following from equation (4).

$$Y = b_0 + b_1X_1 + b_2X_2 + \cdots + b_nX_n \qquad (4)$$

$Y =$ the dependent variable
$X_1, X_2, \ldots X_n =$ the independent variables
$b_0 =$ the constant

III. RESULTS AND DISCUSSION

Rib eye beef steak image in each level was shown in figure 2. Steak was determined numerical data from surface images and physical properties and results were presented in table 1. It was found that levels of rib eye steak was varied depending on marbling of sample consisting of different fat and protein content. Fat content was fond both internuscular and intramuscular fat [11]. It was found that percentage of protein of beef surface image with premium level was low comparing with slight level, while fat content was high comparing with slight level. This is because higher amount of fat content in premium level was found both intermuscular and intramuscular fat than those of other levels. Lightness of rib eye steak related with fat content and result was found that lightness increased as levels of rib eye increased. Redness of rib eye steak related with myoglobin pigment in protein and was found that slight level of rib eye represented highest redness compared with other levels with significantly different.

Figure 2. Images of rib eye steak with (a), medium (b) and slight (c), respectively.

a
b
c


Water holding capacity, cooking loss and firmness of rib eye steak in each level were significantly different according to protein content and fat content of sample. High content of protein in rib eye beef (shown as slight level) represented high WHC, cooking loss and firmness.

Table 1 Physical property of rib eye steak

Value	Rib eye levels		
	Premium	Medium	Slight
Image			
IM-P(%)	82.32 ±4.03^a	89.60±0.84^b	93.19±1.50^c
IM-F (%)	17.27±4.15^c	10.38±0.83^b	6.83±1.46^a
L^*	46.32±4.37^c	42.78±3.89^b	38.47±6.04^a
a^*	21.84±2.77^a	23.89±2.48^b	24.16±2.99^c
b^*	3.50±1.37^b	3.11±1.32^b	2.24±3.94^a
WHC (%)	23.74±4.63^a	26.10±4.06^b	28.77±4.53^c
cook loss (%)	91.34±1.65^a	93.76±0.74^b	94.45±0.55^c
firmness (N)	71.08±34.31^a	78.45±55.40^a	111.51±47.82^b

Properties modeling of rib eye steak presented in terms of IM-F (X_1) and IM-P (X_2) were analyzed using multiple regression analysis. Equations prediction of all physical properties shown in equations (5)-(10) were found that numerical data of surface image had high correlation with physical properties. Surface images presented in terms of IM-F and M-P used to calibrate all physical data had R_c^2 higher than 0.91 in all cases except for redness. In addition, surface images presented in terms of IM-F and M-P could predict all physical data with R_p^2 higher than 0.79 in all cases. IM-F (X_1) and IM-P (X_2) had high correlation in prediction of redness and cooking loss with R_p^2 of 0.92.

$$L^* = 74.695+1.158X_2+0.009(X_1X_2)+4.415\times10^{-6}(X_1X_2)^2 \qquad (5)$$

R_c^2 = 0.84; SEC = 2.15; R_p^2 = 0.88; SEP =3.24

$$a^*=21.589+9.120\times10^{-4}(X_1X_2)+3.654\times10^{-6}(X_1X_2)^2-2.342\times10^{-9}(X_1X_2)^3 \qquad (6)$$

R_c^2 = 0.69; SEC = 1.35; R_p^2 = 0.92; SEP =11.28

$$b=^{*}0.591-0.001(X_1X_2)+2.478\times10^{-6}(X_1X_2)^2-8.60\times10^{-9}(X_1X_2)^3 \qquad (7)$$

R_c^2 = 0.93; SEC = 0.69; R_p^2 = 0.79; SEP =1.12

$$WHC=244.774-1.508X_2-0.009(X_1X_2)-6.958\times10^{-6}(X_1X_2)^2 \qquad (8)$$

R_c^2 = 0.81; SEC = 0.76; R_p^2 = 0.84; SEP =8.06

$$\text{cooking loss}=38.876-1.555X_1+0.076X_1^2-0.002X_1^3 \quad (9)$$

$R_c^2 = 0.85$; SEC = 1.76; $R_p^2 = 0.92$; SEP =7.57

$$\text{firmness}=6174.306-60.454X_2-0.611(X_1X_2)-1.232\times10^{-4}(X_1X_2)^2 \quad (10)$$

$R_c^2 = 0.90$; SEC = 12.62; $R_p^2 = 0.88$; SEP =13.62

IV. CONCLUSION

Numerical data of surface images of rib eye beef steak presented in terms of percentage of protein (IM-P) and fat (IM-F) could be used to predict the physical properties of rib eye steak with R_c^2 higher than 0.91 in all cases, except for redness and R_p^2 higher than 0.79 in all cases. IM-P and IM-F correlated well redness and cooking loss with R_p^2 of 0.92. The further research to predict physical properties of other Thai beef cattle would be studied.

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