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DETERMINATION OF FAT CONTENT IN RETAIL READY MEAT SAMPLES USING IMAGE ANALYSIS

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Background

As a result of constantly growing consumer expectations for meat quality, the meat industry is placing more and more emphasis on quality assurance issues. Fat content in meat influences some important meat quality parameters and meat marketability. Visible fat includes marbling (intramuscular) and intermuscular fat. Chemical analysis is currently used to determine the fat percentage in meat. However, this is a tedious, expensive and time-consuming method. Some measurements, like the number, size distribution and spatial distribution of marbling, are totally impossible by chemical analysis. For the meat industry, it is very useful to have an accurate, reliable, cost effective, fast and non-destructive technique to determine the fat content.

Computer vision has enormous potential for evaluating meat quality because image processing and analysis techniques can quantitatively and consistently characterize complex geometric, colour and textural properties. Early studies have shown that image analysis technology has great potential to improve the human based meat quality operation (Cross et al., 1983; Wassenberg et al., 1986). In the last two decades, image analysis technology has been developed in several countries and tested for beef, lamb and pork quality evaluation purposes. These include the quantification of intramuscular fat content in the beef ribeye (Chen et al., 1989), evaluation of marbling percentage and colour scores in beef (Gerrard et al., 1996; Schutte et al., 1998) and prediction of marbling (Ballerini and Bocchi, 2001; Kuchida et al., 1998; 2000).

Texture analysis approaches have also been used in the prediction of fat content using image analysis techniques (Ballerini and Bocchi, 2001). In addition to visible light images, the other types of images, such as ultrasound (Kim et al., 1998) and nuclear magnetic resonance images (Ballerini et al., 2002) have been tested in quantification of intramuscular fat content of live beef cattle and beef steaks, respectively.

Objectives

The objectives of the present study were: a) to apply image processing techniques to quantify fat content of beef and lamb steaks; b) to develop a relationship between the chemical fat content and the fat content measured by image analysis.

Methods

Sample collection: Beef porterhouse steaks (n = 32) and lamb leg steaks (n = 17) from New Zealand supermarkets were selected for this analysis. After image acquisition, the samples were stored at -20^0C for subsequent chemical fat analysis.

Chemical fat analysis: Frozen meat samples (as purchased) were weighed, freeze-dried and re-weighed to obtain the moisture content. Moisture free samples were crushed using Retsch Ultra Centrifugal Mill ZM 100 (Retsch GmbH & Co., Germany) and passed through a 2mm sieve. The crude fat was determined gravimetrically according to Soxhlet method using Soxtec System (model 1043 Tecator, Sweden) following the manual instructions and the values were expressed on wet tissue base.

Image capture: The imaging system consisted of a digital camera, lighting system, personal computer and image processing and analysis software (Chandraratne et al., 2002). The samples were all bloomed for 30 min. and surface moisture removed with a paper towel prior to image capture. For imaging, meat samples were placed flat on a non-glare black surface and illuminated with standard lighting. Both sides of the meat samples were imaged, as the amount of visible fat was different on top and bottom surfaces. The still colour images were later transferred to the PC for storage and analysis.

Image processing and analysis: Image processing and analysis was accomplished using Image-Pro Plus (Media Cybernetics, USA). We have developed semi automatic image processing and analysis algorithms to determine the fat content from meat images, initially calculating the lean area and then total area, using Image-Pro Basic programming language. Background segmentation was performed on the original images to give a uniform white background. Thresholding was done through trial and error by observing and selecting the best value, in the three-dimensional colour space (RGB). Initial values for thresholding were selected from the plot of pixel intensities. The fat content was then calculated as the fat area ratio using the formula, % fat content = (total area - lean area) x 100 / total area.

Data analysis: Statistical analysis was performed with SPSS (release 10.0.5, SPSS Inc.). The SPSS curve estimation procedure was used to develop the best-fit models.

Results and Discussion

We analysed 32 images of beef and 17 images of lamb. The results of chemical and image analyses based fat measurements are shown in Table 1.

Table 1. Fat content from chemical and image analyses

	Min	Max	Mean ± SD	CV
Chemical fat content	2.4	25.9	13.6 ± 4.7	34.8
Fat content from images	5.9	42.6	26.7 ± 6.9	26.0

Percentage of chemical fat (C) can be expressed as

$$C = \frac{V_{fat}\rho_{fat}}{V_{fat}\rho_{fat} + V_{lm}\rho_{lm} + E} = \frac{V_{fat}}{V_{fat} + V_{lm}\rho + E_1} \quad (1)$$

where V_{fat} and V_{lm} are volume of fat and volume of lean, respectively

ρ_{fat} and ρ_{lm} are density of fat and lean meat, respectively

E is the weight of constituents other than fat and lean

$\rho = \rho_{lm}/\rho_{fat}$

$E_1 = E/\rho_{fat}$

Percentage of fat from images (I) can be expressed as

$$I = \frac{A_{fat} + A_r}{A_{fat} + A_r + A_{lm}} \quad (2)$$

where A_{fat} and A_{lm} are fat and lean area from images, respectively

A_r is the residual area (other than fat and lean) from images

The equation 2 can be modified as

$$I = \frac{V_{fat} + (V_r t_{fat}/t_r)}{V_{fat} + (V_r t_{fat}/t_r) + (V_{lm} t_{fat}/t_{lm})} = \frac{V_{fat} + V_R}{V_{fat} + V_R + (V_{lm} t_{fat}/t_{lm})} \quad (3)$$

where t_{fat}, t_{lm} and t_r are thickness of fat, lean meat and residual, respectively

$$V_{fat} = A_{fat} t_{fat} \qquad V_r = A_r t_r$$

$$V_{lm} = A_{lm} t_{lm} \qquad V_R = V_r t_{fat} / t_r$$

The equations 1 and 3 are comparable except the term V_R in the numerator of the equation 3. The denominator of the equation 3 has V_R and t_{fat}/t_{lm} in places of E_I and ρ in the equation 1, respectively. The value of ρ is always greater than 1. As a result of V_R in the numerator of the equation 3, the value C (chemical fat content) is always less than I (fat content from images). This is in agreement with the results shown in Table 1. The difference in the values of C and I will mainly depend on the component V_R and the minimization of V_R will help the value of I approach that of C.

We used SPSS curve estimation module to determine whether the relationship between fat measurements using chemical and image analyses was best described by a linear or non-linear regression. The curve estimation module specifies 11 different types of curves. Statistically the regression was best fit by a non-linear regression. Figure 1 shows the relationship between fat measurements using chemical and image analyses. The equation obtained for the prediction of crude fat percentage from image analysis measurements was $\ln(C) = e^{1.2755-(8.6291/I)}$ ($R^2 = 0.81$). The prediction equation for beef samples was $\ln(C) = e^{1.2984-(8.7442/I)}$ ($R^2 = 0.84$) and for lamb samples was $\ln(C) = e^{1.2647-(9.2375/I)}$ ($R^2 = 0.72$).

Our analysis was based on retail ready meat samples and the equations are for predicting total fat content (marbling, intermuscular fat and subcutaneous fat). Most of the reported works were for the prediction of marbling in experimentally prepared meat samples. Kuchida et al. (1998, 2000) reported linear equations for predicting crude fat content of beef from fat area ratio calculated using image analysis (R^2 of 0.91 and 0.96, respectively). Ballerini and Bocchi (2001) reported a good correlation (0.977) between chemical fat analysis and fat content calculated using image and fractal texture analyses. However, image segmentation alone produced lower correlation (0.788). Both these studies analysed carefully prepared samples in contrast to meat samples from supermarkets used in our study.

Image analysis is a powerful technique to quantify the fat content in meat. However, the fat content values calculated by image analysis are quite different from the chemical fat content. This is probably due to; 1) image analysis takes 2 dimensional image of the meat surface to calculate fat content, 2) in image analysis a constant thickness of meat samples is assumed, but practically samples can get stretched unless they are carefully handled, 3) the image only reflect the meat surface and the distribution of fat across the thickness of the meat sample may be different from what we see on the surface and 4) in some cases, segmentation cannot distinguish fat and connective tissue.

Conclusion

The experimental results showed that the prediction of crude fat content from image data was non-linear. The coefficient of determination of prediction was 0.81. However, the analysis was based on area measurements only. It is expected that the results can be further improved by using different feature extraction techniques like texture analysis.

References

Ballerini, L., and Bocchi, L. (2001). *2nd International Symposium on Image and Signal Processing and Analysis* (ISPA 2001), Pula, Croatia, 19 - 21 June 2001.

Ballerini, L., Hogberg, A., Borgefors, G., Bylund, A. C., Lindgard, A., Lundstroam, K., Rakotonirainy, O. and Soussi, B. (2002). *IEEE transactions on Nuclear Science*, 49 (1), 195 - 199.

Chandraratne, M.R., Kulasiri, D., Samarasinghe, S., Frampton, C. and Bickerstaffe, R. (2002). *48th ICoMST,* Rome, Italy, 25-30 August 2002, pp 756 - 757.

Chen, Y. R., McDonald, T. P. and Crouse, J. D. (1989). *ASAE Paper No. 893009*, ASAE, St. Joseph, Michigan, U.S.A.

Cross, H. R., Gilliland, D. A., Durland, P. R. and Seideman, S. (1983). *Journal of Animal Science,* 57(4), 908 - 917.

Gerrard, D. E., Gao, X., & Tan, J. (1996). *Journal Food. Science*, 61, 145 - 148.

Kim, N. D., Amin, V., Wilson, D., Rouse, G. and Udpa, S. (1998). *Ultrasonic Imaging*, 20, 191 - 205.

Kuchida, K., Konishi, K., Suzuki, M. and Miyoshi, S. (1998). *Animal Science and Technology*, 69 (6), 585 - 588.

Kuchida, K., Konk, S., Konishi, K., Van Vleck, L. D., Suzuki, M. and Miyoshi, S. (2000). Journal of *Animal Science*, 78, 799 - 803.

Schutte, B. R., Biju, N., Kranzler, G. A. and Dolezel, H. G. (1998). *Research Report P 965,* Oklahoma Agricultural Experimental Station.

Wassenberg, R. L., Allen, D. M. and Kemp, K. E. (1986). *Journal of Animal Science*, 62, 1609 - 1616.

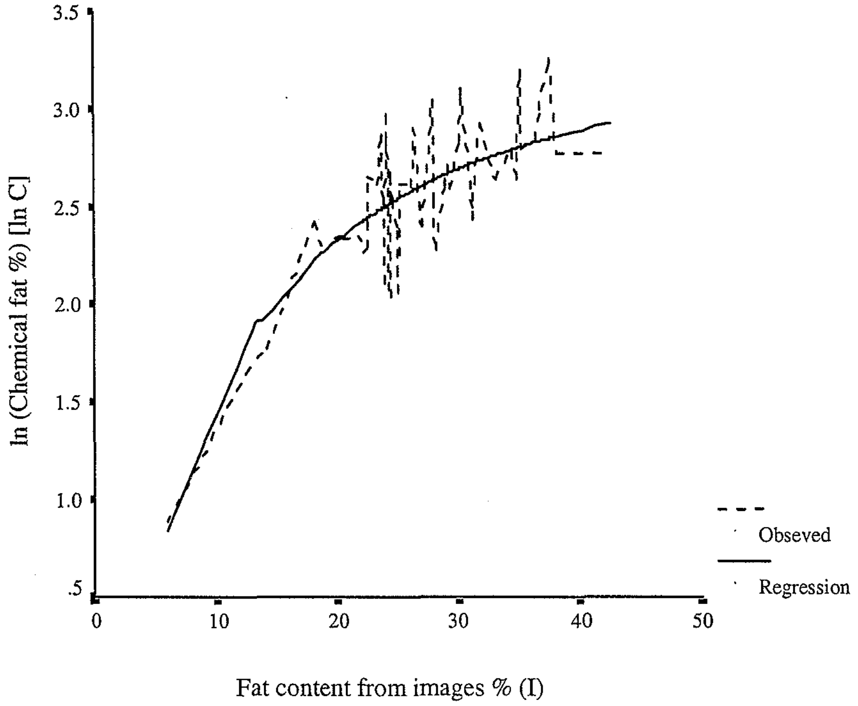

Figure 1. The relationship between crude fat measured by chemical and image analyses