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BEEF QUALITY: INTEGRATED ANALYSIS BY COMPUTER VISION AND PHYSICOCHEMICAL PARAMETERS

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I. INTRODUCTION

Meat is one of the most valuable animal products and an essential source of protein. Its quality is determined by physicochemical and sensory characteristics, such as color, texture, and odor, which are influenced by various intrinsic and extrinsic factors [1]. One of the main quality defects in beef is the Dark, Firm, Dry (DFD) condition, which occurs due to prolonged *antemortem* stress that depletes muscle glycogen stores, limiting *postmortem* glycolysis and reducing lactic acid formation. As a result, the muscle pH remains high, leading to meat that is darker, firmer, and drier. This alteration compromises sensory characteristics and negatively affects its appearance, often resulting in a lack of consumer acceptance [2]. Given these challenges, accurately assessing meat quality is essential. However, conventional methods have limitations, as they are often time-consuming and destructive. In this context, computer vision-based image analysis has emerged as a promising alternative, allowing rapid, nondestructive and objective monitoring of meat quality [3]. The physicochemical and sensory characteristics of beef have been analysed to categorize it according to its quality, either as normal or DFD meat.
This study aims to build a model to estimate the quality of the meat by using a computer vision system.

II. MATERIALS AND METHODS

The *longissimus thoracis et lumborum* (LTL) muscle on the left side of the carcasses of 20 male bovine, excised at 24h *pm*, was used to assess beef quality. The pH at 24h *pm* was measured directly on the meat. The colour coordinates: L* (lightness), a* (redness), b* (yellowness), C* (chroma), and h (hue angle) were measured after 1h of blooming using a Minolta CR-400 colorimeter. The intensity of the red colour by sensory analysis was evaluated on a scale of 1 to 7 by trained panelists. Drip loss was assessed after 6 days of storage at 4°C in trays covered with polythene film. Cooking loss was assessed after 6 days *pm* in samples cooked in polythene bags in a water bath at 80°C until they reached 71°C internally [4]. For shear force determination, samples processed for cooking loss were cut into parallelepipeds with muscle fibres parallel to the length and placed on a Warner-Bratzler rectangular probe coupled to a TA.XT plus texturometer with a 30kg load cell, blade velocity 200mm/min and trigger force of 5.00g [5]. Samples were photographed using a Sony α58 digital camera (20 MP; 1/8 at F7.1; ISO 100) in a darkroom with four LED bulbs (1710 lm each) and a PET LED light diffuser film. The captured images were analysed using a MATLAB-developed algorithm to calculate the average L^*_{image}, a^*_{image}, and b^*_{image} values in the region of interest. Seventy-five percent of the images were used to build the model in XLSTAT, while the remaining images were used for testing.

III. RESULTS AND DISCUSSION

Meat with a pH_{24h} > 5.8 were classified as DFD (n=9), while the remainder were considered normal (n=11) [6]. Table 1 shows the mean, standard deviation (SD) and range of beef LTL muscle quality parameters after 24 hours *pm*.

Table 1. Mean, standard deviation (SD) and range of Normal (n=11) and DFD (n=9) beef quality parameters.

	Quality					
	Normal			DFD		
	Mean	SD	Range	Mean	SD	Range
pH	5.56	0.13	5.45 – 5.81	6.29	0.29	5.91 – 6.75
L*	41.29	2.50	37.39 – 45.39	35.11	2.62	30.33 – 39.04
a*	15.98	1.89	12.97 – 19.47	11.15	0.66	10.33 – 12.28
b*	8.74	1.28	7.32 – 11.02	5.06	0.63	4.46 – 6.24
C*	18.23	2.24	15.01 – 22.37	12.27	0.83	11.33 – 13.64
h	28.67	1.30	26.21 – 30.54	24.24	1.70	22.11 – 27.67
Drip loss (%)	1.06	0.30	0.65 – 1.67	0.55	0.37	0.22 – 1.40
Cooking loss (%)	20.67	4.33	14.41 – 26.75	12.52	4.35	6.13 – 19.84
Shear Force ($N.cm^{-2}$)	65.19	26.61	38.24 – 119.7	43.35	26.55	14.78 – 94.51
Colour (sensory analysis)[1]	4.09	0.70	3.00 – 5.00	5.44	1.13	3.00 – 6.00

[1] Expressed as a percentage of mass loss in relation to the initial mass.
[2] The intensity of the red colour (24 hours *post-mortem*) varies on a scale of 1 to 7 (1 – pale; 7 – dark).

Principal Component Analysis (PCA) effectively distinguished the colour information between DFD and normal beef from computer vision-based image analysis, achieving a 95% success rate (Figure 1). PC1 and PC2, which explain 96.47% of the data variability, reveal a clear separation: DFD meat samples cluster distinctly on the left, while normal meat samples are positioned on the right. Test data from DFD samples (TB2 and TB5) clustered with the DFD beef, whereas normal test samples (TB1, TB3, and TB4) aligned with the normal ones.

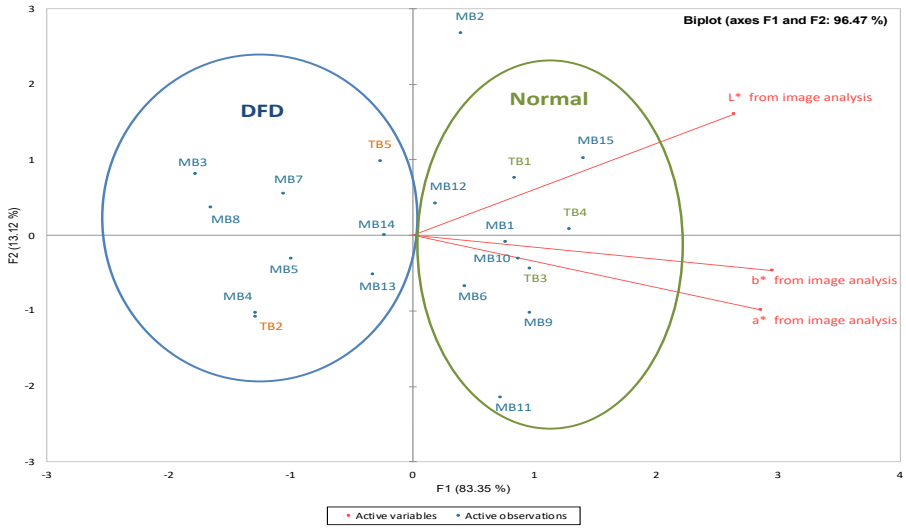


Figure 1. Classification of different beef qualities by colour information from computer vision-based image analysis. MB: Model beef data; TB: Test beef data.

IV. CONCLUSION

Computer vision-based image analysis successfully estimated the quality of DFD and normal beef based on colour information. This technique is promising compared to conventional methods since it is nondestructive, fast, and easily adaptable to slaughterhouses.

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