Feasibility of Hyperspectral Imaging as a tool for Quality Evaluation of Beef Burger Patties

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I. INTRODUCTION

Quality monitoring in added-value products, is a critical factor to achieve consistent production and transparency in the meat supply chain from farm to fork and ensure products are healthy and desired by consumers. Beef burgers are a major value added product typology in the beef sector with a globally high consumption pattern. Offline quality measurement of processed meat product quality attributes can be carried out using wet chemistry, sensory analysis etc. However, these methods are time consuming, destructive, and not adaptable to rapid or inline evaluation in an industry that is significantly sensitive to time. Technologies available for inline application inform on crude composition and contaminants but do not currently predict attributes reflective of process, technological, or sensory quality. The application of Industry 4.0 in the food sector would permit data-driven decisions that can help reduce batch rejection, and consequently food losses and waste, and increase consistency in quality and safety traceability [2]. The main objective of this study, therefore, is to investigate the feasibility of developing predictive models for quality attributes of raw and grilled beef burger patties, as a model system, using hyperspectral imaging and machine learning algorithms.

II. MATERIALS AND METHODS

An experimental design established variable burger patty formulations for quality prediction including fat content (5, 10, 15, 20, 25, and 30%), mincing levels (coarse and fine), and muscle types (round, brisket, and chuck steak). Figure 1 shows the workflow. Each batch of burgers (1 Kg) was prepared by chopping lean beef (95% VL) into approximately 20x20x20 mm pieces, then adding designated quantity of subcutaneous fat cubes along with 1% salt (1 g). The mixture was minced using a food mincer for 60 seconds. Coarse minced batches were prepared with 8 mm plate; whereas fine minced batches were made by passing the mixture first through the coarse plate(8 mm) and then a finer 3 mm plate. A hand burger former was used to form burgers of 90 mm diameter and 14 mm thickness. The total number of batches was 36 comprising 10 burgers for each batch. Quality attributes measured for raw burgers included water activity (a_w), Water Holding capacity (WHC). Samples were scanned, on both sides, using a NIR hyperspectral imaging (900-1700 nm), then stored at -18 °C until cooking. Each batch of burgers was grilled using an electric table grill for 15 minutes until the core temperature reached 75 °C, then scanned, and the cooking loss was calculated, followed by Texture Profile Analysis (TPA) using a texture analyzer. Compositional analysis (moisture content, fat, protein, and ash) was conducted following frozen storage. The Region of Interest (ROI) (i.e., the burger) was segmented, for each image, at each wavelength and the Mean Reflectance Spectra (MRS) as shown in Figure 2. MRS was calibrated using a standard white reference plate and the background (i.e., dark) images. Preprocessing techniques were applied to eliminate the effect of noise in the spectra. Prediction models were developed using Partial Least Squares Regression (PLSR), where data was divided into training (80%) and testing (20%) sets and 4-fold cross validation was applied on the training set, and the

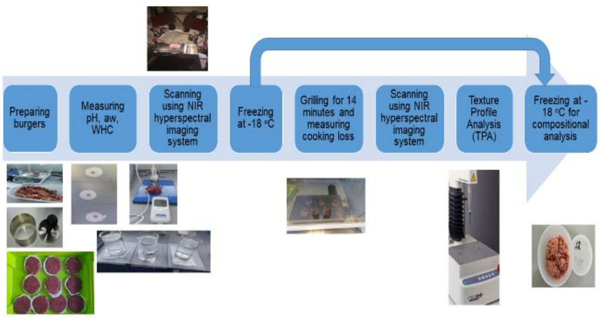

Figure 1. A schematic diagram of the workflow.

optimal training model was chosen based on the Root Mean Square Error of Cross Validation (RMSECV).

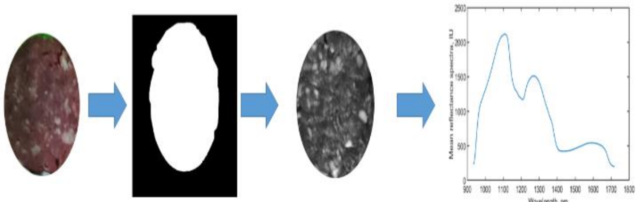

Figure 2. Procesisng of the hyperspectral images.

III. RESULTS AND DISCUSSION

Results of mean reflectance spectra for raw and grilled burgers, shown at Figure 3, revealed several absorption peaks around 960 nm and 1460 nm due to moisture content, and around 1200 nm due to the C- H stretching second overtone related to lipids. In general, high fat batches (i.e., lighter in color) showed lower absorbance than low fat batches (i.e., darker in color) which is comparable to results in [4]. Coarse patties showed more disperse spectra than fine patties due to the rougher surfaces of the former. Similarly, grilled patties showed more disperse spectra than raw ones. Predictive modeling of different quality attributes for the test set are shown in Table 1. The best PLSR models for raw burgers yielded r(RPD) values of 97.34%(3.34), 96.18%(3.62), and 81.55%(1.72) for moisture, fat, and protein, respectively. Whereas, grilled burgers showed less performance with r(RPD) values of 83.47%(1.83), 81.96%(1.75), and 80.62%(1.68) for moisture, fat, and cooking loss, respectively. These values are comparable to previous studies, which resulted r values of 97% for moisture and fat contents [5].

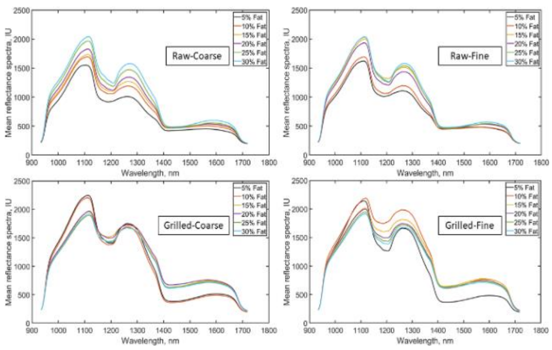

Figure 3. Results of MRS for raw and grilled burgers.

Table 1. PLSR results of different quality traits for raw and grilled burgers.

Burger status	Quality traits	Test set metrics*		
		r (%)	RMSEP	RPD
Raw	Moisture (%wb)	97.34	1.34	3.34
	Protein (%wb)	81.55	1.48	1.72
	Fat (%wb)	96.18	2.13	3.62
	Water holding capacity	64.40	10.60	1.30
Grilled	Moisture (%wb)	83.47	3.36	1.83
	Protein (%wb)	58.87	1.46	1.25
	Fat (%wb)	81.96	4.08	1.75
	Cooking loss (%)	80.62	3.75	1.68
	Gumminess, g	66.10	923.84	1.34
	Chewiness, g	69.69	1311.30	0.84
	Hardness, g	64.41	1355.30	1.19

IV. CONCLUSION

This study presented a feasible methodology for rapid and non-invasive quality assurance of nutrients and technological attributes of raw and cooked beef burgers using optical technology, offering a unit-based quality tracking. Results obtained in this study can be enhanced with feature selection as well as deep learning algorithms.

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