

# STEAK PERFECTION: HOW VISUAL AND INSTRUMENTAL MEASUREMENTS ENSURE THE IDEAL TEMPERATURES FOR DEGREES OF DONENESS

Marbi Schwartz<sup>1\*</sup>, Phillip E. Strydom<sup>2</sup>, Louwrens C. Hoffman<sup>3</sup>, Marieta Van der Rijst<sup>4</sup>, and Jeannine Marais<sup>1\*</sup>

<sup>1</sup>Department of Food Science, Stellenbosch University, South Africa

<sup>2</sup>Department of Animal Sciences, Stellenbosch University, South Africa

<sup>3</sup>Centre for Nutrition and Food Sciences, QAAFI, The University of Queensland, Australia

<sup>4</sup>ARC-Biometry, Infruitec-Nietvoorbij, South Africa

\*Corresponding author email: [jeanninemarais@sun.ac.za](mailto:jeanninemarais@sun.ac.za)

## I. INTRODUCTION

Raw beef is characterised by a blood-like taste due to the presence of blood salts and saliva in the mouth [1]. Cooking results in better palatability and the pleasant flavours and textures associated with cooked meat. Furthermore, cooking meat to a specific internal temperature at the geographical centre results in meat with different cooking states (i.e., degrees of doneness, DOD) depending on the cooking method and the final temperature. Different DOD of beef influence the eating quality and sensory perception of consumers, which is a unique obstacle to beef quality research [2], [3]. Another challenge is that there is no consolidation of the temperatures used for the different DOD of beef steaks. The aim of this study was to use visual perception and instrumental measurement of internal meat colour to select end-point temperatures best linked to three main categories of degree of doneness (rare, medium, and well-done).

## II. MATERIALS AND METHODS

Four beef striploin muscles (~4 kg) aged 21 d, were randomly assigned to four experimental sessions over four days. Before every session, the assigned striploin was defrosted (24 h;  $4 \pm 1^\circ\text{C}$ ), trimmed of all subcutaneous fat and sinew, and cut into approx. 2.54 cm (1 inch) steaks using a cutting grid. Each steak was randomly assigned to one of 15 temperatures (52, 55, 60, 63, 65, 65.5, 70, 71, 72, 74, 75, 76.6, 77, 80, and  $92^\circ\text{C}$ ) obtained from literature corresponding to five categories of DOD (rare, medium-rare, medium, medium-well, well-done). Steaks were cooked on a double-sided clam-shell grill until the respective temperatures were reached ( $2.27 \pm 0.52$  to  $5.41 \pm 0.66$  min). Raw steaks were bloomed for 1 h, while cooked steaks were cooled ( $21 \pm 1^\circ\text{C}$ ; ~2 min resting period) before surface colour measurements (CIE Lab colour coordinates) were taken on the inside of the halved, cooked steak. The internal face of the cooked steak halves ( $n = 58$ ) was photographed using standardised photographic equipment and used in an online consumer questionnaire. In the image identification sections of the questionnaire, participants were asked to categorise 15 individual and randomly presented photographs into one of five categories of DOD. Thereafter, participants were presented with a collage of the photographs and asked to indicate their most and least preferred images based on the visual internal steak colour. Participants were instructed to indicate their preferences for beef steak, how they preferred beef steak cooked at home and in a restaurant, and their methods of determining the DOD of cooked steak. Statistical analyses were conducted as described by Prill *et al.* [4] using SAS software (Version 9.4; SAS Institute Inc, Cary, CA, USA).

## III. RESULTS AND DISCUSSION

Results from a principal component (PC) bi-plot suggested that participants could discern categories of DOD based on the photographs of the internal steak colour ( $P < 0.05$ ), particularly for steaks cooked to lower (rare to medium-rare) and higher (well-done) temperatures (Fig. 1). Well-done ( $77 - 92^\circ\text{C}$ ) and rare ( $52^\circ\text{C}$ ) to medium-rare ( $65^\circ\text{C}$ ) photographs were closely linked to their preferred DOD, however, some categories fell in the middle (medium – 70, 71 and  $72^\circ\text{C}$ ; medium-well – 74, 75 and  $76.6^\circ\text{C}$ ). Ward's

clustering identified three groups, corresponding to three commonly used categories of DOD (rare, medium, and well-done) (Fig. 1). The latter assisted in selecting temperatures for the rare and well-done categories.

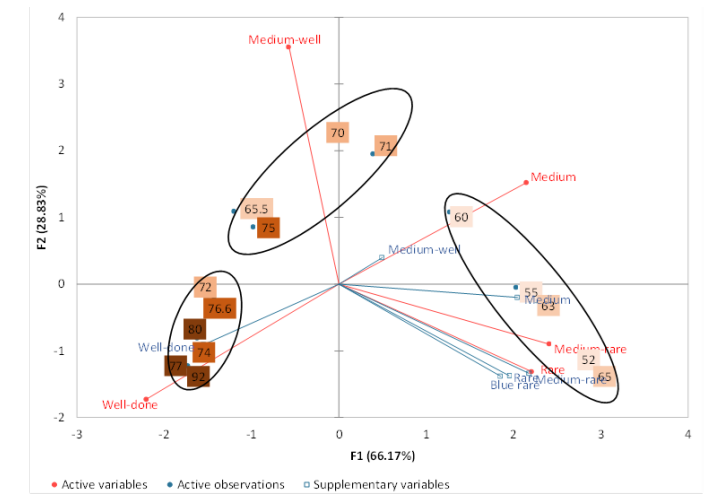


Figure 1. Principal component bi-plot showing internal end-point temperatures (52, 55, 60, 63, 65, 65.5, 70, 71, 72, 74, 75, 76.6, 77, 80, and 92°C) in the space created by participant (n = 350) evaluation of degree of doneness based on 15 photographs. The different colours of the projection points indicate the category of degree of doneness (rare, medium-rare, medium, medium-well, and well-done) into which the respective end-point temperatures were grouped. The active variables (red) represent the perceived degrees of doneness based on the photographs, while the supplementary variables (blue) represent the most preferred photographs based on the internal colour of the steaks. The black circles around the PC scores represent the groups into which the scores were sorted after the implementation of agglomerative hierarchical clustering.

Although there were a few temperatures to choose from, the lower temperature for rare (52°C) and higher temperature for well-done (92°C) was chosen to ensure that steaks cooked to these temperatures will be a true representation of the respective DOD categories. Due to the abundant protein denaturation that occurs between 42 – 70°C [5], the consumers' perception of internal meat colour may not be the best method to standardise an internal temperature for the medium DOD category. Instead, the inflection point of a sigmoidal regression curve ( $R^2 = 0.80$ ) of the chroma values of cooked steaks allowed for the identification of the temperature best linked to the medium category of DOD. The inflection point at 71°C (where chroma change started slowing down) was considered the best temperature representing the medium category of DOD and is most represented for the medium DOD category in literature.

#### IV. CONCLUSION

The recommended temperatures for rare, medium, and well-done are 52, 71, and 92°C, respectively.

#### REFERENCES

1. Duan, W., Wang, L., Zhang, Y., Huang, Y., Xiao, J. & Pu, D. (2020). Optimization of the cooking methods of stir-fried beef by instrumental analysis. *Journal of Food Processing and Preservation* 44: 1-9.
2. Cox, R. J., Thompson, J. M. & Gordo, A. J. (1997). The effect of degree of doneness of beef steaks on consumer acceptability of meals in restaurants. *Meat Science* 45: 75–85.
3. Lucherk, L. W., O'Quinn, T. G., Legako, J. F., Rathmann, R. J., Brooks, J. C. & Miller, M. F. (2016). Consumer and trained panel evaluation of beef strip steaks of varying marbling and enhancement levels cooked to three degrees of doneness. *Meat Science* 122: 145–154.
4. Prill, L. L., Drey, L., Olson, B. A., Rice, E. A., Gonzalez, J. M., Vipham, J. L., Chao, M. D., Bass, P. D., Colle, M. J. & O'Quinn, T. G. (2019). Visual degree of doneness impacts beef palatability for consumers with different degree of doneness preferences. *Meat and Muscle Biology* 3: 411–423.

5. Schwartz, M., Marais, J., Strydom, P. E. & Hoffman, L. C. (2022). Effects of increasing internal end-point temperatures on physicochemical and sensory properties of meat: A review. *Comprehensive Reviews in Food Science and Food Safety* 21: 2843–2872.