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THE INFLUENCE OF DIFFERENT MUSCLE FIBER STRUCTURES ON THE EFFECT OF IRIDESCENCE IN COOKED CURED PRODUCTS

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I. INTRODUCTION

Iridescence is an optical phenomenon caused by interference in which the surface appears in a different iridescent color depending on the viewing angle [1]. In meat and meat products, this is often misinterpreted by consumers as a sign of spoilage or the addition of chemical additives. There are two main theories for the formation of interference colors in meat, but the actual cause has not yet been clarified. In multilayer interference, the incident light strikes sarcomeres and is reflected partly at the surface and the Z-disk and partly deeper in the sarcomeres at the I- and A-bands due to their different refractive indices. The periodic arrangement of the myofibrils protruding from the surface is reminiscent of a diffraction grating. This could bend incident light rays according to their wavelengths [1]. In order to avoid financial losses for manufacturers, solutions are being sought to prevent the occurrence of iridescence. As a hypothesis, it is postulated that iridescent and non-iridescent areas differ microscopically depending on the structural surface of muscle fibers.

II. MATERIALS AND METHODS

Raw material: 14 cooked pork hams were produced out of *M. semitendinosus* (ST)(n=3), *M. longissimus dorsi* (LD) (n=4), *M. biceps femoris* (BF)(n=3) and *M. rectus femoris* (RF)(n=4) as described [2]. The maximum iridescence of three slices of each ham was photographed and the iridescent area in percent determined. Images were taken with camera (Alpha 58) with an 18-55 mm objective (DT 18-55 mm F3.5-5.6 SAM II) (Sony Corporation, Tokyo, Japan).
Image analysis of CLSM: To examine the surface topographies and calculate the cross-sectional area of the muscle fibers, 3D images of the cut surfaces of each section were taken using a confocal laser scanning microscope (model Nikon D-Eclipse C1, Nikon GmbH, Düsseldorf, Germany). Circular samples with a diameter of 1.5 cm were punched out of a 5 mm thick slice; one sample from the iridescent area (I) and one from a non-iridescent area (NI) of the slice. The samples were stained with 20 µL calcofluor white. Images were converted to TIFF using RawTherapee 5.6, and evaluated with ImageJ 1.52a. The cross-sectional areas of the muscle fibers (cross sectional area, CSA) were determined using confocal laser scanning microscopy (CLSM) at 10x and 20x magnification (min. 60-250 fibers per image). The height profile and the measured maximum height difference can be recorded to +/- 3 µm via the color differences of the sections of muscle fibers in a specified image area (400 µm x 400 µm).
Statistical analysis: For data evaluation, the assumptions for ANOVA are tested using a test for normal distribution (Shapiro-Wilk) and equal variances (Browne-Forsythe). If both assumptions are met, an ANOVA with a Student-Newman-Keuls post-hoc test is run; if not, an ANOVA on ranks with a Student-Newman-Keuls post-hoc test is used. The significance level of $p<0.05$ was used.

III. RESULTS AND DISCUSSION

A total of 14 cooked pork ham samples were examined for the presence of iridescence. The mean values of the image analysis are presented in Table 1. The areas of iridescent surfaces on the meat pieces of LD were found to be significant ($p < 0.05$) larger. However, the iridescent surfaces of the meat slices varied greatly in different muscles but also between the same muscles (Table 1).
This study investigates the potential influence of the cross-sectional area of muscle fibers in cooked pork ham on the expression of iridescence as observed by three-dimensional confocal laser scanning microscopy (3D-CLSM). The investigation revealed that the cross-sectional area of the muscle fibers has no direct influence on the iridescence of cooked pork ham. Using 3D-CLSM at 10x and 20x magnification, the cross-sectional area (CSA) of the iridescent and non-iridescent areas in each cut was accurately determined. The diffraction grating hypothesis would mean that the CSA of the iridescent regions would have smaller measurement deviations and would be smaller than those of the non-iridescent regions. The results showed that the iridescent and non-iridescent areas of the cuts did not differ significantly in their CSA ($P>0.05$). There were also no significant differences between the cuts. To examine the 3D-images of CLSM from each section of the iridescent and non-iridescent areas, the maximal hight difference were calculated and the results are shown in Table 1.

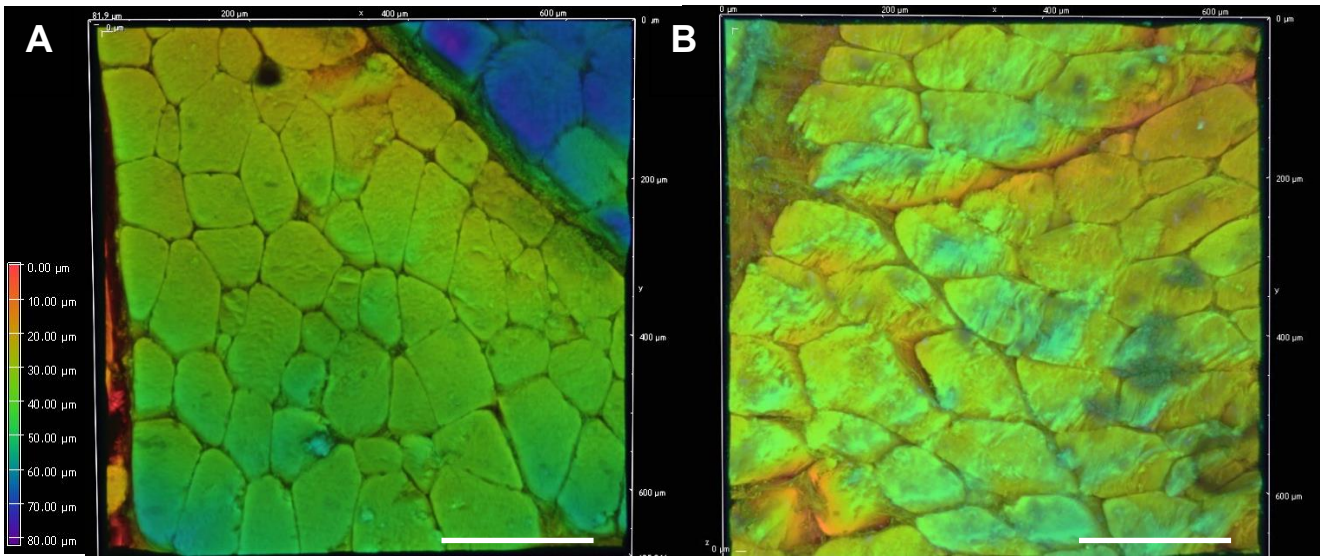


Figure 1. 3D image of a ham slice of the iridescent area of *LD* 2 at 20x magnification. (A) 3D image of a ham slice of the non-iridescent area of *LD* 2 at 20x (B). (scale bar 200 µm)

Table 1 – Calculated iridescent area (I) per cooked ham slices, cross sectional areas (CSA) and max. hight difference of iridescent (I) and non-iridescent (NI) areas of muscle fibers in the 3D-CLSM-images (mean ± standard error).

Muscle	I-Area per slices*		CSA*		CSA	Max. hight difference*	
	n	I (%)	I (µm²)	NI (µm²)	I /NI (%)	I (µm)	Ni (µm)
ST	3	2.5 - 28.1^{a}	1510 ± 335^{aA}	1306 ± 277^{aA}	53.0 / 47.0 ± 5.2	8.8 ± 1.9^{aA}	28.1 ± 5.5a^{aB}
LD	4	13.4 - 51.5^{b}	1644 ± 40^{aA}	2412 ± 522^{aA}	42.6 / 57.4 ± 5.7	7.6 ± 2.6^{aA}	33.8 ± 5.1^{aB}
BF	3	6.2 - 14.6^{a}	1396 ± 248^{aA}	1463 ± 297^{aA}	49.7 / 50.3 ± 3.4	15.8 ± 1.7^{aA}	17.5 ± 2.2^{aA}
RF	4	1.2 - 8.5^{a}	988 ± 169^{aA}	1404 ± 230^{aA}	41.0 / 59.0 ± 4.2	9.4 ± 1.6^{aA}	24.6 ± 1.9^{aB}
ΣM	14	17.1 ± 4.5	1374 ± 107^{A}	1684 ± 209^{A}	45.9 / 54.1± 2.5	10.1 ± 1.2^{A}	26.0 ± 2.6^{B}

* Different lowercase letters indicate significant differences between the muscles and uppercase letters between I and NI ($p<0.05$)

According to the hypothesis, the images of the iridescent regions showed a smoother appearance in comparison to the non-iridescent regions (Figure 1). The 3D images show a more uniform appearance of the muscle fibers of the iridescent areas. This would support the statement of another study that structural uniformity promotes iridescence [3]. The results showed that the hight differences of the iridescent regions did significantly differ between the iridescent and non-iridescent regions ($P<0.05$) (Table 1). Future measurements could investigate these smaller structures that consider avoiding iridescence at a certain roughness.

IV. CONCLUSION

It appears that the hypothesis could be confirmed. It seems that there are different structural surface elements, such as roughness, as seen in the 3D-CLSM images. The topography of the 3D-CLSM images showed a smoother surface for the iridescent regions. The maximal height difference appeared to confirm these results to a significant degree. It may be worthwhile for future research to investigate the possibility of preventing the iridescence on the surface of cooked pork ham by adjusting the roughness of the surface of the muscle fibers.

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REFERENCES

1. Ruedt, C., Gibis, M., & Weiss, J. (2023). Meat color and iridescence: Origin, analysis, and approaches to modulation. Comprehensive Reviews in Food Science and Food Safety, 22(n/a), 3366–3394.
2. Ruedt, C.; Gibis, M.; & Weiss, J. (2021). Influence of muscle type and microstructure on iridescence in cooked, cured pork meat products. Journal of Food Science, 86(8), 3563-3573.
3. Wang, H. (1991): Causes and solutions of iridescence in precooked meat. Ph.D. dissertation. Kansas State University, Manhattan