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*wavelength, hue angle, chroma, CIE (L*a*b*)*

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INSTRUMENTAL COLOR MEASUREMENT OF MEAT AND MEAT PRODUCTS IN X-RITECOLOR® MASTER

Abstract

The aim of the study was to evaluate the influence of lyophilized plant extract on color of canned meat with reduced amount of sodium (III) nitrite measured by spectrophotometric methods. The results were collected through the X-RiteColor® Master software. The results of the experiment show that reduction of nitrite salt is possible but additional fortification is required: the best results were obtained when the extract was added in the amount of 0.015%.

1. INTRODUCTION

Color of meat is one of the most important factors which influence the consumer's decision about purchase (Suman & Joseph, 2013; Mancini & Hunt, 2005; León et al. 2006; Trinderupet, Dahl, Jensen, Carstensen & Conradsen, 2015). Color criteria is used to select or reject products and generally depends on myoglobin, the primary red pigment in meat. Evaluation of meat color is an essential part of product development and identification of roots of processing problems. Instrumental measure of color parameters is powerful laboratory method used by meat scientists. However, properly designed procedures are especially important. A lot of scientific publications present inconsistent and incomplete information especially regarding the aperture size, angle of observation, kind of illuminant (Tapp, Yancey & Apple, 2011).

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Barkley et al. (2018) reported weak influence of the kind of used apparatus and number of replications on color value. Therefore, the location of measurements is more important when performing color evaluations, assuming the settings are the same. Especially, the parameters of meat color strongly depend on oxygenation level and storage conditions of meat. Highly oxygenated beef steaks are redder than steaks in air and they show significant detrimental effects when frozen storage is extended (Henriott et al., 2020).

Basic standards and procedures of metrology in the fields of light and lighting are published by CIE (Commission Internationale de l'Eclairage) with Central Bureau in Vienna, Austria. The CIELAB color space (also known as CIE L*a*b*) describes all the colors visible to the human eye, defines colors independently of how they are created or displayed and is device-independent. It was defined in 1976. The color of sample is expressed as three values: L* for the lightness from black (0) to white (100), a* from green (−) to red (+), and b* from blue (−) to yellow (+). This model is perhaps the most frequently mentioned in scientific publications (Mancini & Hunt, 2005). It can be transferred to other spaces such as CIEXYZ, CIELCh, CIELUV, Hunter Lab.

The protein responsible for meat color is myoglobin (Mb) – a sarcoplasmic heme protein. In muscle of living animals, Mb is also responsible for, among others, oxygen transportation. Depending on iron atom's structure, Mb can exist in oxidized (Fe^{3+}) or reduced (Fe^{2+}) forms. Thanks to various forms of Mb meat and meat products can present different palette of colors: bright-red, purplish-pink or dull brown (Suman & Joseph, 2013; Danijela et al., 2013). The forms of Mb in reduced state are: deoxymyoglobin (DeoxyMb) – related with meat freshness and is characterized by purplish-red/purplish-pink color, oxymyoglobin (OxyMb) and carboxymyoglobin (COMb) - characterized by bright cherry-red color (Suman & Joseph, 2013; Danijela et al., 2013; Mancini & Hunt, 2005). The discoloration of Mb – the change from OxyMb to MetMb (metmyoglobin) – is associated with the oxidation of the heme group central iron atom. MetMb has gray-red/brownish color (Faustman, Sun, Mancini & Suman, 2010; Suman & Joseph, 2013; Danijela et al., 2013). This color of meat can also be formed as a result of pathogenic bacteria growth (Danijela et al., 2013).

The color of meat is possible to control – in case of fresh meat various packaging methods are applied: e.g. MAP (Modified Atmosphere Packaging) when different ratio of gases (the most common are CO_2, CO, O_2 and N_2) are applied or vacuum packaging through the removal of all the air from the package (Danijela et al., 2013). In the processed meat products, the characteristic pink color is an effect of reaction between sodium nitrite salt ($NaNO_2$) and metmyoglobin. During complicated reaction steps, nitric oxide (NO) formed from $NaNO_2$, reacts with Mb and creates NO-Mb (unstable) which, under the heat treatment, is converted into stable, pink nitrosylhemochrome (Suman & Joseph, 2013).

Oxidation process leads to deterioration of smell, taste, nutritional value of the product and it negatively influences its color. All these factors deteriorate the quality of the product which becomes unsafe for consumption (Ribeira et al., 2019). Additive E 250 – sodium III nitrite – plays a crucial role in meat industry. It not only allows to generate desirable color of meat products but also presents strong protecting (antioxidant, antibacterial) properties. And these properties also translate into, among others, maintaining the characteristic color (Gassara, Kouassi, Brar & Belkacemi, 2016; Alahakoona, Jayasena, Ramachandra & Jo, 2015).

Unfortunately, nitrite addition contributes to the formation of N-nitrosamines – cancerogenic, genotoxic substances (European Food Safety Authority, 2017). N-nitrosamines can occur in final products due to heat treatment or in specific conditions (low pH) such as in human gastrointestinal tract (Food Chain Evaluation Consortium, 2016).

For this reason, the amount of sodium (III) nitrite must be limited. The amount of 0–15 mg/kg of nitrite salt allows the nitrosylomioglobin formation but the amounts of 55–70 mg/kg allow to create proper color in meat products (other than dry fermented ones) (Rivera, Bunning & Marti, 2019; Food Chain Evaluation Consortium, 2016). However, apart from the appearance, product must be safe for consumption. Therefore, the Food Chain Evaluation Consortium (2016) concluded that lowering the nitrite addition, to the amount of 80–100 mg/kg (for most types of meat products) is possible but with additional measures to ensure safe consumption.

Color, like other factors such as antioxidant value, are important parameters for determining the quality, durability and safety of food (Ferysiuk & Wójciak, 2019).

The aim of the research was to determine the color of the canned meat containing reduced by half amount of nitrite and fortified with the addition of plant extract contrary to the control sample.

2. MATERIAL AND METHODS

2.1. Preparation of canned pork

Canned pork was prepared from pork dewlap and pork shoulder obtained from an organic farm (Zakład Mięsny Wasąg SP. J.). The recipe for all variants was: 5% of water, 2% of salt and alternatively: control sample – 100 mg/kg or sample fortified with herb extract – 50 mg/kg of sodium (III) nitrite. Meat was then cut with knife, grinded (KU2-3E – Mesko-AGD, Poland) on 5 mm mesh and mechanically mixed with above mentioned components. Each steel can was next filled with 300 g of meat, closed with lid and treated in temperature 120°C in a vertical steam sterilizer (AS2, Poland) and lastly cooled with fresh cold water. The obtained sterilizing value (F0) measured with TrackSense® wireless temperature logger (Ellab A/S, Denmark) placed in one of cans was 7,1. Products were then chilled at 4°C and stored for 60 days.

2.2. Color attributes

The samples intended for color testing were prepared as follows: the meat was removed from the can, cleaned of jelly and sliced (30 mm thickness). Measurement was taken after 10 min of product stabilization at normal laboratory conditions (air temperature 20°C, daylight app. 700 lx). The color was determined using the CIELAB color space (Hunt, 1987).

The X-Rite Color 8200 series spectrophotometer (X-Rite Inc., MI, USA) was used. The aperture size was 13 mm, standard observer 10˚ and illuminant D65 (daylight 6500K) was used. The measurement was taken in extended wavelength range from 360 to 740 nm. The color was measured at three different places of each slice surface.

2.3. Color parameters

Amount of MetMb – metmyoglobin was calculated according to Wójciak & Dolatowski (2015) from the reflectance measured at 580 nm and expressed as the percentage. The color difference was calculated according to Mokrzycki & Tatol (2011) using formula CIE76 (1)

$$\Delta E = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2} \quad (1)$$

where: ΔE – color distance between two colors,
ΔL – difference of lightens of two colors,
Δa – difference of redness of two colors,
Δb – difference of yellowness of two colors.

3. THE CIELAB METHOD MEASUREMENT

Color measurement is possible thanks to the spectrophotometer (Fig. 1). The device must be connected to the computer unit; the recommended software for X-Rite Color 8200 series spectrophotometer is X-RiteColor® Master. This type of devices includes transmittance chamber, port reducer, sample holder hook and power switch.

In general, color can be expressed by a various system applied for measurement using spectrophotometer and colorimeters. Those instruments allow to choose apparatus sizes, observers, solo systems and illuminates (Mancini & Hunt, 2005). CIELAB space takes into account the lighteness/luminance (L*), color space from green to red (a*), and color space from blue to yellow (b*). The lightness values range from 0 (dark) to 100 (white). The a* and b* parameters range from -120 to 120 (León, Mery, Pedreschi & León, 2006).

Except for the lightness, redness and yellowness measurements it is also possible to define other parameters by calculating selected reflectance in their wavelengths (Khatri et al., 2012). The various form of Mb is possible to identify by applying spectrophotometric method at the wavelength between 500 and 600 nm (Suman & Joseph, 2013). It is also possible to calculate the differences between samples (ΔE (total color differences), hue angle (h°) and chroma (C).

The ΔE present the change in color over a selected period of time (AMSA, 2012), the differences can be described as small differences (1.5 < ΔE), distinctive (1.5 < ΔE < 3) or very distinctive (ΔE < 3) (Pathare, Opara & Al-Said, 2013). Mokrzycki & Tatol (2011) suggest another classification: 0 < ΔE < 1 – no differences are noted by observer, 1 < ΔE < 2 – differences are noted only by experienced observer, 2 < ΔE < 3.5 – differences are noted by unexperienced observer, 3.5 < ΔE < 5 – clear differences are noted, 5 < ΔE – two different colors are noted by observer.

For calculating the h° parameter, which represents the whole color spectrum and which takes values from 0° to 360°, this equation should be applied (2):

$$h° = arctan\frac{b^*}{a^*} \tag{2}$$

According to Yancey & Kropf (2008), the combination of those two color parameters is vital when the result of the equation has a positive value (h° is between 0° and 90°). When result of the equation is a close to number 0, the value of red parameter (a*) decreases, h° increases and its value is closer to 90°. When the red color becomes stronger, the situation is reverse.

Chroma (saturation index) is calculated from (3):

$$C = (a^{*2} + b^{*2})^{1/2} \tag{3}$$

More options for parameter calculation can be found in the guidelines created by American Meat Science Association (2012).

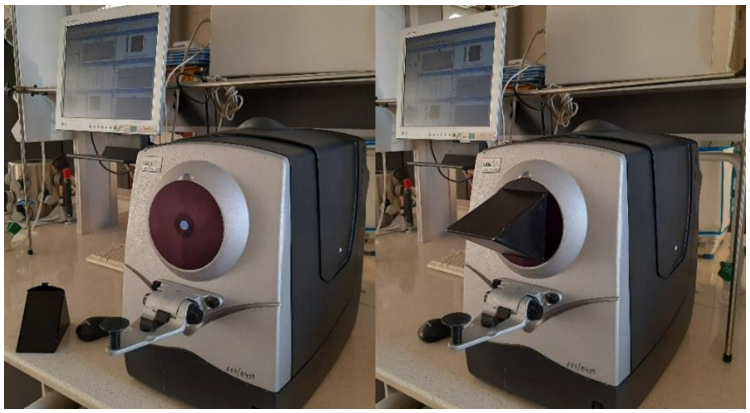

Fig. 1. The spectrophotometer before (left photo) and during calibration process (right photo)

Spectrophotometer must be calibrated before each use through calibration standards applied (Fig. 2) via computer program (Fig. 3). The light trap standard is used for zero reflectance measurement, the SRM is a white standard. X-RiteColor® Master program allows the calibration and configuration of the instrument and also the sample measurements (Fig. 4).

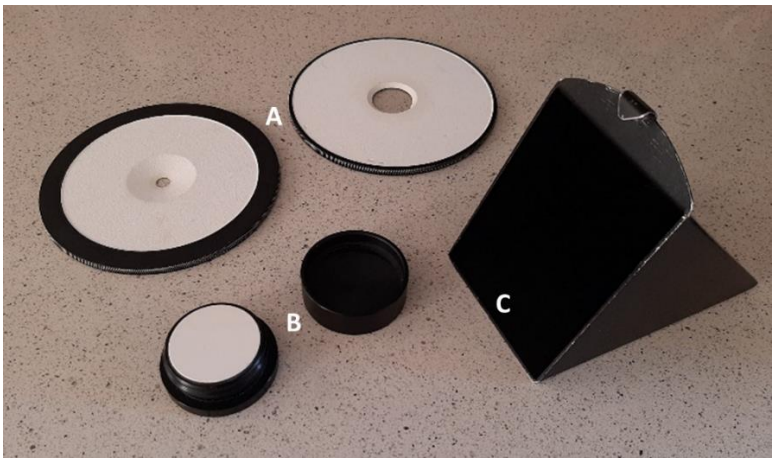

Fig. 2. Port redactors (A), calibrations standards: Standard Reflection Material – SRM (B), light trap (C)

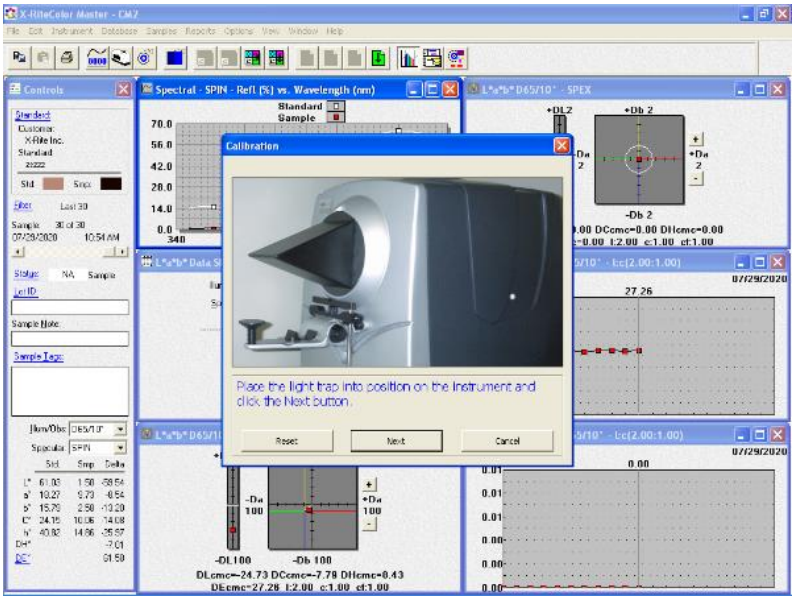

Fig. 3. Main menu of X-RiteColor® Master program – calibration process

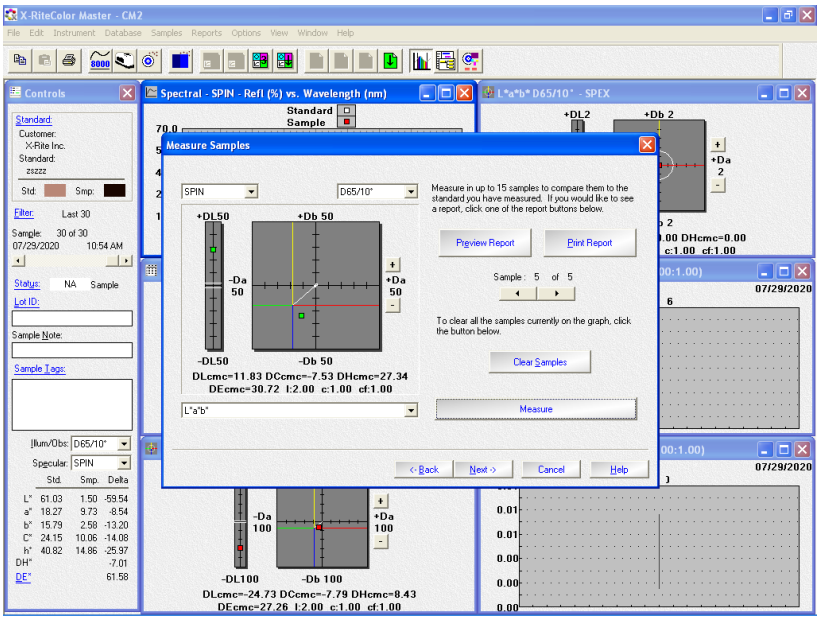

Fig. 4. Sample analyses

The data collected by software can be imported by another program e.g. Excel® – then the calculated values for parameters L*, a*, b* and parameters C and h° are obtained. X-RiteColor® Master allows to select the results from a specific time period (e.g. data from last month, week or the last 20 samples).

The instrument measures the wavelength in the range from 340 nm to 780 nm (in 10 nm intervals). Knowing the isobestic wavelengths of selected color traits it is possible to calculate other parameters (ΔE, nitrosating index, Mb content etc.) from the reflectance values, as it was mentioned earlier.

4. RESULTS AND DISCUSSION

The differences between samples with various amount of sodium (III) nitrite are presented in Fig. 5. As it could be noted, the greatest differences are between samples N_0 and with the nitrite addition. However, after 60 days of storage the change in total color of canned meat decreased for samples N_0 and N_50 and increased for samples N_0 and N_100. Differences between samples with various amount of sodium (III) nitrite were at the low level (3.07) at the day after production. Yet after 60 days it was observed that the differences started to increase slowly (3.37). This situation allows the conclusion that canned meat without the addition of nitrite salt clearly differs from the others, so it may not be purchased by a potential consumer. The decrease of the differences between samples

without nitrite and with reduced amount of nitrite were getting smaller after two months of storage. It may indicate the insufficient addition of nitrite salt to keep the stable color. Therefore, it may be necessary to fortify this sample.

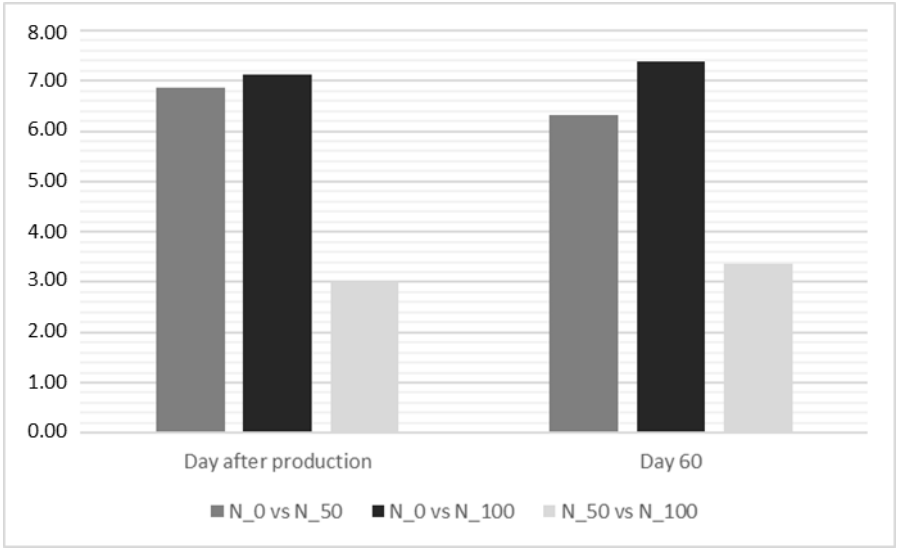

Fig. 5. Differences in color between canned meat with various amount of nitrite addition: N_0 - nitrite free, N_50 – 50 mg/kg of sodium (III) nitrite addition, N_100 – 100 mg/kg of sodium (III) nitrite addition

The percentage amount of MetMb and color intensity of cured canned pork are presented in Fig. 6. As it was mentioned earlier, MetMb is responsible for unattractive, gray-brownish meat color. The addition of nitrite counteracts this process. As it can be noted, nitrite-free sample (N_0) presented higher percentage amount of MetMb (36.5%) compared to samples with nitrite addition (29.9% and 29.4% respectively). According to the Regulation No 1333/2008 (2008) the maximum amount of sodium (III) nitrite which can be added to the canned meat is 100 mg/kg. In our experiment, this amount was reduced by half and did not cause negative effects. However, to maintain the consumer safety lyophilized plant extracts were added. The addition of red pepper and black currant leaf extracts in the amount of 0.005% contributed to the increased amount of MetMb where in the sample with higher amount of these extracts, the percentage value was similar to the samples with nitrite salt.

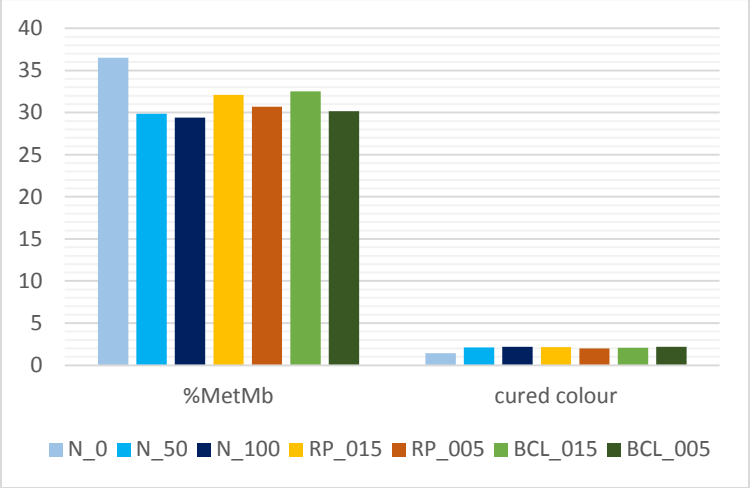

Fig. 6. Percentage amount of metmyoglobin and cured color parameter of canned meat after 60 days of storage: N_0 – nitrite free, N_50 – 50 mg/kg of sodium (III) nitrite addition, N_100 – 100 mg/kg of sodium (III) nitrite addition, RP_015 – red pepper extract addition (0.015%), RP_005 – red pepper extract addition (0.005%), BCL_015 – black currant leaves extract (0.015%), BCL_005 – black currant leaf extract (0.005%)

5. CONCLUSIONS

The data collected through the X-RiteColor® Master software via spectrophotometer instrument measurement allows to state that sharp reduction of sodium (III) nitrite in canned pork is possible. However, for better color results additional fortification with lyophilized herb extract is needed – addition of red pepper and blackcurrant leaf extracts in the amount of 0.015 allows to get greater results than the addition of these herbs in lower amount.

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REFERENCES

Alahakoon, A.U., Jayasena, D.D., Ramachandra, S., & Jo, Ch. (2015) Alternatives to nitrite in processed meat: Up to date. *Trends in Food Science & Technology*, *45*, 37–49. https://doi.org/10.1016/j.tifs.2015.05.008

American Meat Science Association (2012). Meat color measurements guidelines. Champaign, Illinois, USA: AMSA. 43–49.

Barkley, K.E., Fields, B., Dilger ,A.C., & Boler, D.D. (2018). Rapid Communication: Effect of machine, anatomical location, and replication on instrumental color of boneless pork loins. *Journal of Animal Science*, *96*(7), 2747–2752. https://doi.org/10.1093/jas/sky223

Danijela, Š.Z., Vera, L.L., Ljubinko, L.B., Lato, P.L., Vladimir, T.M., & Nevena, H.M. (2013). Effect of specific packaging conditions on myoglobin and meat color. *Food and Feed Research*, *40*(1), 1–10.

European Food Safety Authority. (2017). Re-evaluation of potassium nitrite (E 249) and sodium nitrite (E 250) as food additives. https://doi.org/10.2903/j.efsa.2017.4786

Faustman, C., Sun, Q., Mancini, R., & Suman, S.P. (2010). Myoglobin and lipid oxidation interactions: Mechanistic bases and control. *Meat Science*, *86*, 86–94. https://doi.org/10.1016/j.meatsci.2010.04.025

Ferysiuk, K., & Wójciak, K.M. (2019). The spectrophotometric analysis of antioxidant properties of selected herbs Invision-Pro™ UV-VIS. *Applied Computer Science*, *15*(4), 49–62. https://doi.org/10.23743/acs-2019-29

Food Chain Evaluation Consortium. (2016). Study on the monitoring of the implementation of Directive 2006/52/EC as regards the use of nitrites by industry in different categories of meat products.

Gassara, F., Kouassi, A.P., Brar, S.K., & Belkacemi, K. (2016). Green Alternatives to Nitrates and Nitrites in Meat-based Products – A Review. *Critical Reviews in Food Science and Nutrition*, *56*(13), 2133–2148. https://doi.org/10.1080/10408398.2013.812610

Henriott, M.L., Herrera, N.J., Ribeiro, F.A., Hart, K.B., Bland, N.A., & Calkins, C.R. (2020). Impact of myoglobin oxygenation level on color stability of frozen beef steaks. *Journal of Animal Science*, *98*(7), skaa193. https://doi.org/10.1093/jas/skaa193

Hunt, R.W.G. (1987). A model of colour vision for predicting colour appearance in various viewing conditions. *Color Research & Application*, *12*(6), 297–314. https://doi.org/10.1002/col.5080120605

Khatri, M., Phung, V.T., Isaksson, T., Sørheim, O., Slinde, E., & Egelandsdal, B. (2012). New procedure for improving precision and accuracy of instrumental color measurements of beef. *Meat Science*, *91*, 223–231. https://doi.org/10.1016/j.meatsci.2012.01.012

León, K., Mery, D., Pedreschi, F., & León, J. (2006). Color measurement in L*a*b* units from RGB digital images. *Food Research International*, *39*, 1084–1091. https://doi.org/10.1016/j.foodres.2006.03.006

Mancini, R.A., & Hunt, M.C. (2005). Current research in meat color. *Meat Science*, *71*, 100–121. https://doi.org/10.1016/j.meatsci.2005.03.003

Mokrzycki, W., & Tatol, M. (2011). Colour difference ΔE – A survey. *Machine Graphics and Vision*, *20*(4), 383–411.

Pathare, P.P., Opara, U.L., & Al-Said, F.A. (2013). Colour Measurement and Analysis in Fresh and Processed Foods: A Review. *Food Bioprocess Technology*, *6*, 36–60. https://doi.org/10.1007/s11947-012-0867-9

Ribeiroa, J.S., Santosb, M.J.M.C., Silvac, L.K.R., Pereirab, L.C.L., Santosb, I.A., da Silva Lannesd, S.C., & da Silva, M.V. (2019). Natural antioxidants used in meat products: A brief review. *Meat Science*, *148*, 181–188. https://doi.org/10.1016/j.meatsci.2018.10.016

Rivera, N., Bunning, M., Marti, J. (2019). Uncured-Labeled Meat Products Produced Using Plant-Derived Nitrates and Nitrites: Chemistry, Safety, and Regulatory Considerations. *Journal of Agricultural and Food Chemistry*, *67*, 8074–8084. https://doi.org/10.1021/acs.jafc.9b01826

Suman, S.P., & Joseph, P. (2013). Myoglobin chemistry and meat color. *Annual Review of Food Science and Technology*, *4*, 79–99.

Tapp, 3rd W.N., Yancey, J.W.S., & Apple, J.K. (2011). How is the instrumental color of meat measured? *Meat Science*, *89*, 1–5.

Trinderup, C.H., Dahl, A., Jensen, K., Carstensen, J.M., & Conradsen, K. (2015). Comparison of a multispectral vision system and a colorimeter for the assessment of meat color. *Meat Science*, *102*, 1–7. https://doi.org/10.1016/j.meatsci.2014.11.012

Wojciak, K.M., & Dolatowski, Z.J. (2015). Effect of acid whey on nitrosylmyoglobin concentration in uncured fermented sausage. *LWT – Food Science and Technology*, *64*, 713–719. https://doi.org/10.1016/j.lwt.2015.06.009

Yancey, J.W.S., & Kropf, D.H. (2008). Instrumental reflectance values of fresh pork are dependent on aperture size. *Meat Science*, *79*, 734–739. https://doi.org/10.1016/j.meatsci.2007.11.006