INSTRUMENTAL ANALYSIS OF COLOR DURING STORAGE IN DRY-CURED PORK LOIN PRODUCED WITH SWISS CHARD POWDER

Aleksandra Silovska Nikolova
Faculty of Agricultural Sciences and Food, Ss. Cyril and Methodius University in Skopje, Republic of North Macedonia, silovska@fznh.ukim.edu.mk
Zlatko Pejkovski
Faculty of Agricultural Sciences and Food, Ss. Cyril and Methodius University in Skopje, Republic of North Macedonia, zpejkovski@fznh.ukim.edu.mk
Katerina Belichovska
Faculty of Agricultural Sciences and Food, Ss. Cyril and Methodius University in Skopje, Republic of North Macedonia, belicovska@fznh.ukim.edu.mk
Daniela Belichovska
Institute of Animal Science, Ss. Cyril and Methodius University in Skopje, Republic of North Macedonia, daniela.belichovska@istoc.ukim.mk

Abstract: Dry-cured meat products hold a rich historical tradition of production and consumption across various global regions. These products have grown to become highly valued and sought-after meat items. Multiple factors influence consumers' choices in this regard. Notably, the product's color holds significant importance for consumers. In recent times, there has been a rising trend among consumers to opt for more naturally produced meat products. This research project focuses on examining the color attributes of dry-cured pork loin during storage, specifically when Swiss chard powder is used as a natural alternative to nitrites. The study was conducted under industrial conditions and involved the production of five distinct groups of dry-cured pork loin: Group I: Table salt, dextrose, Group II: Nitrite curing salt, dextrose; Group III: Nitrite curing salt, BactoFerm Rosa starter culture, dextrose; Group IV: Table salt, Swiss chard powder (manufacturer 1), BactoFerm Rosa starter culture; Group V: Table salt, Swiss chard powder (manufacturer 2), BactoFerm Rosa starter culture.
Color measurements were carried out through instrumental analysis after 90 days of storage within the temperature range of 0 to 4°C. The color assessment was conducted on a fresh cross-section of the meat at intervals of 60 and 90 minutes at room temperature (20 ± 2°C) and normal daylight conditions.
The L-value exhibited a range from 28.42 (Group III) to 34.24 (Group I). Over the 120-minute period of analysis, no statistically significant ($p \leq 0.05$) changes in L-values were observed across all five groups of dry-cured pork loin. The group with the highest red color intensity, represented by a-value, was Group III (10.86), with starter culture added showing a statistically significant impact on red color development compared to control Group II (9.62). Among the groups incorporating Swiss chard powder, Group IV had an a-value of 7.34, while Group V had an a-value of 6.72. The group with the least intense b-value, indicating yellow color, was Group I (2.11), while the highest b-value was observed in Group IV (2.84). The hue, or h-value, ranged from 14.050 (Group III) to 34.770 (Group I).
Using BactoFerm Rosa starter culture showcased a positive effect on maintaining color stability in dry-cured pork loin. Incorporating Swiss chard powder in conjunction with the BactoFerm Rosa starter culture contributed to better color stability, presenting a promising alternative to nitrite usage.
Keywords: color stability, dry-cured pork loin, Swiss chard powder

1. INTRODUCTION

Dry-cured meat products hold immense significance in the human diet owing to their considerable nutritional value. Meat producers are required to ensure the consistent quality of their meat products to meet consumers` expectations and maintain a strong foothold in the market (Silovska Nikolova et al., 2019).
Various factors can impact consumers' choices and decisions when it comes to food selection, but color stands out as a highly crucial element in marketing, particularly within the realm of food marketing Zaki, (2013). Ranđelović, (2009) states that the color of a product serves as a means of communication with consumers, effectively conveying the genuine commercial value of the product. Professional literature offers a great variety of research which points out that color in meat products is a key factor when choosing them. (Møller & Skibsted, 2007; Brewer, 2010; Dragoev, 2014; Abdulhameed et al., 2016).
To achieve the distinct, consistent, and appealing reddish-pink color in meat products, beyond the presence of myoglobin inherent to the meat itself, the incorporation of nitrites is essential. These additives are introduced to

facilitate the creation of nitrosylmyoglobin, the compound responsible for the visually appealing red hue in meat products. Vuković, (2012) states that the red color arises through the bonding of reactive nitric oxide, generated from nitrites to the iron within the heme porphyrin ring of myoglobin.

The use of nitrites limits and prevents the growth and reproduction of microorganisms in meat products. It prevents the oxidation of fats, improving the taste of the product (Silovska-Nikolova & Belichovska, 2019 Lavado et al. 2021). Nitrites are widely used in the meat industry.

Nevertheless, over the past fifty years, the use of nitrites has come under scrutiny due to concerns about the potential creation of N-nitrosamines as a result of the interaction between nitrites and secondary amines. (Flores & Toldrá, 2021). For several decades, efforts have been dedicated to finding a substitute for nitrites; however, a suitable alternative has not been identified thus far.

Numerous studies are available in the literature that explore the use of higher quantities of naturally occurring nitrates from select vegetables in conjunction with starter cultures containing nitrate-reducing bacteria. (Madentzidou et al., 2012; Choi et al., 2017; Kim, 2017; Hwang et al., 2018; Kim et al., 2019).

The objective of this study is to assess the color stability of commercially manufactured dry-cured pork loin, incorporating Swiss chard powder as a natural nitrite source, in conjunction with the BactoFerm Rosa starter culture, during the storage period.

2. MATERIALS AND METHODS

Materials

The research was carried out in the meat industry "Rimes MS Group". Their technological procedure for the production of dry-cured pork loin was taken as a basis. Five groups of dry-cured pork loin were produced in three iterations, as follows: I group: table salt, dextrose; II control group (nitrite curing salt, dextrose; III group: nitrite curing salt, starter culture BactoFerm Rosa, dextrose; IV group: table salt, Swiss chard powder (manufacturer 1) and starter culture BactoFerm Rosa and V group: table salt, Swiss chard powder (manufacturer 2) and starter culture BactoFerm Rosa.

Frozen pork loin (*m. longissimus dorsi*) was used in the research. Technological operations took place in the following order: dry defrosting of the frozen pork loin, removal of the fatty tissue and fascia, then salting. Salted pieces were left to mature for 21 days in a dark room at a temperature of 0 to 4°C. Afterwards, the pork loin pieces were subjected to a 24-hour draining, at a temperature of 24°C and a relative humidity of 85-90%. This step was followed by a single day cold smoking at a temperature of 22^0C, and a relative humidity of 82%.

After the smoking phase, a span of 18 days was dedicated to ripening (fermentation). This stage initiated with a temperature of 22°C and a relative humidity of 82%. Subsequently, the temperature was gradually reduced to 12°C while the relative humidity decreased to 72%. Dry-cured pork loin pieces were vacuum-sealed in polyethylene bags and stored at a temperature of 0-4°C.

Methods

Instrumental color analysis was conducted at the halfway point of the production, specifically at the 90-day mark. The color assessment was performed on the central section of the dry-cured pork loin piece (as shown in Figure 1). Color measurements were taken at three distinct locations on five individual pieces. The initial color measurement was taken from a fresh cross-section, followed by measurements at the 60-minute and 120-minute intervals.

Figure 1. Schematic representation illustrating the part where the cross-sectional color analysis of dry-cured pork loin was conducted

Color measurement was performed at room temperature (20 ± 2°C) and normal daylight. For the instrumental analysis of the color, the chromometer Dr. Lange, spectro color was used. With the chromometer, the color of the samples is measured in the basic system X, Y, Z with coordinates Y, x, y or, alternatively, in the derived color system, among which the most important system is L*, a* and b* (CIE, 1976).

From the obtained values L*, a*, b*, the hue angle (h) is calculated according to the following formula:

$$h = \tan^{-1}(b/a)$$

Essentially, the hue angle (h) of a color specifies the value of the angle in the a,b plane moving counter-clockwise, where the color point is located. Ergüneş & Tarhan (2006) state that the value of the red color (+a) is 0^0, for yellow (+b) it is 90^0, for green color (-b) 180^0 and for blue color (-b) 270^0.
The data collected in the experiment were processed and edited using the program Excel XP. The normality of the distribution of the values was checked by analyzing the homogeneity of the variances. If the homogeneity was confirmed, the analysis was continued with the multivariate general linear model (GLM) or the ANOVA test (comparison of three or more groups), and the associations between the parameters with the multivariate linear descriptive analysis (LDA) (IBM SPSS Statistics 23, release 23.0.0.0).

3. RESULTS AND DISCUSSION

The results obtained from the instrumental color analysis of the cross-section of dry-cured pork loin, stored for 90 days within the temperature range of 0-4°C, are presented across Table 1 through Table 4.
Table 1 displays that the L-value exhibits a range spanning from 28.42 (Group III) to 34.23 (Group I) in the case of the fresh cross-section. Notably, the dry-cured pork loin groups that incorporated the starter culture demonstrated a lower L-value, indicating a darker color in the cross-sectional area. Findings in Table 1 reveal that, even after the 120-minute mark, there were no statistically significant ($p \leq 0.05$) changes in the L-value observed within the cross-sectional color analysis across all five groups of dry-cured pork loin.

Table 1. Dynamics of L*-values in dry-cured pork

Time of sampling	Groups of dry-cured pork loin				
	I	II	III	IV	V
			x̄ ± SD		
0 min	34.23 ± 1.24^{aB}	31.60 ± 1.17^{bB}	28.42 ± 0.97^{cA}	28.98 ± 1.47^{cBA}	31.19 ± 1.47^{bA}
60 min	33.53 ± 1.23^{aB}	30.97 ± 1.15^{bB}	27.87 ± 0.95^{cB}	28.26 ± 1.43^{cB}	30.36 ± 1.43^{bB}
120 min	37.87 ± 1.44^{aA}	32.54 ± 1.20^{bA}	28.49 ± 0.97^{cA}	$29.21 \pm 1.45d^{A}$	31.52 ± 1.48^{cA}

x̄ - mean value. SD standard deviation. statistically insignificant effect; means with a different letter ($^{a-d}$) within a row are statistically significantly different ($p \leq 0.05$; significance of group differences). means with a different letter ($^{A-C}$) within a column and parameter are statistically significantly different ($p \leq 0.05$; significance of sampling differences).

The largest share of red color, i.e. the highest a-value can be found in group III (10.86) (Table 2). Added starter culture has a statistically significant ($p \leq 0.05$) impact on the development of red color compared to control group II (9.62). It is expected that group I, which is salted only with table salt, will have the lowest a-value, that is, the share of red color will be the smallest, 3.09. In groups IV and V where Swiss chard powder was added in combination with starter culture, the share of red color was statistically significantly ($p \leq 0.05$) lower compared to control group II where nitrite curing salt was added. Kim et at., (2019) used previously converted nitrites from frozen Swiss chard powder. In doing so, they found the highest a-value (9.08). Also, Hwang et al., (2018) used converted nitrites from natural sources (spinach, lettuce, celery, and radish) in the production of raw and boiled sausages. Through their research, they reached the conclusion that the most optimal enhancement of the red color occurred in the samples produced using nitrites converted from spinach. The utilization of pre-converted nitrites derived from natural plant sources appears to enhance the development of red color in meat products. Silovska Nikolova et al., (2022) point out that pre-converted nitrites (pre-fermented cure that contains nitrites) is only allowed in the United States and Asia.

Table 2. Dynamics of a*-values in dry-cured pork

Time of sampling	Groups of dry-cured pork loin				
	I	II	III	IV	V
			x̄ ± SD		
0 min	3.09 ± 0.97^{eA}	9.62 ± 1.08^{bA}	10.86 ± 0.84^{aA}	7.34 ± 0.69^{cA}	6.73 ± 0.68^{dA}
60 min	3.03 ± 0.95^{eA}	9.41 ± 1.06^{bA}	10.64 ± 0.83^{aA}	7.10 ± 0.67^{cA}	6.50 ± 0.65^{dA}
120 min	2.78 ± 0.86^{eA}	8.53 ± 1.01^{bB}	10.10 ± 0.73^{aB}	6.63 ± 0.63^{cB}	5.99 ± 0.60^{dB}

x̄ - mean value. SD standard deviation. statistically insignificant effect; means with a different letter ($^{a-d}$) within a row are statistically significantly different ($p \leq 0.05$; significance of group differences).

means with a different letter ($^{A-C}$) within a column and parameter are statistically significantly different (p ≤ 0.05; significance of sampling differences).

It can be concluded (Table 2) that a-value measured after 60 minutes spent at room temperature (20 ± 2°C) and normal daylight decreases in all five groups of dry-cured pork loin. The difference in the measured a-value of the fresh section is statistically not significant in all five groups even after 60 minutes. After 120 minutes spent at room temperature (20 ± 2°C) and normal daylight the a-value, also decreases in all five groups and it ranges from 2.78 (I group) to 10.10 (III group).

Table 3. Dynamics of b*-values in dry-cured pork

Time of sampling	**Groups of dry-cured pork loin**				
	I	**II**	**III**	**IV**	**V**
	x̄ ± SD				
0 min	2.11 ± 0.75^{cA}	2.68 ± 1.12^{baA}	2.70 ± 0.96^{baA}	2.84 ± 1.09^{aA}	2.26 ± 0.85^{cbA}
60 min	2.07 ± 0.74^{cA}	2.63 ± 1.10^{baA}	2.65 ± 0.94^{baA}	2.77 ± 1.06^{aA}	2.20 ± 0.83^{cbA}
120 min	2.03 ± 0.72^{cA}	2.51 ± 1.09^{cbaA}	2.59 ± 0.92^{baA}	2.67 ± 1.02^{aA}	2.11 ± 0.80^{cbA}

x̄ - mean value. SD standard deviation. statistically insignificant effect; means with a different letter ($^{a-d}$) within a row are statistically significantly different (p ≤ 0.05; significance of group differences). means with a different letter ($^{A-C}$) within a column and parameter are statistically significantly different (p ≤ 0.05; significance of sampling differences).

The smallest share of b-value, i.e. yellow color, was observed in I group (2.11), while the highest b-value was observed in IV group (2.84) (Table 3). In all five groups of dry-cured pork loin, there is no statistically significant difference in the change of the b-value when exposed to room temperature (20 ± 2°C) and normal daylight.

Table 4. Dynamics of h-values in dry-cured pork

Time of sampling	**Groups of dry-cured pork loin**				
	I	**II**	**III**	**IV**	**V**
	x̄ ± SD				
0 min	34.77 ± 11.35^{aA}	15.57 ± 6.30^{dcA}	14.05 ± 5.15^{dA}	20.91 ± 7.79^{bA}	18.66 ± 7.43^{cbA}
60 min	34.69 ± 11.34^{aA}	15.60 ± 6.31^{dcA}	14.06 ± 5.15^{dA}	21.04 ± 7.83^{bA}	18.78 ± 7.47^{cbA}
120 min	36.31 ± 11.62^{aA}	16.32 ± 6.70^{dcA}	14.41 ± 5.22^{dA}	21.70 ± 8.01^{bA}	19.50 ± 7.70^{cbA}

x̄ - mean value. SD standard deviation. statistically insignificant effect; means with a different letter ($^{a-d}$) within a row are statistically significantly different (p ≤ 0.05; significance of group differences). means with a different letter ($^{A-C}$) within a column and parameter are statistically significantly different (p ≤ 0.05; significance of sampling differences).

The hue, i.e. h - the value of a fresh cross-section (0 minutes) ranges from 14,050 (III group) to 34,77 (I group) (Table 4). The lowest h-value is observed in III, which means that in the plane a, b is closest to the red (+a) color. It is understandable that group I, in which table salt has been added, has the highest h-value on the plane a,b, that is, it has a tendency towards the yellow color (+b). It can be noted (Table 4) that even after 120 minutes of exposure at room temperature (20 ± 2°C) and normal daylight the hue ranges from 14.41 (III group) to 36.31 (I group).

4. CONCLUSION

Drawing from the results garnered through instrumental cross-sectional color measurements after 90 days of storage for dry-cured pork loin within the temperature range of 0 to 4°C, the following conclusions can be made:

- In the case of Group III, where dry-cured pork loin was produced using nitrite salt along with BactoFerm Rosa starter culture, a positive impact on the color stability of the fresh cross-section was noted. This effect endured even after a 120-minute exposure to air, room temperature (20 ± 2°C), and natural daylight.
- Incorporating Swiss chard powder as a substitute natural nitrate source along with nitrate-reducing bacteria from the BactoFerm Rosa starter culture yields a beneficial impact on the color stability of the fresh cross-

section. This influence persists even after a 120-minute duration of exposure to regular daylight and room temperature (20 ± 2°C).

- The use of BactoFerm Rosa starter culture has a positive effect on the color stability of dry-cured pork loin during storage. The use of starter cultures in the meat industry will contribute to greater color stability in meat products.
- The meat industry should prioritize the creation of meat products with a more natural profile. The use of Swiss chard powder along with starter cultures containing bacteria capable of reducing nitrates presents a potential solution for replacing nitrites.

REFERENCES

Abdulhameed, A. A., Yang, T. A., & Abdulkarim, A. A. (2016). Kinetic of texture and colour changes in chicken sausage during superheated steam cooking. *Polish Journal of Food and Nutrition Sciences*, *66*(3), 199–209. https://doi.org/10.1515/pjfns-2015-0044.

Brewer, S. (2010). Technological Quality of Meat for Processing. In: *Handbook of meat processing*, edited by F. Toldrá (pp. 25-42). Ames, Iowa, USA: Blackwell Publishing.

Choi, Y., Kim, T., Jeon, K., Park, J., Kim, H., Hwang, K., & Kim, Y. (2017). Effects of Pre-Converted Nitrite from Red Beet and Ascorbic Acid on Quality Characteristics in Meat Emulsions. *Korean Journal for Food Science of Animal Resources*, *37*(2), 288–296. https://doi.org/10.5851/kosfa.2017.37.2.288.

CIE (1976). International Commission on Illumination, Colorimetry: Official Recommendation of the International Commission on Illumination Publication CIE No. (E-1.31). Bureau Central de la CIE, Paris, France.

Dragoev, S.G., Staykov, A.S., Vassilev, K.P., Balev, D.K., & Vlahova-Vangelova, D.B. (2014). Improvement of the Quality and the Shelf Life of the High Oxygen Modified Atmosphere Packaged Veal by Superficial Spraying with Dihydroquercetin Solution. *International Journal of Food Science 2014*, 629062.

Ergüneş, G., & Tarhan, S. (2006). Color retention of red peppers by chemical pretreatments during greenhouse and open sun drying. *Journal of Food Engineering*, 76, (3), 446-452. https://doi.org/10.1016/j.jfoodeng. 2005

Flores, M., & Toldrá, F. (2021). Chemistry, safety, and regulatory considerations in the use of nitrite and nitrate from natural origin in meat products - Invited review. *Meat Science*, *171*, 108272. https://doi.org/10.1016/j.meatsci.2020.108272.

Hwang, K., Kim, T., Kim, H., Seo, D., Kim, Y., Jeon, K., & Choi, Y. (2018). Effect of natural pre-converted nitrite sources on color development in raw and cooked pork sausage. Asian-australasian Journal of Animal Sciences, 31(8), 1358–1365. https://doi.org/10.5713/ajas.17
0767.

Kim, T., Kim, Y., Jeon, K., Park, J., Sung, J., Choi, H., Hwang, K., & Choi, Y. (2017). Effect of fermented spinach as sources of Pre-Converted nitrite on color development of cured pork Loin. *Korean Journal for Food Science of Animal Resources*, *37*(1), 105–113. https://doi.org/10.5851/kosfa.2017.37.1.105.

Kim, T., Hwang, K., Lee, M., Paik, H., Kim, Y., & Choi, Y. (2019). Quality characteristics of pork loin cured with green nitrite source and some organic acids. *Meat Science*, *152*, 141–145. https://doi.org/10.1016/j.meatsci.

Lavado, G., Higuero, N., León-Camacho, M., & Cava, R. (2021). Formation of Lipid and Protein Oxidation Products during In Vitro Gastrointestinal Digestion of Dry-Cured Loins with Different Contents of Nitrate/Nitrite Added. Foods, 10(8), 1748. https://doi.org/10.3390/foods10081748.

Madentzidou, E., Gerasopoulos, D., Siomos, A. S., & Bloukas, I. (2012). Salt-stressed fresh cut leek accelerates CO_2 and C2H4 production and enhances the development of quality characteristics of traditional Greek sausages during storage. *Meat Science*, *92*(4), 789–794. https://doi.org/10.1016/j.meatsci.2012.07.002.

Møller, J. K. S., Skibsted, L. H. (2007). Color. In: *Handbook of fermented meat and poultry,* edited by F. Toldrá, Y.H. Hui, I. Astiasarán, W.K. Nip, J.G. Sebranek, E.T.F. Silveira, L.H. Stahnke, R. Talon (pp. 203-216). Ames, Iowa, USA: Blackwell Publishing.

Ranđelović, D. (2009). *Boja prehrambenih proizvoda. Tehnologija hrane*. Retrieved from https://www.tehnologijahrane.com/enciklopedija/boja-prehrambenih-proizvoda

Silovska-Nikolova, A., Pejkovski, 3., Belichovska, D., Belichovska. K., (2019). Domestic market research detecting the factors that influence consumer`s choice of meat products by domestic or foreign producers. *Knowledge International Journal, 31* (3), 681-687.

Silovska Nikolova, A., Pejkovski, Z., Velkoska-Markovska, L., Belichovska, D., Nakov, D., Belichovska K. (2022). The effect of Swiss chard powder and starter cultures on colour development in smoked pork loin. *Journal of Agricultural, Food and Environmental Sciences, 76,* (2) 1-11.

Vuković, I. (2012). *Osnove tehnologije mesa* (4. Izdanje). Veterinarska komora Srbije, Beograd.

Zaki, F. E. (2013). The Significance of Color In Food Marketing. Syracuse University Honors Program Capstone Projects, 113.