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DRY-AGED BEEF: COLOR PARAMETERS AND SENSORY CHARACTERISTICS

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Abstract. Research work involves the instrumental analysis of the change in color (*L*, a*, b**) and the sensory characteristics of the Simmental beef, parts of the carcass: T-bons, received from the local farm, during the dry-aging period for 0, 14, 21, 28, 35 days and for the roasted aged beef at high and very high temperatures. The analyzed beef samples presented uniform results for the chromatic parameters during the dry-aging period, being influenced by the values of meat pH and the water-holding capacity, namely: for the dry-aged meat, the *L** parameter values indicate an increase in the brightness of the meat, for the *a** parameter, decreasing values were established, which indicates a reduction in the oxygenation of the meat, a reduction of oxymyoglobin in meat, responsible for the intense red color and for the *b** coordinate a slight decrease in values was observed, oriented to yellow color. For roasted beef parameter *L** decreases due to the reduction of the beef moisture during the roasting process. The redness of beef *a** decreases in intensity primarily depending on the beef aging period but also with the increase in the roasting temperature, due to the drastic degradation of myoglobin. The *b** parameter also decreases, possibly due to the increase in metmyoglobin content during heat treatment. The sensory characteristics of the dry aged beef have been considerably improved due to the increase in the pH of the meat, which attracts the activation of meat-specific enzymes that contribute to the accumulation of secondary compounds with a major impact on the beef taste, aroma and juiciness. These aspects are later reflected on the sensory properties of the roasted aged beef, being intensified by the heat treatment process.

Keywords: *dry aging process, beef, cooked dry aged beef, cromatic parametres, color differences, sensory properties.*

Rezumat. Prezenta lucrare include analiza instrumentală a modificării culorii (*L*, a*, b**) și a caracteristicilor senzoriale ale cărnii de bovină, rasa Simmental, părți din carcasă: T-bons, recepţionate de la ferma locală, în timpul procesului de maturare prin uscare timp de 0, 14, 21, 28, 35 de zile si pentru carnea de bovină maturată prin uscare prăjită la temperaturi ridicate si foarte ridicate. Probele de carne de bovină analizate au prezentat rezultate uniforme pentru parametrii cromatici în perioada de maturare prin uscare, fiind influențate de valorile pH-ului cărnii și de capacitatea de reținere a apei și anume: pentru carnea maturată prin uscare, valorile parametrului *L** indică o creștere a luminozităţii cărnii, pentru parametrul *a** s-au stabilit valori în scădere, ceea ce indică o scădere a oxigenării cărnii, o

reducere a oximioglobinei din carne, responsabilă de culoarea roșie intensă și pentru coordonata *b** a fost observată o scădere ușoară a valorilor, situată pe partea pozitivă a axei, care reprezintă culoarea galbenă. Pentru carnea de bovină prăjită parametrul *L** scade datorită reducerii umidității cărnii în timpul procesului de prăjire. Culoarea roşie a cărnii de bovină *a** scade în intensitate în primul rând în funcție de perioada de maturare a cărnii, dar și odată cu creșterea temperaturii de prăjire, din cauza degradării drastice a mioglobinei. Parametrul *b** scade și el, posibil din cauza creșterii conținutului de metmioglobină în timpul tratamentului termic. Caracteristicile senzoriale ale cărnii de bovină maturate prin uscare au fost considerabil îmbunătățite datorită creșterii pH-ului cărnii, care implică activarea enzimelor specifice cărnii ce contribuie la acumularea de compuși secundari cu impact major asupra gustului, aromei şi suculenţei cărnii. Aceste aspecte se reflectă ulterior asupra proprietăților senzoriale ale cărnii de bovină maturată prin uscare prăjite, caracteristicile cărora sunt intensificate de procesul de tratare termică.

Cuvinte cheie: *process de maturare prin uscare, carne de bovină prăjită, parametric cromatici, diferenţă de culoare, proprietăţi senzoriale.*

1. Introduction

The transformation of muscle tissue into meat is a complex process that involves biochemical processes of proteolysis, glycolysis, lipolysis and oxidation, specific to the aging period, with a major impact on improving the meat palatability [1-3].

The obtained quality characteristics as a result of these changes are important in the appreciation of meat quality by the consumer [4].

Color is a key quality characteristic of meat serving as an indicator of quality and freshness. The value of the carcass / half-carcass will be assessed according to this index, which will change depending on the pH value, the content of myoglobin and the attached ligand (for example, O_2, CO, NO) and the structure of the meat [5, 6]. The structure of the meat will influence and direct the passage of light in the meat, an effect that will affect the color parameters. Respectively, upon contact with the meat, the light is reflected, absorbed and spread. These characteristics will determine the color of the meat. The main characteristic, which influences the degree of consumer acceptability, is the light reflection. The pH value of the muscle tissue will influence the ability to spread light. A lower pH of the meat will positively influence the light spreading property [7]. In addition, during the decrease in meat pH, the proteins approach the isoelectric point, the myofilaments undergo changes, leading to more difficult separation of the filaments [8]. In addition, the diameter of the muscle fiber changes, it decreases, which allows the space between the cells to increase [9]. The translucency of the meat decreases and the distribution coefficient increases, phenomena that beneficially influence the scattering of light [7]. Accordingly, light is distinguished into color attributes a* and b* and achromatic color attributes L*.

The main chromatic component of the meat is the myoglobin pigment, which can influence the color of the meat based on the oxidation state of the iron atom incorporated in the structure of the porphyrin ring of the hem group. In comparison, the structure of the muscle tissue will influence the L* value. Thus, the light is absorbed by the myoglobin, and the unabsorbed light is transmitted around the structural elements. The reflected light will help determine the final changes.

Light is scattered when it is diffused through collisions with the particles of the medium it crosses. In muscle, the medium can be either connective tissue, muscle fibers, myofibrils, extracellular fluid, or sarcoplasm. The amount of reflected light will depend on its degree of diffusion in the structure of the meat, the less it reaches the depth of the meat, the more will be reflected. So, the degree of light scattering contributes to the formation of the color perceived by the human eye [10].

Color remains an indicator in assessing the degree of doneness of dry-aged beef, considering the various types of thermal treatments applied to these products, from "very rare" to "well done". Consumer perception of doneness by color parameters can lead to safety issues as research on meat preparations, especially minced meat, shows that visual appearance does not mean that reached temperature could ensure the necessary microbiological stability. But these arguments are not specific for meat in pieces, as in the case of steaks, when indeed the microbiological danger exists more on the surface of the meat pieces, which can be reduced even with short-term thermal treatments [11].

The sensory characteristics and main color parameters of cooked meat may differ depending on the heat treatment method and parametres (grilling, roasting, boiling, etc.) including temperature and heating rate [12].

Heat treatment type used in prepering meat can be classified according to cooking temperatures: low temperature (till 100°C), high temperature (more than 100°C) and high temperature (which exceeds 200°C) [13].

The use of high and very high temperatures leads to an increase in the heating rate and degree of the Maillard reaction, which enhances the flavor of the cooked meat [12].

This study was carried out to determine the effects of beef dry aging conditions on sensory indices with an emphasis on color parameters through L^*, a^* and b^* values, as well as the change of color parameters during the heat treatment of dry aged beef as factors of meat quality appreciation by consumers.

2. Materials and Methods

For analysis, sliced from the carcass of Simmental breed were used: T-bons, fresh meat was received from local farm. The quality requirements specified in [14].

Fresh meat and dried aged meat were subjected to determinations. Beef was aged during 14, 21, 28 and 35 days in aging rooms where temperature varied within limits 1±1 °C, relative humidity between 80±5 %, air circulation speed - 0.5-2 m/s.

Thin slices of beef were used to obtain color change information during heat treatment. The samples were subjected to grilling heat treatment at 150°C or 230°C, about 3 minutes per each part using an electric grill.

Sensory analysis of fresh, aged and cooked meat. The sensory properties of the meat samples were analyzed under standardized conditions by a group of evaluators, by description, according of standard ISO 6658:2017 [15]. Quality requirements ware characterized according to [14] for fresh and aged meat and to characterize the organoleptic indices of cooked meat [16] was used.

Color parameters analysis. The CIE-Lab parameters, L^*, a^*, and b^* were measured using a Chroma Meter CR-400/410 colorimeter (Konica Minolta, Tokyo, Japan) according to the method of [17]. Each sample was analyzed at five distinct points, measuring variations of L^*, a^*, b^*, the differences of color (ΔE^*), hue angle (H^*) and chroma (C^*).

The following Equation (1) was used to determinate the ΔE^*:

$$\Delta E^* = \sqrt{(L_i^* - L_0^*)^2 + (a_i^* - a_0^*)^2 + (b_i^* - b_0^*)^2} (1)$$

where:

L^* - brightness coordinate,

a^* - green versus red coordinate,

b^* - blue versus yellow coordinate,

L_0^*, a_0^* and b_0^* - the values at zero time;

L_i^*, a_i^* and b_i^* - the values with time.

ΔE^* - comparisons based on two different factors: color values at t = 14, 21, 28, 35 days versus fresh meat.

Statistical analysis. The statistical processing of the obtained results was performed using the Student test and the Microsoft Office Excel version 2010 program. The differences were considered statistically too significant when the probability was greater than 95% ($p<0.05$). The tests were repeated in triplicate. Experimental results are expressed as mean ± SD.

3. Results

The dry aging process has a favorable impact on the quality indices of the beef, highlighting improved sensory properties, intensifying the color parameters, processes influenced by the decrease in acidity and the increase in the water retention capacity of the meat [18, 19].

Biochemical reactions such as lipolysis, proteolysis and oxidation are some of the processes that occur during the post-slaughter period. The decomposition of myofibrillar proteins, achieved through the process of proteolysis, leads to the formation of peptides and amino acids, which act as precursors of water-soluble flavors, subsequently contributing to the formation of the taste properties and flavoring characteristics of meat [1, 20].

In the post- slaughter period, the accumulation of metabolic by-products occurs in the muscle tissue, which leads to a decrease in pH. The decrease in pH from the neutral value brings about favorable changes in the beef flavor. The results obtained during the beef dry aging period show a significant improvement in the organoleptic indices (sample M21, M28, M35), especially the flavor becomes more intense specific to aged beef in comparison with unaged beef which has a weak and bland odor. These characteristics may be due to the intensification of the lipid oxidation process which, by combining with protein degradation substances, contributes to the improvement of the meat flavor. Similar results were shown by other authors [21, 22].

Although the visual appreciation of the color and consistency of meat subjected to dry aging process is considered subjective by some authors [23]. In the respective research the results obtained showed clearly visible differences in the modification of these parameters depending on the aging period.

The color of the dry aged beef samples for 21, 28, 35 days is dark red and with a much finer consistency compared to the control sample or aged up to 14 days. The fine consistency resulting from the degradation process of meat proteins under the action of proteolytic enzymes, similar results described by [22].

The sensory indicator results for the raw dry aged beef were analyzed and presented in the work of Bulgaru et al. 2022 (Tables 1 and 2) [18].

The values of the organoleptic indices are also supported by the variation of the beef pH. The values obtained for pH contribute to the release of Ca^{2+} ions from the sarcoplasmic reticulum and mitochondria when the ATP reaches its lowest values, which leads to the intensification of calpain activity.

Table 1

Sensory indicators of roast dry aged beef

Indicators	Samples				
	Fresh beef	**M14**	**M21**	**M28**	**M35**
Color	Dark, depending on the aging time and roasting temperature				
Consistency	Relatively cooked, reduced elasticity	A high degree of cooking, elastic, easy to chew			
Flavor	Low flavor, lingering flavor of fried meat	Pleasant flavor of roasted meat mixed with volatile compounds specific to aged meat.			
Juiciness	Dry beef	Juicy beef, perception of water content in the sample after 3–4 chewings			

Note: M14—beef dry aged for 14 days; M21— beef dry aged for 21 days; M28— beef dry aged for 28 days; M35— beef dry aged for 35 days.

Also these pH values coincide with the pH values specific for cathepsins, which begin to destroy the miofibrilar proteins such as myosin and actin [24, 18]. Other researchers present similar data, such as Lee et al. [25] when an increase in pH of just over 11% at dry aging for 63 days. Responsible for increasing the pH of dry aged meat may be the formation of nitrogenous compounds in the process of protein hydrolysis.

Water holding capacity (WHC) and color are often related to the final pH of the meat, these indicators being in fact considered important indices of meat quality. The WHC of meat is increased by the presence of meat-specific enzymes that break down connective tissues and myofibrillar proteins and are thus responsible for improving the meat WHC. The chemical reactions with the participation of these enzymes result in a decrease in the heat treatment time along with the increase in the drying maturation period [26].

The results of the sensory analysis of the roasted beef were more affected by the heat treated conditions than the dry aging period, and heat treatment at very high temperatures had a major impact on the color of the meat for all samples. For the other sensory indicators, the aging period is important in obtaining the specific characteristics.

The values of the color parameters, *L*, a*, b*,* of the dry-aged beef are shown in Table 2.

Table 2

CIE-Lab parameters of dry aged beef

Chromaticity coordinates	Samples				
	Fresh Beef	**M14**	**M21**	**M28**	**M35**
L***	37.38±0.10	38.25±0.1	39.75±0.42	40.69±0.42	41.91±0.09
a*	19.31±0.07	18.73±0.34	17.98±0.67	18.38±0.08	13.55±0.11
b*	13.81±0.39	13.68±0.22	13.56±0.22	13.58±0.18	13.5±0.43
C*	23.70±0.14	22.86±0.20	21.94±0.09	20.70±0.77	19.12±0.10
Δ*E**	-	1.05±0.11	2.73±0.11	3.44±0.26	7.33±0.18

Note: M14—beef dry aged for 14 days; M21— beef dry aged for 21 days; M28— beef dry aged for 28 days; M35— beef dry aged for 35 days.

During the dry aging period for parameters *L** were obtained values between 37.38 and 41.91 units. This values support the high brightness of meat. Coordinate *a** showed the average values between 19.31 and 13.55 units - decreasing values. This results could be explaining by the reduction in the oxygenation capacity of the beef which depends on the availability of oxygen, the diffusion of oxygen in the meat and the rate of oxygen consumption. In addition, the decreased water-holding capacity of dry aged beef can result in more intense reflection of light from the surface of the meat, making it appear pale. Hopkins et al. [27] showed a decrease in chroma *a** for meat aged for 42 days compared to that aged for 4 days.

In the case of chroma *b**, the average values were between 13.81 and 13.50, an insignificant decrease was recorded, all being located on the positive side of the axis, which represents the yellow zone.

The uniform values were obtained for all three chromatic coordinates *L*, a*, b** throughout the dry aging period, similar results were also showed by Obuz et al. [22] for dry aged meat for 23 days.

For chroma C* the results decreased from 23.7 to 19.12, values that explain why the color intensity of the analyzed beef decreased.

The values for the ΔE* parameter represented the color differences between the analyzed beef samples. The color difference cannot be perceived by evaluators when $0<\Delta E^*<1$, the experienced ones will notice the color difference between the analyzed samples when the relationship is $1<\Delta E^*<2$, and if ΔE* will be included in the following limits $2<\Delta E^*<3.5$, then the color differences will be able to be noticed even by inexperienced evaluators [28, 29].

According to the data presented in Table 2, Δ*E** increases proportionally with the increase in the dry aging period, from 1.05 to 7.33, which correlates with the results of the sensory analysis by which the color change is detected with the naked eye. For beef aged for 14 days, the color difference cannot be perceived with the naked eye, but for beef aged for 21, 28 and 35 days respectively, the color difference can be distinguished with the naked eye even by inexperienced evaluators.

The beef color, both in depth and on the surface, was analyzed separately and the appearance of the brown color is largely due to the denaturation of myoglobin during roasting at high and very high temperatures [30].

No major changes were observed in roasted meat depending on the beef dry aging period. The most obvious changes in the color parameters were related to the heat treatment temperatures (Table 3).

The obtained results for the surface color parameters of the roasted meat at very high temperatures were lower compared to the treatment at high temperatures and obviously compared to the results obtained inside beef color. Similar results were obtained by [11, 12] in research conducted on roast beef.

The values of the parameter *L** decrease due to the reduction of the moisture of the meat on the surface during roasting process and it was directly proportional to the increase in the temperature of the heat treatment process. The redness of beef *(a*)* decreases in intensity primarily depending on the beef aging period but also with the increase in the roasting temperature, due to the drastic degradation of myoglobin.

Table 3

Color parametres of roast dry aged beef

Color parametres	Beef samples	Surface color of roast beef		Internal color of roast beef	
		150˚C	230˚C	150˚C	230˚C
L*	Fresh Beef	29.76±0.10	28.12±0.13	30.15±0.18	28.89±0.18
	M14	28.15±0.70	26.78±0.17	29.0±0.10	28.18±0.03
	M21	27.45±0.09	26.07±0.34	28.34±0.75	27.50±0.33
	M28	27.08±0.11	25.57±0.30	27.97±0.15	26.09±0.66
	M35	26.78±0.03	24.82±0.42	27.04±0.26	25.36±0.17
a*	Fresh Beef	17.82±0.11	17.02±0.66	18.42±0.22	18.12±0.42
	M14	17.23±0.24	16.23±0.34	18.12±0.71	17.90±0.08
	M21	16.78±0.15	15.71±0.16	17.78±0.19	17.04±0.11
	M28	16.23±0.25	15.25±0.11	17.03±0.07	16.82±0.10
	M35	16.00±0.11	15.18±0.19	16.89±0.10	16.03±0.21
b*	Fresh Beef	12.70±0.11	12.32±0.22	13.00±0.07	12.90±0.10
	M14	12.65±0.08	11.52±0.22	12.87±0.67	12.26±0.10
	M21	12.36±0.07	11.34±0.10	12.60±0.64	12.00±0.09
	M28	12.02±0.18	11.28±0.07	12.34±0.34	11.98±0.25
	M35	11.80±0.09	11.16±0.12	12.05±0.07	11.90±0.10
C*	Fresh Beef	21.88±0.28	21.01±0.11	22.55±0.24	22.24±0.07
	M14	21.38±0.07	19.90±0.66	22.23±0.36	21.70±0.22
	M21	20.84±0.18	19.38±0.58	21.79±0.18	20.84±0.64
	M28	20.20±0.18	18.97±0.11	21.03±0.07	20.65±0.72
	M35	19.88±0.10	18.84±0.10	20.75±0.18	19.96±0.34
Δ*E**	Fresh Beef	-	-	-	-
	M14	1.72±0.11	1.75±0.32	1.20±0.07	1.33±0.19
	M21	2.56±0.07	2.62±0.11	1.96±0.37	2.29±0.80
	M28	3.19±0.22	3.27±0.20	2.67±0.02	2.70±0.16
	M35	3.61±0.10	3.95±0.07	3.59±0.26	3.88±0.30

Note: M14—beef dry aged for 14 days; M21— beef dry aged for 21 days; M28— beef dry aged for 28 days; M35— beef dry aged for 35 days

The *b** parameter also decreases, possibly due to the increase in metmyoglobin content during heat treatment. The obtained results were close to those presented in his work by Lee et al. regarding the chromatic parameters of dry aged beef and wet aged for 28 days [31].

Chroma *C** values show decreasing results for roasted meat, depending on the used temperature. For higher temperatures, the chroma *C** values are the lowest, which characterizes the decrease in color intensity. The results for chroma *C** analyzing the meat on the surface or inside demonstrate that the same law of decrease in the intensity of the meat color is preserved, but the decrease of inside meat color intensity is lighter.

According to the data presented in Table 3, Δ*E** increases with extending meat dry aging period, as in the case of non-thermally treated meat. The change in the color of roasted meat can be observed with the naked eye on the surface for dry aged meat for 28 and 35 days, inside only for dry aged meat for 35 days. Depending on the used temperature, 230 ˚C had the major impact on the meat color differences.

4. Conclusions

Dry aging process proved to be an effective technique in order to improve sensory indices, color parameters, especially for aged beef samples during 21, 28 and 35 days. Color coordinates *L*, a*, b** throughout the dry aging period showed stable values depending on the pH value and the increasing water holding capacity. The difference in color ΔE* is more visible as the dry aging period increases, both for raw and roasted dry aged beef, which correlates with the obtained results. The results obtained for the analyzed quality indices, together with the results of other researches in the field, may have implications in the development of the dry aging technology in the Moldovan meat industry branch.

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