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IMPACT OF DISODIUM DIPHOSPHATE ON THE COLORIMETRIC PROFILE IN A MEAT PRODUCT WITH HETEROGENEOUS STRUCTURE: AN ANALYSIS IN ACTUAL TECHNOLOGY

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Abstract

The aim of this work focused on the analysis and evaluation of the emulsion stabilizer, $Na_2H_2P_2O_7$ on the colorimetric profile in a meat product with a heterogeneous structure of Sus scrofa domesticus. Water (%), fat (%), protein (%), collagen (%), and salt (%) contents were also monitored. Depending on the fat and water content, the agent absorption may vary, which may affect the uniformity or intensity of the color of the finished product. The experimental samples consisted of a control batch and 0.09% $Na_2H_2P_2O_7$ per 3000 g of meat fed to the experimental batch. Data distribution was evaluated using SPSS Statistics 26.0 software and Graph Pad Prism 9 software. A T-test was applied to evaluate the influence of the $Na_2H_2P_2O_7$ on quality biomarkers (%). Linear regression was applied to determine if there was a linear relationship between $Na_2H_2P_2O_7$ and the CIE(Lab) system parameters: L(D65), a*(D65), and b*(D65). The results showed significant effects of $Na_2H_2P_2O_7$ in fat content (%) and water (%), thus influencing the colorimetric profile.*

Key words*: emulsion stabilizer, meat product, quality.*

INTRODUCTION

There is now a shift in dietary patterns in modern society, with consumers increasingly aware of the relationship between food and health. In this context, some meat products are often perceived as unhealthy due to their composition (Câmara et al., 2020; Boișteanu et al., 2023; Ciobanu et al., 2023).

The many negative connotations of processed products can be alleviated by decreasing the amounts of harmful elements such as saturated fats, salt, nitrites, and phosphates (Alirezalu et al., 2019; Anchidin et al., 2023). Studies have indicated that reducing the level of these components can lead to more technological limitations in meat products (Ciobanu et al., 2023; Câmara & Pollonio, 2015).

From a technological point of view, lipid reformulation using vegetable oils is a great challenge because it influences the physical and chemical stability of the emulsified matrix (Câmara & Pollonio, 2015).

Phosphates offer a wide range of possibilities when used in meat production. They are used in meat products for several reasons, such as modifying and/or stabilizing the pH value, and increasing water holding capacity to lead to higher yields from a technological point of view. Phosphates in meat products are also sources of phosphorus supply to consumers through feed (Long et al., 2011).

Phosphates are important for human health because they are responsible for the growth, maintenance, and repair of tissues and cells of living organisms. However, an avoidable health risk results from the increased use of phosphates as food additives and preservatives (Ritz et al., 2012).

Diphosphates can immediately dissociate the actomyosin complex of meat, and tri- and polyphosphates help activate meat proteins by partially chelating Mg^{2+} and Ca^{2+} proteins, both of which lead to increased solubilization of myosin and actin and depolymerization of thick and thin filaments (Glorieux et al., 2017). This work aimed to analyze and evaluate the effect of the emulsion stabilizer, $Na_2H_2P_2O_7$, on the colorimetric profile of a meat product from domestic pigs with a heterogeneous structure. In

addition, the content of water, fat, protein, collagen, and salt was monitored.

MATERIALS AND METHODS

The experimental samples were designed in accordance with (Regulation (EC) No 1333/2008 of the European Parliament and of the Council of 16 December 2008). The experimental samples consisted of a control batch and 0.09 % $Na_2H_2P_2O_7$ per 3000 g of meat fed to the experimental batch. The samples used in this study, together with the reference material, were obtained in the Meat Microproduction Department (IULS Iași), following ISO quality standards. The raw materials, from a local producer, were stored in cold storage for 24 hours before the start of the study. For the research, muscle samples from *Musculus gluteus maximus* were taken for the study after the removal of excess fat and connective tissue. Only one type of salt was used: NaCl (table/natural salt) for both the control and experimental groups. These were mixed manually with the muscle samples and then subjected to a 12-hour maturation period at a controlled temperature of 2-4°C. After maturation, the samples were coarsely grinded by Grinder WP - 105 using a sieve with a diameter of 3 mm, then the emulsion was obtained using the Cutter Titane V 45L. The samples were mixed with the control emulsion and the emulsion containing the emulsion stabilizer 0.09 % $Na_2H_2P_2O_7$ per 3000 g of meat fed to the experimental batch. The resulting paste was placed in collagen membranes with a diameter of 45 mm, which were previously hydrated to form elasticity. The samples were subjected to a specific heat treatment according to Table 1.

Table 1. Heat treatment steps for the control sample (meat product with heterogeneous structure without $Na_2H_2P_2O_7$) and experimental samples (meat product with heterogeneous structure with $Na_2H_2P_2O_7$)

Heat treatment stage	Time	Temperature inside the cell	Temperature in the thermal center
	minutes	°C	°C
Drying	30	60	50
Smoking	25	60	58
Boiling	-	76	72
Drying	10	80	76

These samples were vacuum-sealed in two-layer bags, the inner layer being 60 μm polyethylene, suitable for food contact, and the outer layer being 15 μm polyamide, UV-filtered, using ATM Machinery equipment with a 630W chamber cooled to 2°C and separated from light for 12 hours. After this period, samples were transported to the control laboratory for further analysis.

The final products were subjected to physicochemical evaluations to test the influence of Na2H2P2O7 on the heterogeneous structure product. Instrumental color characteristics of the product were determined using a Chroma Meter CR-410 colorimeter from Konica Minolta Inc., Japan, on the CIELAB scale. These characteristics were expressed as L*, a*, and b* values. The primary color coordinates L* (brightness), a* (complementary red-green color coordinate), b* (complementary yellow-blue color coordinate) were evaluated according to CIE (Commission Internationale de l'Eclairage) space LAB on the sample surface (presented as the average value of measurements at five equally distributed locations on the sample) and section using a Hunter Minolta CM-2600d colorimeter, with an observation angle of 2° and a measurement area with a diameter of 8 mm, illuminating an area of 50 mm in diameter, according to (Manoliu et al., 2023), (Tapp et al., 2011). Fat (%), protein (%), collagen (%), and salt (%) contents were also monitored using the Omega Bruins Food-Check Near Infrared (NIR) spectrophotometer (Bruins Instruments GmbH, Puchheim, Germany).

Data distribution was evaluated using SPSS Statistics 26.0 software and Graph Pad Prism 9 software. A T-test was applied to assess the influence of $Na_2H_2P_2O_7$ on quality biomarkers (%). Linear regression was applied to determine if there was a linear relationship between $Na_2H_2P_2O_7$ and the CIE(Lab) system parameters L*(D65), a*(D65), and b*(D65).

RESULTS AND DISCUSSIONS

The results of the analysis of the parameters fat (%), protein (%), collagen (%), and salt (%) in the control and experimental samples with the addition of $Na_2H_2P_2O_7$ are shown in Table 2. The current technology may have a significant impact on the raw chemical composition.

Protein is an essential element in determining the quality of the finished product and the current technology may play a significant role in influencing the concentration. Protein is often considered a measure of the nutritional value of a food product and is essential in determining the texture, taste, and nutritional value of the final product. Samples from the control batch show an average protein of 20.02 ± 0.0447%, while the experimental batch records an average of 21.52 ± 0.1924%. The quantity of protein increased significantly. Visible differences can be seen in water and fat content. The addition of $Na_2H_2P_2O_7$ can help to reduce water loss during product processing. The control samples show an average of the water parameter of 69.02 ± 0.1095%, while in the experimental batch, the average is 71.18 ± 0.0447%. By stabilizing the structure of the meat product, $Na_2H_2P_2O_7$ can influence the way fat is distributed in the product. This may lead to a more uniform dispersion of fat throughout the product, which could affect the fat content in the raw composition. The amount of fat in the control samples is 10.22 ± 0.1643%, compared to the experimental samples where the average is 7.58 ± 0.0447%. These results indicate a significant reduction in fat content in the experimental samples, suggesting that the addition of $Na_2H_2P_2O_7$ can positively influence the crude chemical composition of the pork product by reducing fat content and improving water retention.

Table 2. Analysis of the parameters fat, water, protein, collagen, and salt in the control and experimental samples

Parameters	Sample	N	Mean	Std. Deviation	Std. Error Mean
FAT (%)	**C**	5	10.22	0.1643	0.0735
	E	5	7.58	0.0447	0.0200
WATER (%)	**C**	5	69.02	0.1095	0.0490
	E	5	71.18	0.0447	0.0200
PROTEIN (%)	**C**	5	20.02	0.0447	0.0200
	E	5	21.52	0.1924	0.0860
COLLAGEN (%)	**C**	5	18.24	0.0548	0.0245
	E	5	19.01	0.0548	0.0246
SALT (%)	**C**	5	2.34	0.2702	0.1208
	E	5	3.00	0.1095	0.0490

Values are given as means, std. deviation and std. error mean from 5 repeated determinations; C-control samples, E- experimental samples.

Table 3. Results of the evaluation of the impact of $Na_2H_2P_2O_7$ on fat, water, protein, collagen, and salt in a heterogeneously structured meat product of *Sus scrofa domesticus*

Parameters	t	df	Significance		Mean Difference	95% Confidence Interval of the Difference	
			One-Sided *p*	Two-Sided *p*		Lower	Upper
FAT (%)	379	4	<0.001	<0.001	7.58	7.524	7.636
WATER (%)	3559	4	<0.001	<0.001	71.18	71.124	71.236
PROTEIN (%)	238.54	4	<0.001	<0.001	20.52	20.281	20.759
COLLAGEN (%)	773.22	4	<0.001	<0.001	18.94	18.872	19.008
SALT (%)	55.52	4	<0.001	<0.001	2.72	2.584	2.856

The significance level is 0.050. determined by the T-test.

T-test was used to determine if there was a significant difference between the two groups (C-control samples, E-experimental samples). According to Table 3, fat (%), water (%), protein (%) collagen (%), and salt (%) contents in the experimental samples were significantly different from the control samples, suggesting that the addition of $Na_2H_2P_2O_7$ significantly influenced these control parameters. For fat, we have a mean difference of 7.58%, and the 95% confidence interval for this difference is between 7.524% and 7.636%. The *p*-values for all tests are very small, $p<0.001$, indicating that the observed differences are highly unlikely to be the result of random variability and are therefore statistically significant. The mean difference is shown, along with the 95% confidence interval, which indicates how

accurately the mean difference between the treated and control samples is estimated.
Depending on the fat and water content, the agent absorption may vary, which may affect the uniformity or intensity of the color of the finished product.

Figure 1 shows the analysis of the distribution of the means of the primary color coordinates L*(D65), a*(D65), and b*(D65) for two sets of samples: A (control) and B (experimental samples with $Na_2H_2P_2O_7$).

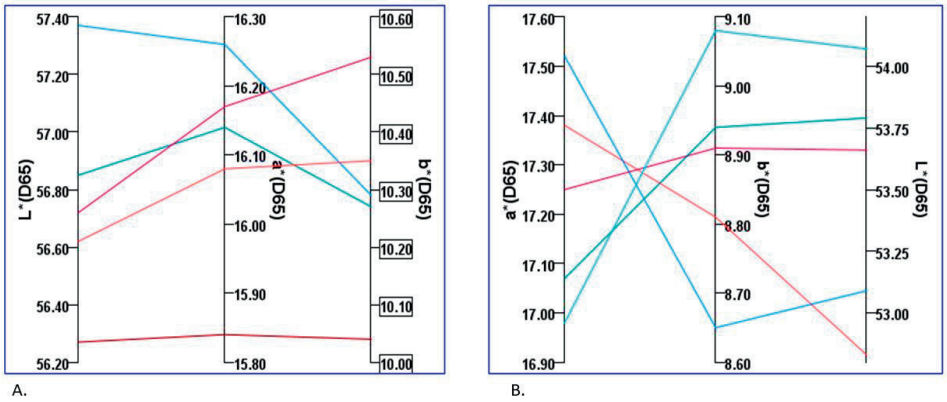

Figure 1. Distribution of the means of the primary color coordinates L*(D65), a*(D65), b*(D65) for A (control samples) and B (experimental samples)

Table 4. Results of linear regression analysis performed to determine the influence of $Na_2H_2P_2O_7$ on CIE(Lab) color coordinates: L*(D65), a*(D65), and b*(D65) in the samples studied

Parameters	Sample	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
						R Square Change	F Change	df1	df2	Sig. F Change
L*(D65)	C	.960[a]	.921	.894	.13017	.921	34.85	1	3	.010
	E	.308[a]	.095	-.206	.56299	.095	.315	1	3	.614
a*(D65)	C	.900[a]	.809	.746	.07975	.809	12.73	1	3	.038
	E	.552[a]	.305	.073	.21238	.305	1.31	1	3	.335
b*(D65)	C	.377[a]	.142	-.144	.18822	.142	.498	1	3	.531
	E	.722[a]	.521	.361	.12779	.521	3.26	1	3	.169

[a] Predictors: Constant

Table 4 shows for the experimental sample (E): R = 0.308, R Square = 0.095, Adjusted R Square = -0.206, Std. Error of the Estimate = 0.56299. This suggests that the influence of $Na_2H_2P_2O_7$ on L*(D65) in the experimental sample is not statistically significant. For the parameter a*(D65), R = 0.552, R Square = 0.305, Adjusted R Square = 0.073, Std. Error of the Estimate = 0.21238. In this case, the influence of $Na_2H_2P_2O_7$ on a*(D65) in the experimental sample is statistically significant. For the parameter b*(D65), R = 0.722, R Square = 0.521, Adjusted R Square = 0.361, Std. Error of the Estimate = 0.12779. In the experimental sample, the influence of $Na_2H_2P_2O_7$ on b*(D65) is statistically significant. These results indicate that $Na_2H_2P_2O_7$ has different influences on CIE(Lab) color coordinates.

Table 5. Results of analysis of variance (ANOVA) for linear regression applied for CIE(Lab) coordinates L*(D65), a*(D65), and b*(D65) in control and experimental samples

ANOVA[a]							
			Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
L*(D65)	C	Regression	0.59	1	0.59	34.851	0.010[b]
		Residual	0.051	3	0.017		
		Total	**0.641**	**4**			
	E	Regression	0.1	1	0.1	0.315	0.614[b]
		Residual	0.951	3	0.317		
		Total	**1.051**	**4**			
a*(D65)	C	Regression	0.081	1	0.081	12.736	0.038[b]
		Residual	0.019	3	0.006		
		Total	**0.1**	**4**			
	E	Regression	0.059	1	0.059	1.315	0.335[b]
		Residual	0.135	3	0.045		
		Total	**0.195**	**4**			
b*(D65)	C	Regression	0.018	1	0.018	0.498	0.531[b]
		Residual	0.106	3	0.035		
		Total	**0.124**	**4**			
	E	Regression	0.053	1	0.053	3.263	0.169[b]
		Residual	0.049	3	0.016		
		Total	**0.102**	**4**			

The significance level is 0.050. C-control samples, E- experimental samples; a. Dependent Variable: L*(D65), a*(D65), b*(D65); b. Predictors: Constant

According to the results of the analysis of variance (ANOVA) for the linear regression applied on the coordinates CIE(Lab) - L*(D65), a*(D65), and b*(D65), presented in Table 5, we observe that there are significant differences between the control and experimental groups. For the parameter L*(D65), the regression is significant for the control group (p=0.010), suggesting a linear relationship between the sample means. In contrast, for the experimental samples, the regression is insignificant (p=0.614), indicating the absence of a linear relationship.

Regarding the parameter a*(D65), we observe that the regression is significant for the control group (p=0.038), while for the experimental group, the regression is not significant (p=0.335), suggesting the absence of a linear relationship.

In the case of parameter b*(D65), both control and experimental samples show insignificant regressions (p=0.531, p=0.169, respectively), indicating the absence of a significant linear relationship between these coordinates in both groups. These results highlight the variation in the significance of linear relationships between CIE(Lab) coordinates and the influence of $Na_2H_2P_2O_7$ in the heterogeneously structured meat product.

CONCLUSIONS

The results showed significant effects of fat and water content on the colorimetric profile. T-test was used to determine significant differences between the two groups (C - control sample, E - experimental samples). The fat, water, protein, collagen, and salt content of the experimental samples was significantly different from the control samples, indicating that the addition of $Na_2H_2P_2O_7$ significantly influenced these control parameters. Depending on the fat and water content, the absorption of the agent may vary, which may affect the uniformity or intensity of the color of the finished product.

The results of linear regression analysis performed to determine the influence of $Na_2H_2P_2O_7$ on CIE (Lab) color coordinates: L*(D65), a*(D65), and b*(D65) in the samples studied suggest that $Na_2H_2P_2O_7$ has different influences on CIE (Lab) color coordinates.

According to the results of analysis of variance (ANOVA) for linear regression applied on CIE (Lab) - L*(D65), a*(D65), and b*(D65) coordinates, significant differences are observed between the control and experimental groups.

Future studies could further explore the effects of $Na_2H_2P_2O_7$ addition on other aspects of the final product, such as texture and taste.

Research investigating how variations in the initial composition of the raw material affect the response of the product to this specific additive could also be useful. In addition, assessing the long-term impact of using $Na_2H_2P_2O_7$ in production processes and finished products could provide a more comprehensive understanding of its potential effects on food quality and safety. Research can also explore alternatives to $Na_2H_2P_2O_7$ and their comparisons in terms of efficacy and impact on finished product properties.

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