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Changes in water activity, free fatty acids, peroxide number, fat content, moisture content, color, and appearance of beef sausage with corn oil replacement and sodium erythorbate addition during storage period

Hega Bintang Pratama Putra*, Qurrotul Ain, Sri Mulyani, Heni Rizqiati

Food Technology Study Program, Department of Agricultural Sciences, Faculty of Animal and Agricultural Sciences, Universitas Diponegoro, Semarang 50275, Central Java, Indonesia.

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*Correspondence:

Corresponding author: Hega B.P. Putra
E-mail address: hegabintang@lecturer.undip.ac.id

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ABSTRACT

Sausage is widely recognized as a popular processed meat product in contemporary society. The oil frequently used in emulsions is palm oil which is high in saturated fatty acids. To develop a healthier alternative, corn oil replacement process was implemented in the sausage formulation. This study aims to identify the changes in water activity, peroxide number, free fatty acids, fat content, moisture content, color, and appearance in beef sausage with corn oil replacement and the addition of sodium erythorbate during storage period. The data were analyzed using Microsoft Excel software and presented in a two-dimensional line graph included with trendline, linear equation, and correlation coefficient (R^2) to observe the changes in parameters over the storage period. The results indicated that the water activity of the sausage ranged from 0.716-0.791; free fatty acids ranged from 0.63-1.00%; peroxide number ranged from 0.012-0.053 meq/kg; fat content ranged from 10.17-14.70%; and moisture content ranged from 11.86-15.26%. Based on this research, it can be concluded that the addition of sodium erythorbate into beef sausage inhibits the rate of fat oxidation during storage. This conclusion is supported by the changes in peroxide number, free fatty acids, and fat content that varied among treatments. Throughout the storage period, the addition of sodium erythorbate positively affected the oxidative stability of beef sausage with corn oil replacement.

Introduction

Sausage is meat processed food that is commonly found in modern dietary eating practices. Based on statistical data from 6W Research, sausage consumption in Indonesia increased by an average of 4.6% per year. The increasing consumption of processed meat products such as sausages occurs due to a shift in people's consumption patterns of meat-based groceries, which were originally processed simply to consume fast processed meat products such as ready-to-eat sausages. Sausage making uses an emulsion system in the production process. Sausage emulsion is a type of oil in water (o/w) emulsion where the fat or oil phase is dispersed in the water phase (Qi *et al*., 2020). Oil in making sausage emulsion usually uses palm cooking oil. Palm oil contains the dominant saturated fatty acid, palmitic acid, which is about 44% (Mancini *et al*., 2015).

Replacing the use of palm oil with other vegetable oils that have lower saturated fat content can overcome the increase in blood cholesterol levels, one alternative solution is by replacing the use of palm oil with corn oil. Corn oil is known to have high unsaturated fatty acids, specifically linoleic and linolenic acids (Stępień *et al*., 2024). However, the polyunsaturated fatty acid content in corn oil has fatty acid molecules with double bonds, making corn oil susceptible to oxidation (Petersen *et al*., 2024). The addition of antioxidants is essential to prevent oil from oxidizing and causing damage to food products, as an example, stated by Canan *et al*. (2024) that the addition of antioxidants to chicken mortadella can inhibit lipid oxidation. In processed meat products, particularly those contain high fat and protein, antioxidant is generally used in the form of sodium erythorbate. As an antioxidant, sodium erythorbate works by inhibiting the oxidation of fat in meat during the storage period. Previous studies have proven that sodium erythorbate works more effectively than ascorbic acid in slowing down the process of fat oxidation and protein degradation in meat (Yuan *et al*., 2022). Addition of sodium erythorbate is frequently used as a preservative for meat products due to its cost-effectiveness (Wongphan *et al*., 2023). When used in conjunction with nitrite salts, sodium erythorbate acts as a reducing agent, increasing the rate of conversion of nitrite to nitric oxide, producing the color pigment nitroso myoglobin, thus maintain the red color of meat products (Osterbauer *et al*., 2017).

A number of studies have been conducted previously to develop nutritional modification of beef sausage, as in example a study that conducted by Alao *et al*. (2021) on the usage of cooking oil in deboned meat-fortified beef sausage to determine the effect on changes in free fatty acid levels. Urgu-Öztürk *et al*. (2020) has also conducted research on replacing palm oil usage in beef sausage emulsion productions with hazelnut oil to create a healthier alternative to beef sausage and measured the fat profile. The usage of other types of plant-based oils has also been done by Nieto and Lorenzo (2021) using olive oil as a substitute for palm oil to create low-fat functional food sausages. Despite the known benefits of sodium erythorbate as antioxidants and corn oil as healthier alternative, there is still a gap in comprehensive studies specifically researching its impact on beef sausage formulations. This study aimed to fill the gap by examining the effect of sodium erythorbate addition on the oxidative stability of beef sausages using corn oil as oil replacer on emulsions, contributing to the existing knowledge regarding the addition of antioxidants additive in meat processed products.

Materials and methods

Materials

The materials used in this study were beef, chicken MDM (mechanical deboned meat), corn oil emulsion, ice cubes, salt, sodium erythorbate, transglutaminase enzyme, beef broth seasoning, sugar, white pepper powder, onion powder seasoning, tapioca flour, cornstarch, and carrageenan obtained from Estika Tata Tiara LLC stocks. The analytical materials used were 96% alcohol, 0.1 N NaOH solution, 0.1 N phenolphthalein, hexane solvent, 0.1 N acetic acid, chloroform, potassium iodide saturat-

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ed solution, distilled water, 1% amylum, and 0.1 N $Na_2SO_2O_3$ (sodium thiosulfate) purchased from local chemical store in Semarang. The tools needed were containers, digital scales, spoons, bowl cutter (Sirman, Italy), spatulas, sausage filler (ACE Hardware, America), steaming pot, vacuum sealer machine (Powerpack, China). The analytical tools used were αw meter (Novasina, Switzerland), color reader (Konica Minolta, Japan), burette, Soxhlet flask (Iwaki, Indonesia), hot plate, magnetic stirrer, moisture content oven (Memmert, Germany), desiccator, gripper, porcelain cup, analytical balance (Shimadzu, Japan), filter paper, mortar, pestle, Erlenmeyer (Pyrex, Indonesia), dropper pipette, beaker (Herma, Indonesia), volumetric flask (Herma, Indonesia), refrigerator (Modena, Indonesia), label, tissue, and pipette.

Methods

The research was conducted from November 2024 to January 2025 at the Research and Development Laboratory of Estika Tata Tiara LLC, and the Food Chemistry and Nutrition Laboratory, Faculty of Animal and Agricultural Science, Universitas Diponegoro. Semarang. The study involved two types of treatments, i.e., treatment without sodium erythorbate addition (P0) and treatment with sodium erythorbate addition (P1). The beef sausages from different treatment then evaluated at six intervals, subsequently every 3 days until day 15 of storage period. This resulted testing periods at day 0, 3, 6, 9, 12, and 15 to monitor the changes of parameters through storage period. The research method consisted of making corn oil emulsion, making beef sausage samples in which the palm oil had been substituted with corn oil, parameter testing, and data analysis. The parameters tested included water activity, free fatty acid, peroxide number, fat content, moisture content, color, and appearance. The research results were analyzed using Microsoft Excel.

Corn oil emulsion making procedure

Making corn oil emulsion was done by using isolate soy protein (ISP) powder, water, and corn oil with a predetermined formulation ratio (ISP : corn oil : water) i.e. 1 : 4 : 5. The emulsion was made using a bowl cutter, starting with ISP and water, then blended until well mixed. Corn oil was added little by little until an emulsion was formed. A well-formed emulsion is characterized by its solid texture, stable mixture of two insoluble liquids, white color, and does not underwent separation phase during processing and treatment process, indicating that the emulsion in a stable condition.

Sausage sample making procedure

Sausage making started with mashing the beef, mechanically deboned meat (MDM), and transglutaminase enzyme using a bowl cutter. After the meat is half smooth, the mixture is added with seasoning (salt, beef extract powder, and white pepper) and corn oil emulsion, then grinded until the ingredients were all mixed, add the filler and binder ingredients (tapioca starch, corn starch, and carrageenan). All ingredients were thoroughly mixed in a bowl cutter until the dough is homogenous and evenly distributed. The beef sausage mixture then filled into collagen sausage casing. The sausages that had been inserted into the casing were then steamed for 45 minutes at 70°C to ensure the best texture development through proper cooking. After steaming process ended, beef sausages left to cool down to room temperature before packed in sealed 0.08 mm thick PP (polypropylene) bags. The packed beef sausages stored in refrigerated temperature before the samples tested according to the test parameters.

Water activity testing procedure

Measurement of water activity value refers to following methodology by Apriantini *et al*. (2021). The αw value was measured using the αw meter (Novasina, Switzerland). The αw meter was powered on and allowed to warm up until the device in appropriate operating conditions. The sample was macerated and placed inside the container, then inserted into the αw meter, and closed tightly. The measurement process considered completed when the αw meter emitted a sound, indicating the reading process achieved stabilized consistent value. The principle of measurement using the αw meter is to calculate the water vapor pressure of the sample divided by the pure water content under the same environmental temperature conditions (Cheng *et al*., 2025).

Peroxide number testing procedure

The calculation method of peroxide number of beef sausage refers to Rahman *et al*. (2015). A total of 10 grams of sausage samples were added to a solution of acetic acid and chloroform in a ratio of 2: 3. The mixture was added with saturated potassium iodide solution and left to stand for 5 minutes, then added with 1% amylum indicator and titrated using 0.1 N sodium thiosulfate solution until the blue color disappeared. The peroxide number is then presented in units of meq/kg with the formula:

Peroxide Numbers = (amount of titrant x titrant normality x 1000)/(gram sample)

Description

Titrant normality= Normality of sodium thiosulfate (0.1 N)

Free fatty acid testing procedure

FFA (free fatty acid) value testing methods refers to Rahman *et al*. (2015). The testing of the FFA value in sausages using the titration method. Sausage samples used as much as 7 grams, 12 ml of high temperature alcohol, and 0.5 ml of 1% PP (phenolphthalein) indicator were put into an Erlenmeyer. The sample was titrated with 0.1 N NaOH until the color turned pink and the color did not disappear for 30 seconds. The FFA value is then presented in units of % (percent) with the formula:

% FFA= (NaOH x NaOH normality x fatty acid molecular weight)/(sample weight x 100) x 100%

Description:

NaOH normality = 0.1 N; Molecular weight (linoleic acid) = 280,45 g/mol

Fat content testing procedure

Fat content testing method that is commonly done on food ingredients is the Soxhlet test. Referring to the AOAC (2005) method, the sample used was 2 grams (weight A). The samples were wrapped in filter paper that had been cut with a size of 11 x 11 cm, then folded neatly and each treatment was given code name. The samples were dried with drying oven for 4 hours at 105°C, then placed inside desiccator for 15 minutes. The samples were again put into the drying oven for the second time for 1 hour at the same temperature and put back into the desiccator for 15 minutes before being weighed until the samples reached a constant weight (weight B).

The dried samples were put into the Soxhlet extraction device in a tight, solid, and neat position. The Soxhlet flask were filled with petroleum ether or other non-polar organic solvent until the entire samples were immersed with solvent liquid. The condenser pipe connected to the extractor, the hot plate then turned on, and the extraction process is carried out for 6 hours. After the extraction process was completed, the samples allowed to be cooled down in the open air for 30 minutes before being placed back inside the drying oven for 1 hour at 105°C. The sample was put back into the desiccator for 15 minutes, then the final weight of the sample (weight C) was weighed. Fat content then calculated using the formula:

Fat content (%):= (weight B-weight C)/(weight A) x 100%

Moisture content testing procedure

This study used the drying oven method based on Indonesian National Standard (SNI) 01-2891-1992 to determine the moisture content of beef sausage samples. The procedure began with sample preparation, where sausages samples were macerated and weighed as per 2 grams. The porcelain cup dried inside the oven at 105°C for 1 hour and cooled down inside the desiccator for 15 minutes, then weighed as a sample container (W_1). The sample was placed in the cup and weighed to obtain the initial weight (W_2). Next, the samples were dried inside the oven at 105°C for 4 hours, then the samples were cooled inside the desiccator for 15 minutes. The samples were put back in the oven until it reached constant weight. After drying process finished, the cup containing the sample was cooled in a desiccator and weighed again as (W_3). Moisture content then calculated by the formula:

Moisture content (%):= $(W2-(W3-W1))/W2 \times 100\%$

Description

W1 = weight of empty porcelain cup

W2 = weight of sample before drying

W3 = weight of porcelain cup and sample after drying

Color and appearance testing procedure

The color analysis of the beef sausages using Hunter or CIELAB method with a color reader, refers to Feng (2024). The color reader (Konica Minolta, Japan) was powered on and stabilized for 5 minutes to ensure the tools taken accurate readings process. The device calibrated using a standard white plate according to the operation manual. For data sampling, the beef sausages samples were macerated and placed in a white porcelain cup. The tip of the color reader placed a centimeter above the surface of the sample without light gap in between to avoid variability of color distribution. Data measurement taken in three repetitions on different position and areas. To evaluate the beef sausages overall appearance, the sausage sample were placed on a white wide board under bright lightning conditions to provide comprehensive and specific appearance of the beef sausages.

Data analysis

Data from parameters testing of water activity (αw), peroxide number, free fatty acids, fat content, and moisture content were analyzed using Microsoft Excel application. The calculations carried out are the average (mean) and standard deviation of all data, then the calculated data displayed in the form of a two-dimensional line graph with a trendline, linear equation, and correlation coefficient (R^2) value to determine changes during storage. Color and appearance result displayed in table form. The results of the data analysis were then explained descriptively.

Results

Water activity

The results of water activity analysis on beef sausage with corn oil replacement without the addition of sodium erythorbate (P0) increased until day 6 of storage, ranging from 0.759-0.791 then decreased on day 9 to day 15 of storage period to 0.787-0.773. In the treatment with the addition of sodium erythorbate (P1), the same thing also happened, which was an increase in the value of αw until day 6 storage with a range between 0.716-0.770 and decreased in storage from day 9 to day 15 to 0.769-0.761 (Table 1 and Fig. 1).

Free fatty acid

Free fatty acid of beef sausage with sodium erythorbate addition treatment (P1) has a lower percentage compared to the treatment without sodium erythorbate addition (P0). The range of results of the analysis of free fatty acid content of the treatment without the addition of sodium erythorbate (P0) is 0.77% - 1%, while the free fatty acid content of the treatment with the addition of natrium erythorbate (P1) ranges from 0.63% - 0.89% (Table 2 and Fig. 2).

Table 1. Water activity and moisture content test results.

Parameter	Storage Time	P0	P1
Water Avtivity	0	0.759±0.038	0.716±0.036
	3	0.786±0.082	0.760±0.056
	6	0.791±0.064	0.770±0.014
	9	0.787±0.041	0.769±0.060
	12	0.783±0.050	0.768±0.074
	15	0.773±0.045	0.761±0.024
Moisture Content (%)	0	15.26±0.743	14.79±1.096
	3	14.68±0.501	14.47±1.079
	6	13.60±0.874	14.32±1.213
	9	13.06±1.072	13.87±0.319
	12	12.98±0.822	13.56±0.136
	15	11.86±1.376	13.45±0.165

Data are shown as mean values of 4 replicates±standard deviation

P0: Treatment without addition of sodium erythorbate; P1: Treatment with the addition of sodium erythorbate.

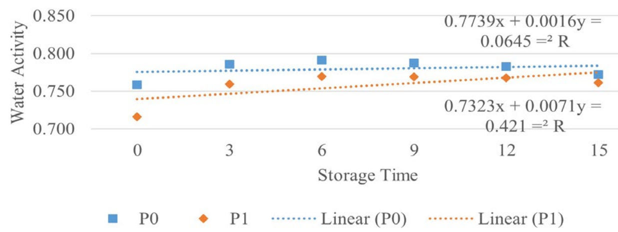

Fig. 1. Changes in water activity value of corn oil fortified beef sausage.

P0: Treatment without addition of sodium erythorbate; P1: Treatment with the addition of sodium erythorbate

Table 2. Free fatty acid test results.

Storage Time	P0 (%)	P1 (%)
0	0.77±0.058	0.63±0.311
3	0.79±0.129	0.64±0.330
6	0.84±0.141	0.66±0.150
9	0.97±0.287	0.76±0.150
12	0.99±0.189	0.82±0.283
15	1.00±0.265	0.89±0.359

Data are shown as mean values of 4 replicates±standard deviation

P0: Treatment without addition of sodium erythorbate; P1: Treatment with the addition of sodium erythorbate.

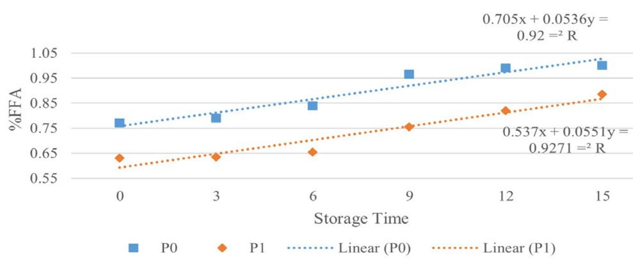

Fig. 2. Changes in free fatty acid of corn oil fortified beef sausage.

P0: Treatment without addition of sodium erythorbate; P1: Treatment with the addition of sodium erythorbate.

Peroxide number

The peroxide number test results of beef sausage without the addition of sodium erythorbate (P0) ranged from 0.014 meq/kg - 0.053 meq/kg, while the treatment with the addition of sodium erythorbate (P1) ranged from 0.012 meq/kg - 0.048 meq/kg. The highest peroxide number was detected on the day 15 storage period because the fat oxidation process occurred with the longest duration (Table 3 and Fig. 3).

Table 3. Peroxide number test results.

Storage Time	P0 (meq/kg)	P1 (meq/kg)
0	0.014±0.082	0.012±0.082
3	0.017±0.096	0.015±0.058
6	0.035±0.050	0.034±0.096
9	0.036±0.082	0. 035±0.096
12	0.052±0.096	0.046±0.096
15	0.053±0.096	0.048±0.096

Data are shown as mean values of 4 replicates±standard deviation
P0: Treatment without addition of sodium erythorbate; P1: Treatment with the addition of sodium erythorbate.

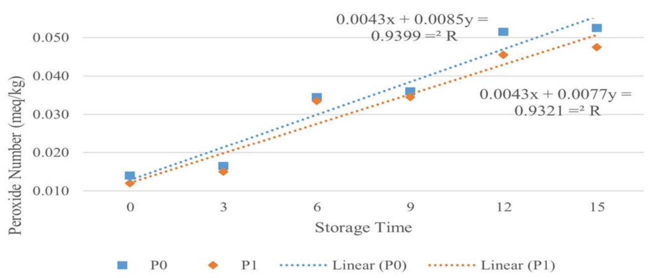

Fig. 3. Changes in peroxide number of corn oil fortified beef sausage.
P0: Treatment without addition of sodium erythorbate; P1: Treatment with the addition of sodium erythorbate.

Fat content

Fat content of beef sausage with sodium erythorbate addition treatment (P1) has a lower percentage compared to the treatment without sodium erythorbate addition (P0). The range of fat content analysis results of the treatment without the addition of sodium erythorbate (P0) was 10.17% - 13.14%, while the free fatty acid content of the treatment with the addition of sodium erythorbate (P1) ranged from 12.22% - 14.70%. Storage method using refrigerator with unstable temperature causing changes in moisture content of the beef sausages, the changes occur due to water vapor transmission between storage environments (Table 4 and Fig. 4).

Table 4. Fat content test results

Storage Time	P0 (%)	P1 (%)
0	13.14±0.742	14.70±1.176
3	12.47±0.901	13.77±1.085
6	11.67±0.727	13.36±1.627
9	11.16±1.085	12.90±0.271
12	10.67±0.779	12.47±0.543
15	10.17±1560	12.22±0.876

Data are shown as mean values of 4 replicates±standard deviation
P0: Treatment without addition of sodium erythorbate; P1: Treatment with the addition of sodium erythorbate.

Moisture content

The moisture content of beef sausage with sodium erythorbate addition treatment (P1) had a higher percentage of moisture content on day 15 of storage than the treatment without sodium erythorbate addition (P0). The range of water content analysis results of the treatment without the addition of sodium erythorbate (P0) is 11.86% - 15.26%, while in the treatment with the addition of sodium erythorbate (P1) is 13.45% - 14.79% (Table 1 and Fig. 5).

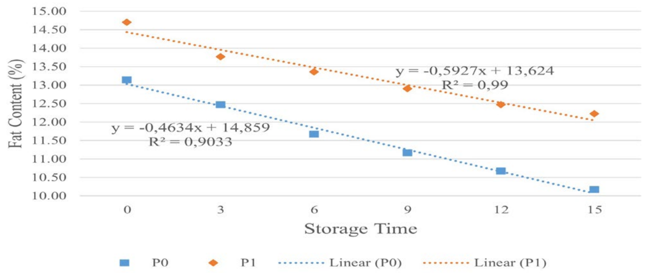

Fig. 4. Changes in fat content of corn oil fortified beef sausage
P0: Treatment without addition of sodium erythorbate; P1: Treatment with the addition of sodium erythorbate.

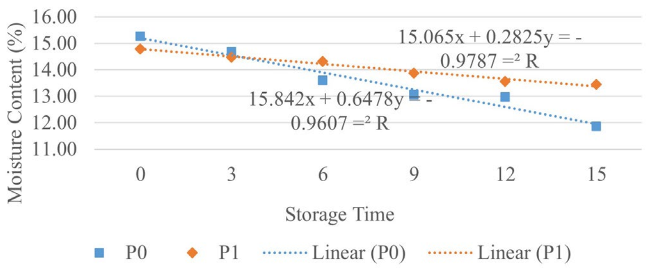

Fig. 5. Changes in moisture content value of corn oil fortified beef sausage.
P0: Treatment without addition of sodium erythorbate; P1: Treatment with the addition of sodium erythorbate.

Color and appearance

The colortest results of beef sausage showed that color of the beef sausage affected by the addition of sodium erythorbate and storage period presented in L* a* b* value. The L* value (lightness) of both treatments increased over 15 days in refrigerated storage. The increase in L* value is a phenomenon in meat processed product and often related to moisture loss during storage, making the color appear darker. Treatment with sodium erythorbate addition resulted in beef sausage with slightly reddish color. Treatment without sodium erythorbate addition resulted in lower a* value due to slower rate of nitrite reduction. The b* value (yellow-blue) of treatment without the addition of sodium erythorbate has higher value than the treatment with sodium erythorbate addition.

Discussion

The increase in αw value during storage was due to the presence of moisture from the storage environment at refrigerated temperatures that did not reach freezing point (0°C) and the storage of sausages that did not use the vacuum method, thus creating water vapor transmission in the packaging. The type of plastic packaging used to wrap the sausages can also affect the water activity value. The type of plastic packaging used to pack the sausages is PP (polypropylene) with a thickness of 0.08 mm. Polypropylene plastic has a high water vapor permeability value that allows the product in the packaging to absorb excess water (Jeong *et al.*, 2024). An increase in αw value also indicates the presence of fat oxidation activity. According to Gumus and Decker (2021), an αw value of 0.7 can indicate the presence of fat oxidation activity, which is classified as high, so the increase in αw value occurs due to the lipid oxidation in the sausage.

The addition of antioxidants to beef sausages can maintain the free

Table 5. Color and appearance test results.

Treatments	Storage Time (Days)	L*	a*	b*	Appearance
Without sodium erythorbate addition (P0)	0	32.8	2.3	9.1	
	3	35	2.8	8.7	
	6	38.1	2.3	7.7	
	9	44.9	3	9.3	
	12	47.6	3.1	9.3	
	15	51.1	2.3	8.6	
With sodium erythorbate addition (P1)	0	27	0.4	6.3	
	3	34.1	4.5	7	
	6	36,9	4.1	7.4	
	9	44.4	3.8	7.8	
	12	46.3	3.4	7.2	
	15	48.4	3.6	7.9	

Data are shown as mean values of 4 replicates ± standard deviation

fatty acid value of the sausages so that the levels remain low. The increase in free fatty acid levels during storage period can also have correlation to the water content inside the fat. If the water content of the fat is high, a hydrolysis reaction will occur and increasing free fatty acid levels (Bouta *et al.*, 2020). The peroxide number of beef sausage with the addition of sodium erythorbate (P1) was lower than the treatment without the addition of sodium erythorbate (P0), proving that the sodium erythorbate addition to sausage can inhibit the lipid oxidation process. This is in accordance with the opinion of Abeyrathne *et al.* (2021) which states that the addition of antioxidants can overcome lipid oxidation by inhibiting the oxidation and hydrolysis reaction to reduce the increase of peroxide number. Based on research conducted by Gotardo *et al.* (2024) regarding of lamb sausages with addition of sodium erythorbate and red propolis extract, there was a difference in a* value (red-green) on both treatments during storage period in refrigerated temperature, the reddish color resulting from nitrogen dioxide (NO_2) reaction with myoglobin, which driven by sodium erythorbate addition that capable to maintain red color of the meat product.

On day 0 to day 3 period storage, both treatments showed a slight increase in peroxide numbers. This can be caused by the formation on peroxide compounds are lower than the rate of formation of other chemical compounds (Domínguez *et al.*, 2019). The oxidation reaction begins with the formation of peroxide compounds and hydroperoxide compounds. Furthermore, the fatty acid component is split accompanied by the transformation of hydroperoxide compounds into aldehydes, ketones and free fatty acids. On the day 6 storage period, the peroxide number doubled from the day 3 storage period. This can occur due to the formation of labile peroxide compounds, but lipid oxidation happens continuously as the peroxide concentration increases sharply towards the maximum value until the end of the oxidation process (Durand *et al.*, 2025).

Changes in humidity and temperature can have an impact on beef sausages due to the transmission of water vapor from the storage environment into the product. This is in accordance with the opinion of Chen *et al.* (2024) that cold storage can cause changes in moisture content because there is absorption process of water vapor from the environment into the product during storage period, leading to moisture loss. The moisture content of sausages decreases during the storage period due to several factors, including evaporation and changes of ingredients chemical composition. Patarata *et al.* (2022) states that there is a correlation between water activity value and moisture content in beef sausages, which indicates a decreased in water activity as a result of moisture loss. On research that has been conducted by Pacheco *et al.* (2024) on sausages with corn oil substitution showed weight loss during refrigerated storage about 6,8%. As the sausages underwent weight loss during storage period, the moisture content in it decreased and as a result, the water activity value will likewise decrease. Changes in moisture content have contrast inverse correlation with fat content. The decrease in fat content is a result of the changes in moisture content that trigger fat oxidation (Gumus and Decker, 2021).

Decrease in moisture content usually considered to have inverse correlation with fat content, similar correlation to protein content. A decrease in fat content often attributed to an increase in protein content. As a water-binding composition, increase in protein content results in decreased water content (Apata *et al.*, 2025).

The addition of antioxidants, can help slow down the oxidation process, potentially preserving moisture content by inhibiting lipid oxidation and improving PUFA compounds (Petcu *et al.*, 2023). This preservation effect can result in a more stable moisture content, thus improving the overall quality of the sausage during storage. The beef sausage without sodium erythorbate addition tends to appear with pale color because this additive have crucial role in stabilizing the color of meat products, capable to retain the red pigment of myoglobin. According to Chouikhi *et al.* (2023), the yellowness of the sausage is decreased with antioxidant ingredients addition and slightly increased during storage period. The changes in yellow color due to lipid and myoglobin oxidation during refrigerated storage, resulting in a less attractive yellow-brown color. Sodium erythorbate acts as an antioxidant, converting nitrite to nitric oxide, which enhances the red color of myoglobin in the meat. Without the addition of sodium erythorbate, the meat product may not capable to retain its vibrant hue, leading to a paler appearance.

Conclusion

Based on the research conducted, it can be concluded that the addition of sodium erythorbate to beef sausage with corn oil replacement resulted in inhibition of fat oxidation rate during storage as indicated by changes in peroxide number, free fatty acids, fat content, moisture content, color and appearance between treatments. The inhibition of lipid oxidation evidenced by lower peroxide numbers in the treatments with antioxidant addition, which is a direct measure of primary oxidation products. The addition of synthetic antioxidant sodium erythorbate improved the oxidative stability of the beef sausage with corn oil as the plant-based replacement, confirm the effectiveness of sodium erythorbate addition to maintain the sausage quality and stability during refrigerated storage period.

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Conflict of interest

The authors declare that in this study, there is a potential conflict of interest because the researcher has a personal interest related to the services of the company that uses students as research subjects. The researcher is committed to ensuring that all data obtained and analysis conducted are not affected by personal interests and will maintain the integrity and objectivity of this research.

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