Improving quality of pastrami stored under different conditions by adding red cabbage (Brassica oleracea var. capitata f. rubra(

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Abstract
This study aims to evaluate red cabbage powder to develop a natural preservative to extend shelf life of pastrami. Pastrami was enriched with red cabbage powder to improve its quality, which included the estimation of total dissolved nitrogen (TSN)and dissolved non-protein nitrogen (NPN), soluble protein nitrogen (SPN), thiobarbituric acid (TBA), percentage of free fatty acids (FFA), and water holding capacity (WHC) were determined under different storage conditions including laboratory temperature storage at 25 ± 2°C for 45 days, refrigerated storage at 4 ± 2°C for 60 days, and frozen storage at -18 ± 1°C for 75 days, adding red cabbage powder at two concentrations 0.5% and 1%, to pastrami resulted in an increase in the value of both total dissolved nitrogen and soluble non-protein nitrogen, and a decrease in the value of soluble protein nitrogen. It also contributed to a decrease in lipid peroxidation (TBA), a decrease in the percentage of free fatty acids, and an increase in water holding capacity compared to control sample without powder additives. The study highlighted the feasibility of using red cabbage powder as a natural and economical alternative to chemical preservatives to extend shelf life of meat products and reduce food waste by extending shelf life of pastrami.

Keywords: Chemical Indicators, nitrogen content, Pastrami, Red Cabbage powder

Introduction

Meat is an important part of the human diet, as it is considered an important source of nutrients and a popular choice among consumers, as it provides essential nutrients such as protein, amino acids, vitamins, and minerals. The increasing demand for food in global markets is attributed to the significant increase in the world's population [1]. Continuing developments in meat processing are influenced by dynamic trends, as consumers' needs for the products they consume change. With consumers' increasing demand for healthier and more sustainable products, the meat industry faces challenges associated with increased levels of processing [2]. Recent years have witnessed a significant improvement in food preservation and shelf life extension due to technological advances. Among the natural antimicrobial agents used or researched are plants, spices, lactoferrin, isosomes, niacin, avidin, bacteriocins, conalbumin, and lactoperoxidase, there is also increasing interest in using natural antimicrobials as food preservatives due to the short- or long-term negative effects of consuming synthetic food preservatives. Since synthetic preservatives can cause health problems, they should be replaced with natural preservatives, which are much better for humans, animals, and the environment [3 .[

Brassicas are among the most widely consumed vegetables in the world. This plant

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family includes approximately 3,500 species. One of the most widely consumed cruciferous vegetables is red cabbage (Brassica oleracea var. capitata f.rubra), a traditional food crop in the diet that is easily available in local markets, where it is consumed in large quantities throughout the year, whether fresh or processed [4]. Red cabbage plays a fundamental role in providing healthy foods rich primarily in nutrients and some phytochemicals such as vitamins C and K, beta-carotene, minerals, fiber, total phenolic compounds, and glucosinolates. Cruciferous vegetables are a rich source of biologically active compounds, and epidemiological studies have confirmed that a high intake of these vegetables is associated with a reduced risk of certain cancers, such as lung, colorectal, breast, and prostate cancer [5 .[

Glucosinolates (GLS) contain sulfur and are found in all varieties of brassica vegetables. Currently, more than 200 different naturally occurring GLS have been discovered and are grouped into aliphatic, aromatic, and indolic GLS, based on their side chain structure. GLS is not biologically active, but its enzymatic derivatives are highly bioactive. Mechanical and thermal damage to cells activates the enzyme myrosinase, which hydrolyzes GLS to active compounds such as thiocyanates, isothiocyanates, indoles, nitriles, epithionitrile, and oxazoidines, which have potent anticancer properties [5,6.[

Pastrami is a popular cured meat product known for its unique flavor and preservation method. Its manufacturing processes include marinating, fermenting, drying, pressing, and packaging. It is made from beef, buffalo, and other meats. Its production involves specific techniques that contribute to its distinctive taste and texture, while providing some health and economic benefits. Table salt, curing salts, and spices are added, followed by pressing and drying. This process improves the flavor and extends its shelf life [7,8]. Although pastrami offers many benefits, there are health concerns associated with its consumption, especially due to its high salt content, which can contribute to health problems if consumed excessively. Therefore, there have been studies and efforts to reduce salt and find alternative methods using plant sources to compensate for the preservation resulting from the use of sodium salts, while taking into account the preservation of the traditional flavor and quality of the product [9,10.[

Processed meats play a fundamental role in the human diet due to their ease and speed of consumption, especially in preparing fast food. Due to the artificial preservatives added to them and the resulting health risks, we decided to conduct this study, which is to use red cabbage as a natural preservative, as it has antioxidant and microbial properties, in addition to the nutritional value of the plant, which it adds to the pastrami product, thus preserving the product's qualitative characteristics and monitoring these characteristics during different storage periods.

Materials and Methods

Raw materials

Beef rump (shoulder area) and beef fat were purchased from local markets in Basra and were ground using a 3 mm hole diameter mincing machine for three consecutive times to obtain finely minced meat and fat. The minced meat and fat were mixed homogeneously. Sheep intestines were purchased from local markets, cleaned and sterilized thoroughly using salt, vinegar, lemon and water. They were soaked for 24 hours, then washed well with water and refrigerated until ready to use for packaging.

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The spice mixture consisted of the following ingredients in the quantities shown below: 40g kibbeh, 40g black pepper, 40g cumin, 40g coriander, 10g nutmeg, 15g cloves, 5g cardamom, 20g ginger and 10g red pepper (paprika). They were ground well in an electric grinder, mixed well and stored in tightly sealed containers until ready to use. Red cabbage was also purchased, cleaned and then dried using an air dryer. The cabbage was ground and stored in tightly sealed containers in the refrigerator until ready to use.

Pastrami manufacturing

The cured pastrami product was prepared according to [11] with some modifications in the proportions of the ingredients. 2 kg of beef shoulder meat was purchased and minced using an electric grinder three times. 400 g of beef fat (greasy) was also purchased and minced three times and mixed well with the meat until a homogeneous mixture was obtained. Table salt was added at a rate of 3%, spices at a rate of 1% and garlic was added. The mixture was divided into 3 treatments: the control treatment included only the mixture without additives, the second treatment added red cabbage powder at a rate of 0.5% by weight, and the third treatment added red cabbage powder at a rate of 1% to the mixture. The samples were mixed well and then packed in natural wrappers obtained from sheep intestines from local markets in Basra Governorate. They were cleaned and sterilized well upon purchase using salt, vinegar, lemon and water. They were soaked for 24 hours and then washed well with water. The samples were packed and sealed well. Then they were placed under a weight of 10 kg for 48 hours and surrounded by several layers of paper towels, taking into account turning them every 8 hours to get rid of liquids well. After that, they were suspended for 14 days at a temperature ranging from 25 to 30 °C until the product matured and dried. After that, the samples were divided into three sections. The first section was kept at laboratory temperature for a period of 45 days to study the percentages of total nitrogen, soluble protein nitrogen and non-protein nitrogen, and the values of thiobarbituric acid (TBA), the percentage of free fatty acids (FAA) and the water holding capacity (WHC) during this period for storage periods of 1, 15 and 30. 45 days. The second section was stored in a refrigerator for 60 days at ±5°C, and changes were monitored during storage periods of 1, 15, 30, 45, and 60 days. The third section was stored in a freezer for 75 days at ±18°C, and changes were monitored during storage periods of 1, 15, 30, 45, 60, and 75 days.

Estimation of soluble nitrogen(TSN) in pastrami

Total dissolved nitrogen content of the pastrami product was estimated for different storage periods according to [12] with some modifications. A weight of 1 g of the sample was taken and homogenized with a quantity of 0.5 M potassium chloride solution (KCl) prepared by dissolving 37.3 g of KCl with a quantity of distilled water and then completing the volume to 1 liter with distilled water. The homogeneous mixture was then transferred to a 100 ml volumetric flask and completed to the mark with the same solution. The mixture was left for 30 minutes with shaking. The homogeneous mixture was then centrifuged at 3500 rpm for 15 minutes. The total dissolved nitrogen in the filtrate was then determined using the Kjeldahl method.

Determination of soluble non-protein nitrogen (NPN) in pastrami

Dissolved non-protein nitrogen was estimated using the filtrate obtained in the previous paragraph. 5 ml of the filtrate was taken and

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10 ml of 30% TCA Trichloracetic acid solution was added. The mixture was mixed well and left for 15 minutes. After that, it was centrifuged at 3500 rpm for 15 minutes. The non-protein nitrogen in the filtrate was estimated using the Kjeldahl method [12.[

Determination of soluble protein nitrogen (SPN) in pastrami

Dissolved protein nitrogen was calculated from the difference between total dissolved nitrogen and dissolved non-protein nitrogen [12.[

Dissolved protein nitrogen = Total nitrogen - non-protein nitrogen

Thiobarbituric Acid (TBA (

Method mentioned in [13]was followed by mixing 20 g of the sample with 100 ml of Trichloroacetic acid solution and mixing it well with a magnetic stirrer for 2 minutes. Then, the homogeneous mixture was filtered using Whatman No. 1 filter paper and 5 ml of TBA reagent (0.02) M was added to 5 ml of the filtrate carefully in a test tube. The tube was placed in a water bath for 40 minutes. Then, the absorbance of the resulting color was measured using a spectrophotometer at a wavelength of 538 nm. The TBA values were calculated according to the following equation

TBA= (0.016 +2.782)/10-X (mg⁄1000g(

X = absorbance of the sample at 538 nm

Free Fatty Acids (FFA(

Free fatty acid (FFA) contents of the product were calculated over different storage periods using the method described in [14] with some modifications by[15]. 10 g of samples were mixed for 2 minutes with 60 ml of chloroform in the presence of 10 g of anhydrous sodium sulfate. Filtered through Whatman No. 1 filter paper, 20 ml of the mixture was taken into a 150 ml Erlenmeyer flask. Approximately 4 drops of 0.2% phenolphthalein reagent were added to the chloroform extract, and the extract was titrated with 0.1 N potassium hydroxide solution until a stable pink color appeared. FFA was calculated as a percentage of oleic acid as follows:

FFA %= (ml of 0.1 KOH ×0.282) / (wt. of sample in g) ×100

0.282oleic acid = 1 ml of 0.1 molar KOH

Water Holding Capacity (WHC(

Water holding capacity (WHC) of the product was determined according to [16] using 15 g of sample. 22.5 ml of 0.6 M sodium chloride solution was added, mixed for 1 min with a glass rod, and the mixture was kept for 15 min at ±4 °C, followed by centrifugation at 12,000 × g for 15 min. The upper liquid layer was taken and the volume was recorded. The WHC of the product was determined using the equation:

WHC = TSV1 − TSV2

WHC is the water load (ml), TSV1 is the total volume of solution added (ml), and TSV2 is the amount of solution in the cylinder (ml.(

Statistical Analysis

The results were statistically analyzed according to the completely randomized factorial experiment design (CRD) to analyze all the studied factors using the ready-made statistical program (GenStat Release 7.2 DE PC/Windows). These factors were tested using the least significant difference (LSD) test at a probability level of 0.05.

Results and Discussion

Estimation of total dissolved nitrogen in pastrami

Results in Figure (1,2 and 3) show the effect of storage temperature on the percentage of total nitrogen in pastrami to which red cabbage was added at two concentrations of 0.5 and 1%, the results of statistical analysis showed a significant increase ($P<0.05$) between the percentages of total nitrogen in all treatments during the storage period at

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laboratory temperature (±25°C), refrigeration (±4°C), and freezing (±18°C), the results showed that freezing storage had a clear effect in reducing the percentage of total nitrogen in all treatments, followed by refrigerated storage and then storage at laboratory temperature. The results showed that adding red cabbage to the product had a significant effect ($P<0.05$) on the percentage of total nitrogen in the product. It was noted that it was lower in treatments to which red cabbage was added for both concentrations of 0.5% and 1% compared to the control sample to which no plant powder was added.

Figure (1) shows the percentage of total nitrogen in the treatments of the product stored at laboratory temperature (±25°C) for 45 days. Percentage increased in treatments to which red cabbage was added at a concentration of 0.5% from 5.62% at the beginning of the storage period to 7.23% after 15 days, to reach 7.48% after 30 days, and at the end of the storage period it reached 7.67%. As for the control sample, it increased from 5.61% before storage to 6.83% after 15 days. To reach 6.95% after 30 days, and the end of the storage period to reach 7.12 .

Results in Figure (2) show the percentage of total nitrogen in pastrami treatments stored in a refrigerator (±4°C) for 60 days. Percentage of total dissolved nitrogen in the control treatment increased from 6.31% at the beginning of the storage period to 6.73% after 30 days, to 6.84% after 45 days, and to 6.92% at the end of the storage period. As for the treatments to which red cabbage was added at a concentration of 1%, percentage increased from 5.51% before storage to 5.88% after 30 days of storage, to 6.64% after 45 days of storage, and at the end of 60-day storage period it reached 6.78%. High percentage of dissolved nitrogen in meat products can be attributed to the presence of plant sources that have ability to solubility of protein and retain nitrogen, which contributes to the levels of total dissolved nitrogen observed during storage [17.[

Results in Figure (3) showed percentage of total dissolved nitrogen in product stored in freezer (± -18°C) for a period of 75 days. Percentage increased in treatments to which 1% red cabbage was added from 5.81% before storage to 6.86% at the end of storage period of 75 days, while in control treatment it was 5.87% before storage and reached 7.1% at end of storage period.Results were similar to those of [18] when they studied percentage of total dissolved nitrogen in meat slices immersed in plant extracts and stored in freezer for 60 days, as they found that percentage increased with increase in the storage period and increase in concentration of added plant extracts

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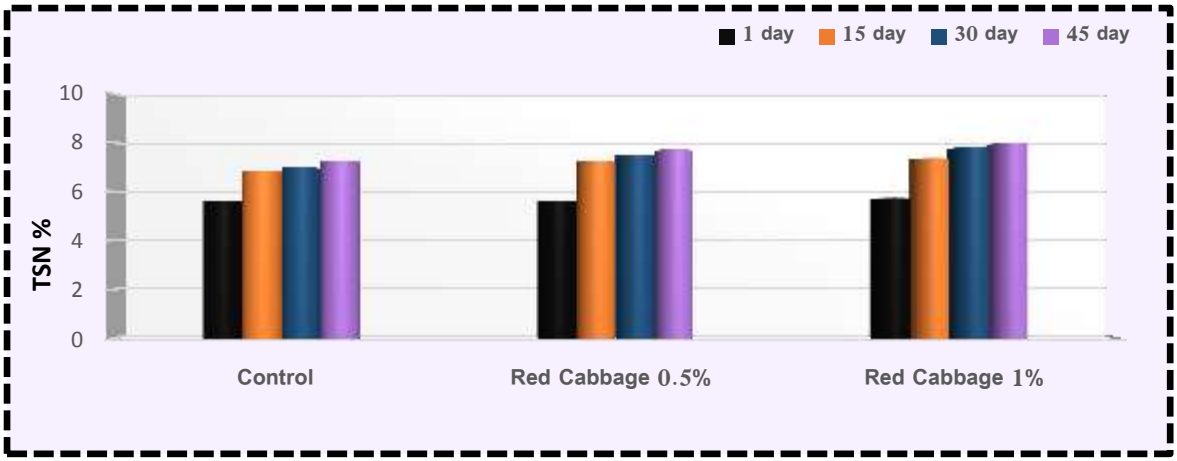

Figure (1): The effect of adding red cabbage powder, temperature, and storage period on the percentage of total dissolved nitrogen in pastr 0.3271ami products stored at laboratory temperature. LSD=

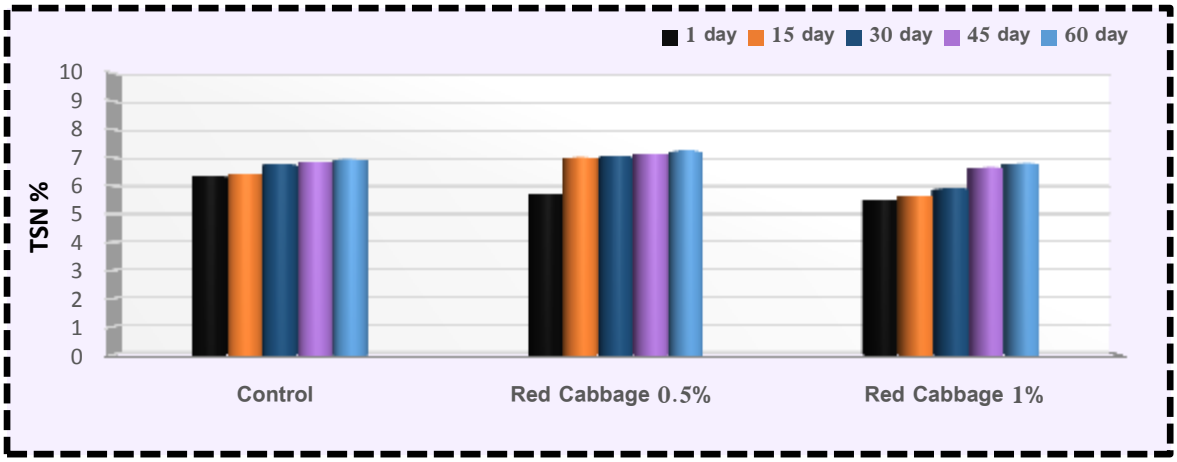

Figure (2): The effect of adding red cabbage powder, temperature, and storage period on the percentage of total dissolved nitrogen in pastrami products stored in the refrigerator. LSD = 0.3826

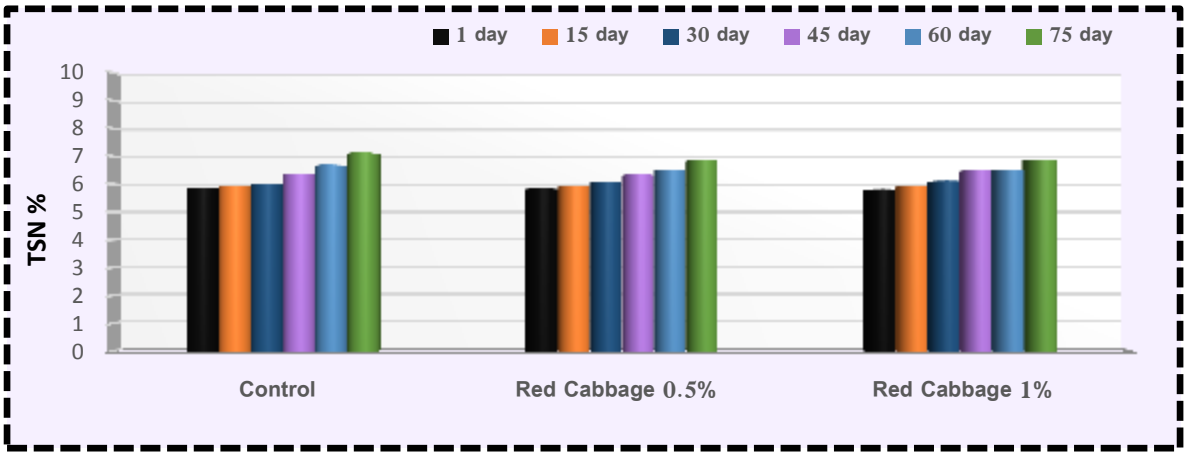

Figure (3): The effect of adding red cabbage powder, temperature, and storage period on the percentage of total dissolved nitrogen in pastrami products stored in the freezer. LSD = 0.3826

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Estimation of soluble non-protein nitrogen in the product (NPN(

Figure (4,5 and 6) shows effect of storage temperature on soluble non-protein nitrogen content in pastrami. Results of statistical analysis showed a significant increase ($P<0.05$) in soluble non-protein nitrogen content in all treatments during the storage period at laboratory temperature (±25°C), refrigeration (±4°C), and freezing (±18°C). The increase was more evident when stored at laboratory temperature, followed by refrigeration and then freezing, Results showed that adding red cabbage to product had a significant effect ($P<0.05$) on the content of soluble non-protein nitrogen (NPN) in product, as it was noted that the lowest content appeared in the treatments to which red cabbage was added at both concentrations of 0.5% and 1% during storage at different temperatures compared to control treatment. The increase in soluble non-protein nitrogen in meat products treated with plant sources may be attributed to dissolution of muscle fiber proteins and increase in cathepsin activity due to sulfur compounds present in plant sources, this process is linked to enzyme activity and role of plant extracts. It has been proven that plant extracts rich in active compounds such as phenols and flavonoids significantly affect enzymatic degradation of proteins and thus affect quality and tenderness of meat products. The activity of these enzymes, which degrade muscle fibrous proteins, can be enhanced by plant-derived compounds, which may subsequently lead to increased levels of non-protein nitrogen in meat products [19,20 .[

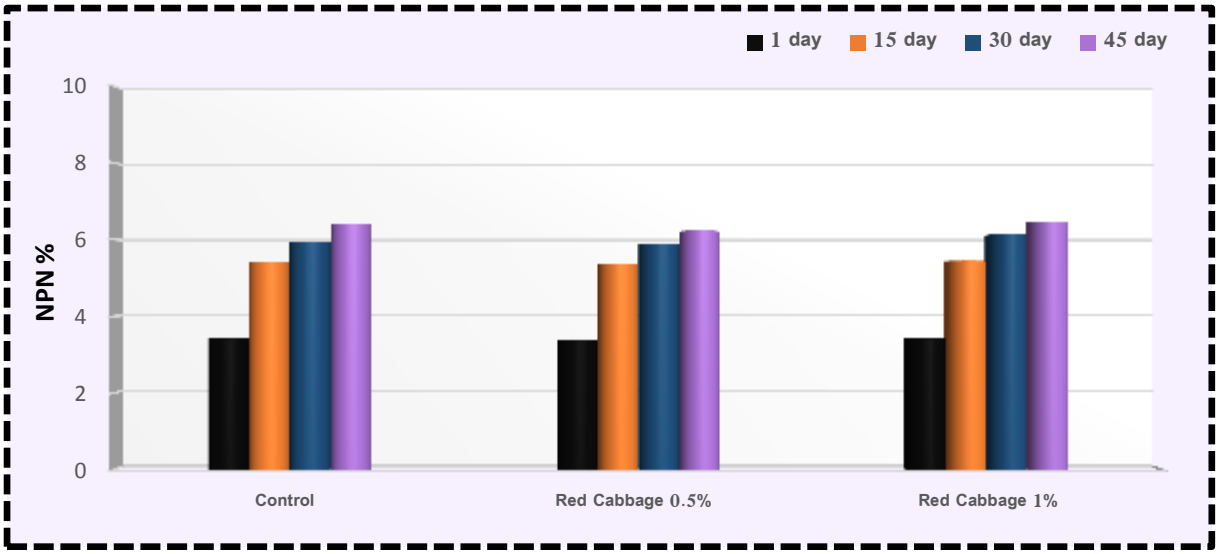

Figure (4): Effect of adding red cabbage powder, temperature, and storage duration on soluble non-protein nitrogen (NPN) in the product stored at laboratory temperature. LSD = 0.3807

Results in Figure (4) show that soluble non-protein nitrogen content increased significantly ($P<0.05$) with advancement of storage period in all treatments during storage period at different temperatures, but this increase varied according to storage temperature, whether at laboratory temperatures, refrigerated, or frozen. Figure (4) shows a significant increase in the soluble non-protein nitrogen content for all treatments

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of the product stored at laboratory temperature (±25°C). The results showed that the treatments to which red cabbage was added at a concentration of 1% increased content from 3.42% at the beginning of storage period to 6.12% after 30 days, reaching 6.46% at end of storage period. As for control treatment, content increased from 3.42% before storage to 5.92% after 30 days of storage, and reached 6.40% at the end of storage period noted [21] concentration of free amino acids increased significantly during storage, indicating continuous protein degradation and production of non-protein nitrogenous compounds.

Results in Figure (5) showed a significant increase in soluble non-protein nitrogen content of pastrami treatments stored in refrigerator (±4 m) for 60 days. If it increased in treatments to which red cabbage was added at concentrations of 0.5% and 1%, it rose from 3.37% and 3.42% before storage to 5.76% and 5.95% at the end of the storage period for both concentrations, respectively. In the control sample, content before storage was 3.42% and reached 5.89% at the end of the storage period. Results were close to what [22] found in their study on soluble non-protein nitrogen content in luncheon meat stored in refrigerator for 15 days, as they noticed an increase in content with advancement of the storage period.

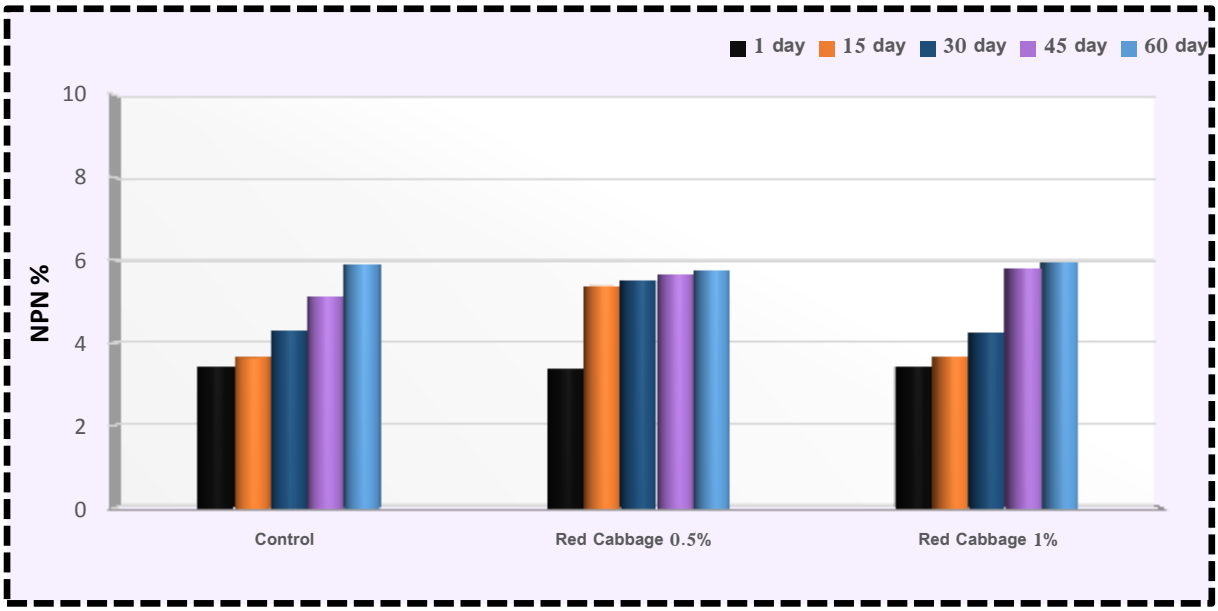

Figure (5): Effect of adding red cabbage powder, temperature, and storage duration on soluble non-protein nitrogen (NPN) in refrigerated product. LSD = 0.0094

Results in Figure (6) show dissolved non-protein nitrogen content in pastrami treatments stored in a freezer (± -18°C) for 75 days. Results showed an increase in treatments, but increase was less clear than in treatments stored at laboratory temperature and refrigerated. The NPN content in the control treatment increased from 3.42% before storage to 4.12% after 30 days, then to 5.33% after 60 days, reaching 5.87% at end of storage period. In treatments to which red cabbage was added at a concentration of 0.5%, the NPN content increased from 3.37% before storage to 4.16% after 30 days, reaching 5.35% after 60 days of storage, and at end of storage period it reached 5.84%, [23] indicated that freezing storage can lead to protein denaturation, which results in

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protein breakdown into smaller peptides and amino acids, contributing to increased NPN content. Studies have shown that freezing affects amino acid composition of meat, although the total protein content remains relatively stable during storage. The researchers stated that the increase in NPN is also associated with breakdown of certain amino acids, such as proline, which was observed to nearly double in content during prolonged frozen storage. These results are similar to those of [21], who studied frozen-stored sirloin meat, stating that NPN content was higher during refrigerated storage than during frozen storage. They stated that reason for increase in content is that ice crystals (produced by freezing of muscle water) cause protein degradation due to a dual mechanism of ionic strength and intracellular water transfer. Hydrolyzed proteins are more sensitive to proteases released from sarcoplasm to outside of cells as a result of membrane perforation by ice crystals. The reason why NPN levels are not affected by these changes during loin freezing may be due to pH, dry matter, and salt content .

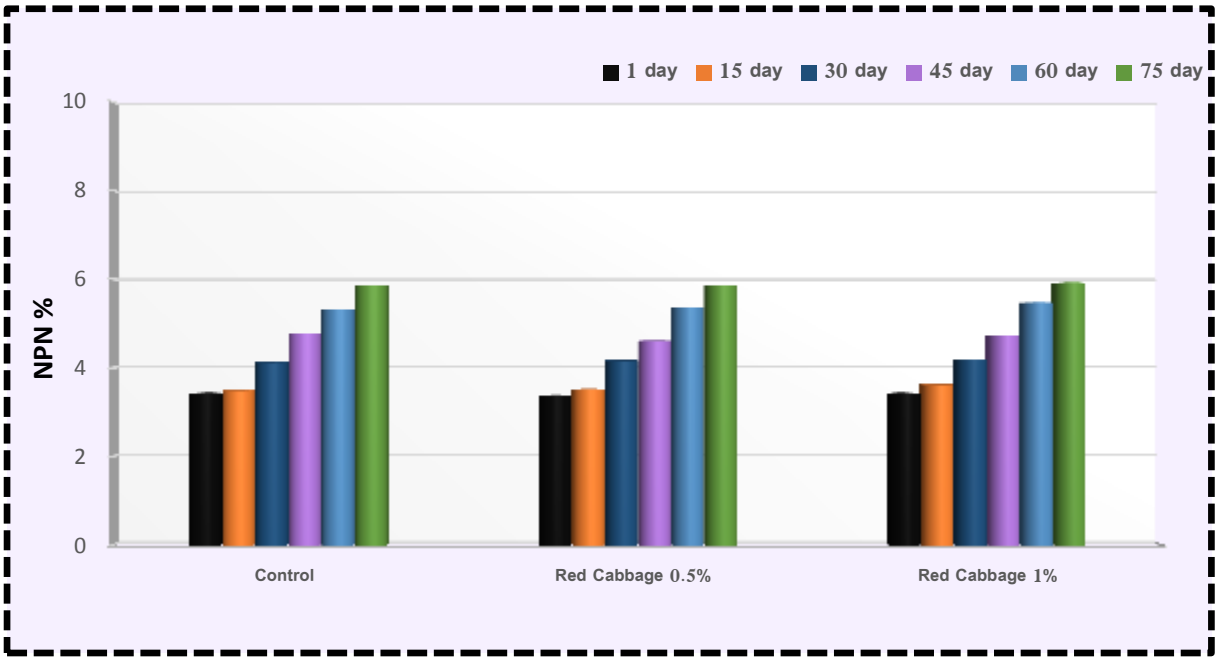

Figure (6): Effect of adding red cabbage powder, temperature, and storage duration on soluble non-protein nitrogen (NPN) in frozen-stored products. LSD =0.00803

Estimation of soluble protein nitrogen (SPN) in pastrami

Figure (7,8 and 9) shows effect of storage temperature on soluble protein nitrogen (SPN) content in pastrami. The results of statistical analysis showed a significant decrease ($P<0.05$) in SPN content in treatments during storage period at laboratory temperature (±25°C), refrigeration (±4°C), and freezing (±18°C), decrease in soluble protein nitrogen content in meat products during storage is

attributed to several factors, including temperature, meat type, and length of storage. The mechanisms behind temperature-induced deterioration involve enzymatic and non-enzymatic reactions. At high temperatures, enzymatic activity increases, leading to decomposition of proteins into peptides and amino acids. This process is further accelerated by formation of free radicals that oxidize proteins and lipids, leading to loss of soluble nitrogen compounds [24]. High temperatures can also promote the growth of microorganisms, which contributes to decomposition of nitrogenous compounds [25, 26] found that refrigeration temperatures slowed growth of microorganisms and reduced enzymatic activity, while [27] indicated that frozen storage was more effective in preserving protein stability and reducing oxidative changes. [28] reported that high storage temperatures accelerated breakdown of proteins and other nitrogen-containing compounds. Studies have shown that beef stored at temperatures above 25°C undergoes faster lipid and protein oxidation compared to lower temperatures.

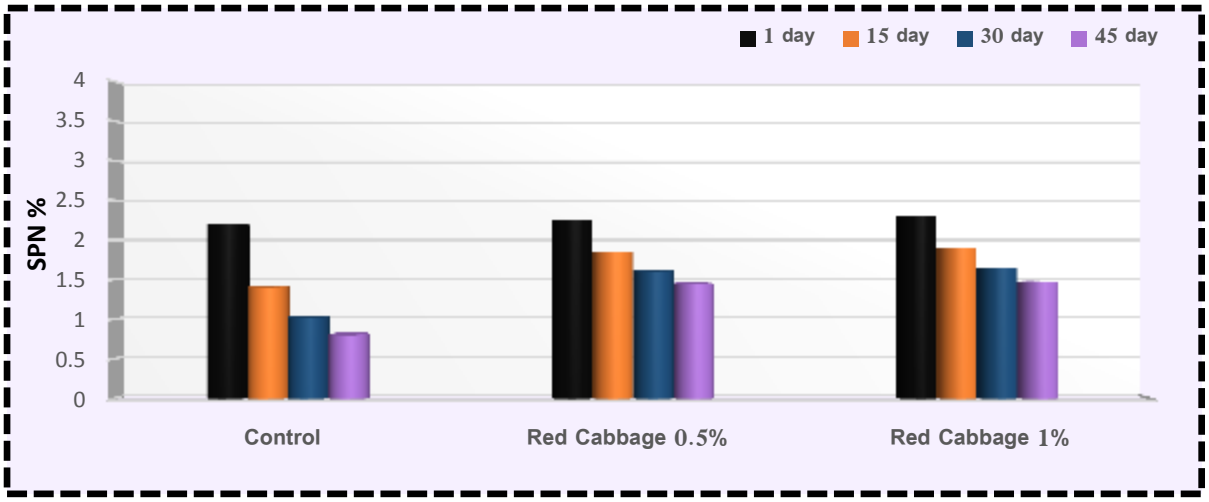

Figure (7): Effect of adding red cabbage powder, temperature, and storage duration on soluble protein nitrogen (SPN) in the product stored at laboratory temperature. LSD A: 0.1651

Results showed that adding red cabbage to product had a significant effect on soluble protein nitrogen (SPN) content in product, as a decrease in content was observed with advancement of storage period and plant concentration, and that 1% concentration was highest compared to 0.5% concentration for all treatments to which plant sources were added. Decrease in SPN when adding plant may be attributed to its containing antioxidants that bind to protein compounds, which reduces solubility of protein nitrogen by forming less soluble clusters. Also, its high fiber content may affect solubility of protein [29, 30]. [31] indicated that red cabbage reduces protein solubility through anthocyanin-protein interactions.

Results in Figure (7,8 and 9) show that soluble protein nitrogen (SPN) content decreased significantly ($P<0.05$) with advancement of storage duration in treatments during storage period at different temperatures, but this decrease varied

according to storage temperature, whether at laboratory temperatures, refrigerated or frozen. Decrease in SPN content may be attributed to a number of biochemical processes that occur in meat products during storage, especially breakdown of protein materials in muscle fibers, as this breakdown leads to an increase in the solubility of muscle fiber proteins and the conversion of soluble protein nitrogen to non-protein nitrogen. Calpain enzyme, which breaks down actin and myosin proteins, is responsible for this process, and extent of breakdown of these proteins and changes are affected, resulting storage conditions such as temperature and length of storage time, which affect rate of enzyme activity [32.[

Results in Figure (7) showed S.P.N content in product treatments stored at laboratory temperature (±25°C) for 45 days. Results showed a significant decrease in content with advancement of storage period, as it decreased in cabbage treatments treated with a concentration of 1% from 2.3% before storage to 1.64% after 30 days of storage to reach 1.47% at end of storage period. In control treatment, S.P.N content was 2.19% and 1.03% for periods before storage and 30 and 45 days, respectively

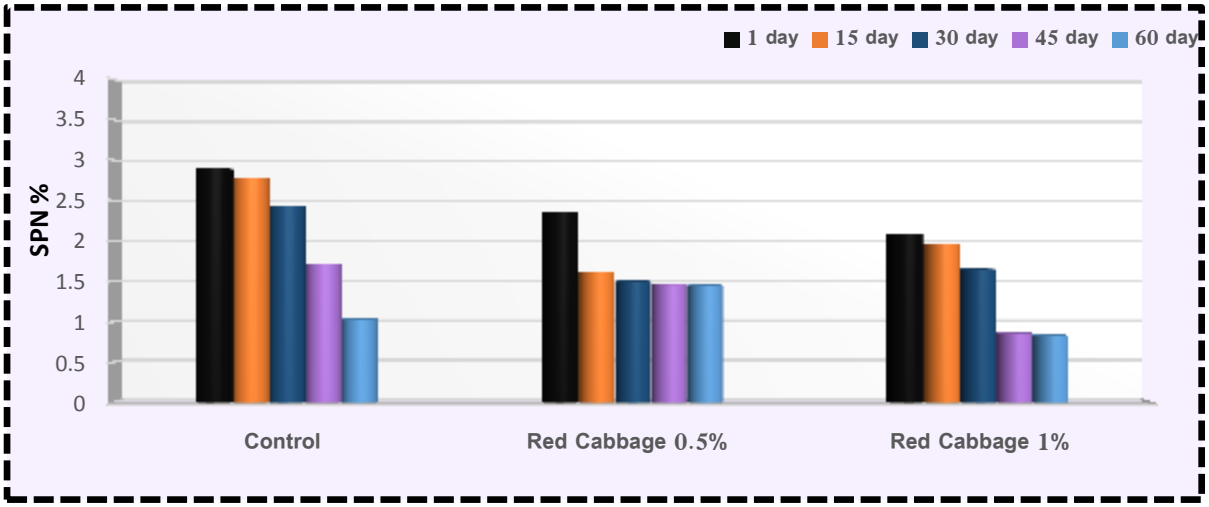

Figure (8): Effect of adding red cabbage powder, temperature, and storage duration on soluble protein nitrogen (SPN) in the refrigerated product. LSD= 0.02520

Figure (8) shows S.P.N. content in refrigerated storage (4 °C) treatments for 60 days. Results showed a significant decrease in treatments, but decrease was clear in treatments treated with red cabbage compared to control sample, as content in control treatment decreased from 2.89% before storage to 2.43% after 30 days of storage and then to 1.03% at end of 60-day storage period. As for red cabbage treatment at a concentration of 0.5%, the S.P.N. content decreased from 2.35% before storage to 1.5% after 30 days and then decreased to 1.45% at end of storage period. It was mentioned that protein stability in cured meat products is greatly affected by storage conditions, such as temperature and storage period. The results agreed with [22], as they found a decrease in S.P.N. content with advancement of refrigerated storage period and with the increase in concentration of plant sources .

When product treatments were stored in freezer, figure (9) showed a significant

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decrease in soluble protein nitrogen (SPN) content of treatments, but decrease was less than in the treatments stored at laboratory temperature and refrigerated, as the SPN content in the red cabbage treatments decreased by 0.5% from 2.45% before storage to 0.99% at end of storage period, and at a concentration of 1% it decreased from 2.39% before storage to 0.85% at end of storage period, and in control sample it decreased from 2.45% before storage to 1.23% at the end of storage period. [33] indicated that decrease in soluble protein nitrogen content during frozen storage results from denaturation of proteins and their change in their nature, as they lose their solubility, which leads to a decrease in amount of soluble protein nitrogen present in meat products.

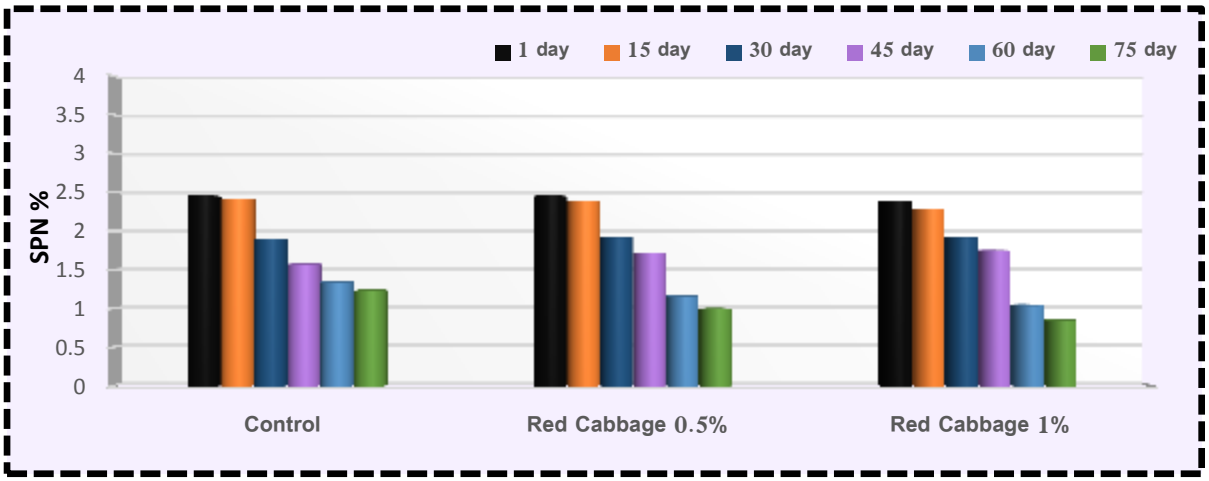

Figure (9): Effect of adding red cabbage powder, temperature, and storage duration on soluble protein nitrogen (SPN) in the frozen product. LSD A: 0.01438

Chemical Indicators

Thiobarbituric Acid (TBA(

Figure (10), (11) and (11) shows effect of storage temperature on thiobarbituric acid (TBA) value in pastrami. Statistical analysis results showed a significant increase ($P<0.05$) in thiobarbituric acid (TBA) value for treatments during storage at laboratory temperature (±25°C), refrigeration (±4°C), and freezing (±18°C). Increase in TBA values in meat products during storage is mainly attributed to lipid oxidation, which is an important factor affecting quality and shelf life of meat products. This process includes decomposition of unsaturated fatty acids, leading to formation of aldehydes, ketones, malondialdehyde (MDA), and other secondary oxidation products that react with TBA to form reactive substances (TBARS). Several factors affect rate and extent of lipid oxidation, and thus affect TBA values during storage. These factors include presence of unsaturated fatty acids in meat, making it susceptible to oxidation, which is exacerbated by inappropriate storage conditions, as well as presence of light. Packaging methods, conditions, exposure to high temperatures during manufacturing, and presence of oxygen during storage contribute to formation of cholesterol oxidation products, which also contribute to raising TBA values [34.[

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Addition of red cabbage to pastrami had a significant (P<0.05) effect in reducing increase in thiobarbituric acid (TBA) values. It was observed that treatments with added red cabbage during storage at different temperatures had lower TBA values compared to control treatment. This was due to addition of red cabbage powder, which contains phenolic compounds with antioxidant activity. This was reflected in TBA values in pastrami treatments stored at laboratory temperature, refrigerated, or frozen. The role of phenolic compounds is achieved through several mechanisms, including their ability to inhibit lipid peroxidation by removing free radicals and trapping and removing metal ions, which are catalysts for lipid oxidation. This inhibition reduces the formation of malondialdehyde (MDA) and other lipid oxidation products, leading to lower TBA values and improved oxidative stability of meat products [35,36.[

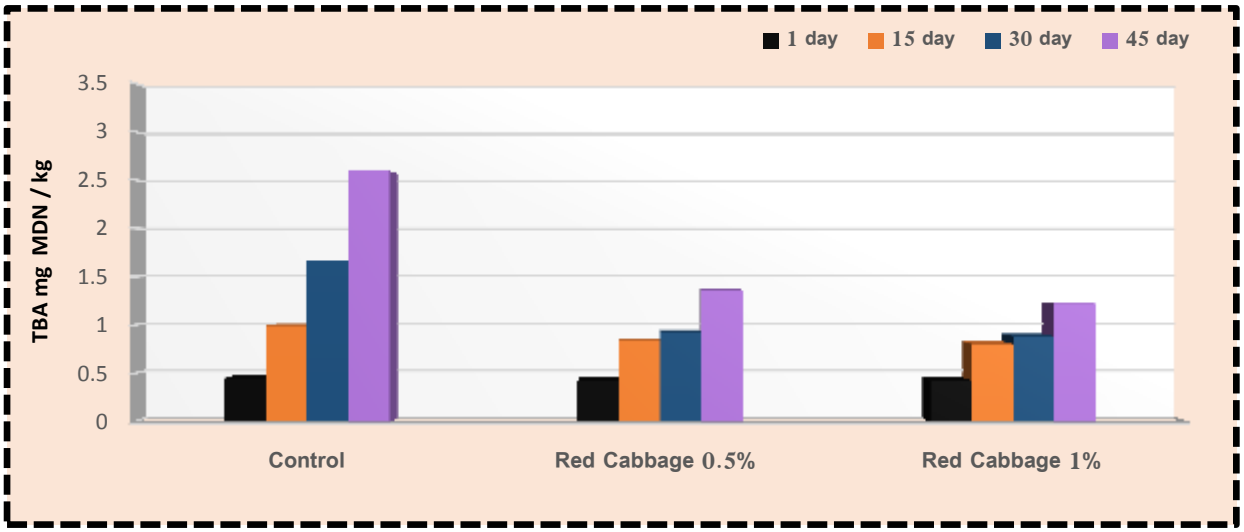

Figure (4): Effect of adding red cabbage powder, temperature, and storage duration on the concentration of thiobarbituric acid (TBA) in the product stored at laboratory temperature. LSD: 0.1599

Results of statistical analysis showed that storage period had a significant effect on TBA values in treatments, as a significant increase in TBA was observed during storage period at different temperatures, but this increase varied according to storage temperature, whether at laboratory temperatures, refrigerated or frozen. Increase in TBA values in treatments with added plant sources was less with advance of the storage period compared to the control treatment, as Figure (10) shows product treatments stored at laboratory temperature (±25°C) for 45 days. In red cabbage treatments at a concentration of 0.5%, TBA value increased from 0.43 mg MDA/kg before storage to 0.841 mg MDA/kg after 15 days of storage, then reached 0.931 mg MDA/kg after 30 days, and at end of the storage period, value reached 1.361 mg MDA/kg. In control treatment, the increase was more evident, as it increased from 0.460 mg MDA/kg before storage to 0.997 mg MDA/kg after 15 days to 1.663 mg MDA/kg after 30 days and then 2.584 mg MDA/kg at the end of storage period, [37] reported that

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storage at laboratory temperature (25°C) facilitates oxidation of fats more rapidly, leading to higher TBA values. Presence of oxygen also facilitates oxidation process, leading to faster spoilage and deterioration of quality of meat products, indicating need for lower storage temperatures to maintain product quality. Figure (11) shows TBA values for refrigerated (±4°C) stored product treatments for 60 days. Results showed a significant increase in acid values, as they increased in red cabbage treatments at a concentration of 1% from 0.43 mg MDA/kg before storage to 0.694 mg MDA/kg after 30 days, and reached 0.867 mg MDA/kg after 45 days of storage, and at the end of the storage period, it rose to 1.387 mg MDA/kg. In control treatment, TBA acid value increased from 0.453 mg MDA/kg before storage to 0.721 mg MDA/kg after 30 days, and reached 0.986 mg MDA/kg after 45 days, then to 2.893 mg MDA/kg at end of storage period. Cooling slows down oxidation process compared to laboratory temperature, as studies have shown that TBA values gradually increase over time with cooling but at a slower rate than at elevated temperatures [37.[

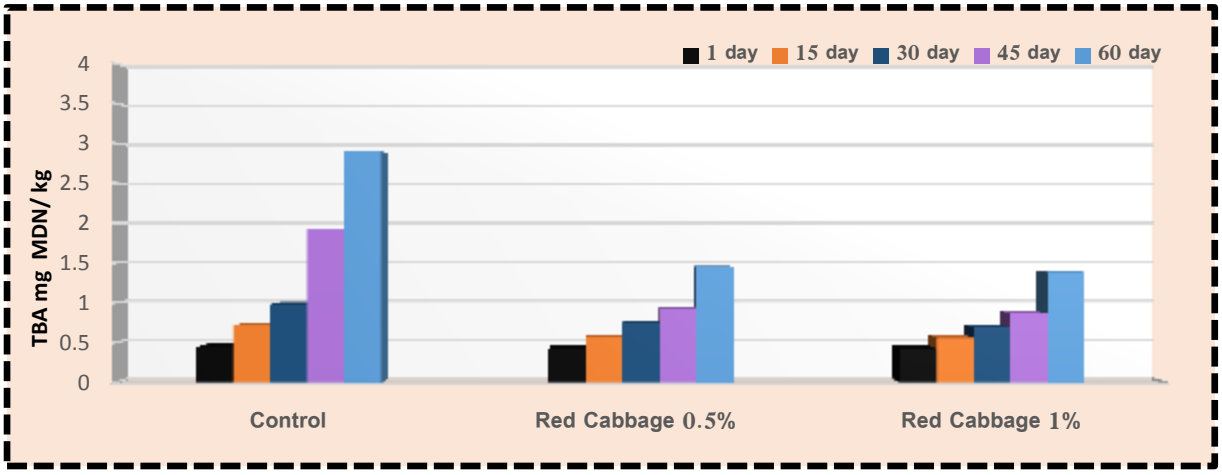

Figure (11): Effect of adding red cabbage powder, temperature, and storage duration on the concentration of thiobarbituric acid (TBA) in the product stored at refrigeration temperature. LSD: 0.003471

In frozen storage (± -18°C) for 75 days, Figure (12) shows a significant increase in TBA values, but this increase was less than in laboratory temperature and refrigerated storage. This is because at -18°C, lipid oxidation is significantly delayed due to low temperature, which reduces movement of reactive molecules and limits availability of oxygen. TBA values remain relatively stable during frozen storage, indicating minimal lipid oxidation. This makes -18°C most effective storage temperature for maintaining quality of meat products [38], TBA values in red cabbage treatments at a concentration of 1% increased from 0.435 mg MDA/kg before storage to 0.742 mg MDA/kg after 30 days of storage and reached 0.997 mg MDA/kg after 60 days. At end of storage period, it increased to 1.217 mg MDA/kg. In control treatment, it increased from 0.455 mg MDA/kg before to 0.791 mg MDA/kg after 30 days and reached 1.573 mg MDA/kg after 60 days, and reached 2.463 mg MDA/kg at end of storage period.

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Results were similar to those of [39] when they studied use of blackberry and blackcurrant extracts to produce sausages and store them at 4°C for 25 days. They stated that adding plant extracts significantly slowed the oxidation of lipids in final product and effectively inhibited formation of peroxides, aldehydes and other secondary oxidation products. It also led to a decrease in the increase in TBA values during storage period in samples to which extracts were added compared to the control sample. Effect of adding a 0.5% concentration was higher than adding 0.2% of plant sources.

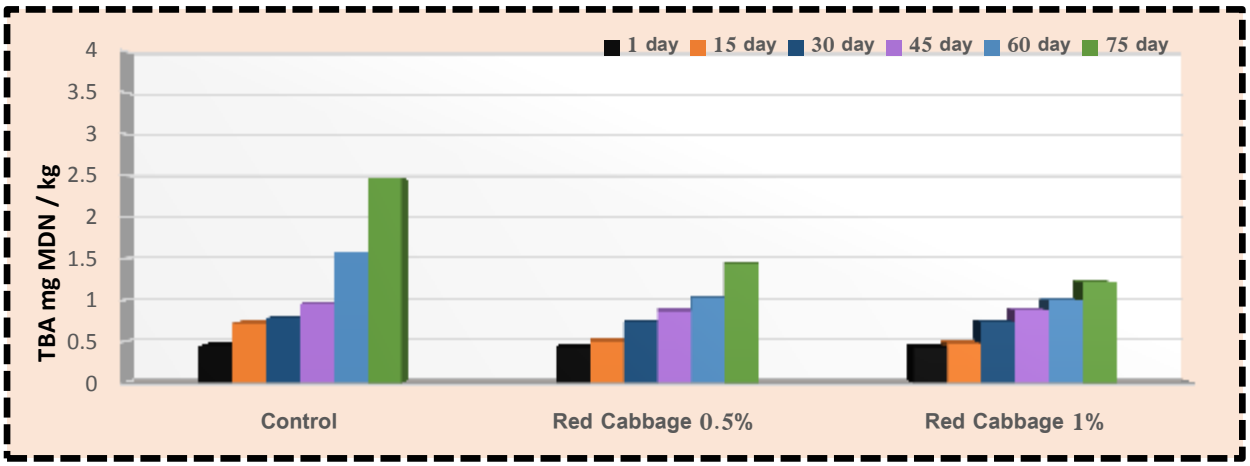

Figure (12): Effect of adding red cabbage powder, temperature, and storage duration on the concentration of thiobarbituric acid (TBA) in the product stored at freezing temperature. LSD: 0.0957

Free Fatty Acids (FFA (

Results in Figure (13),(14) and (15) show that storage temperature has a significant effect ($P<0.05$) on percentage of free fatty acids (FAA) in pastrami to which red cabbage was added at two concentrations of 0.5 and 1%. An increase in FAA was observed in all treatments during storage period at laboratory temperature (±25°C), refrigeration (±4°C), and freezing (±18°C). Results showed that freezing storage had a clear effect in reducing increase in percentage of free fatty acids, followed by refrigerated storage and then storage at laboratory temperature, reason for difference is that storage temperature may lead to increases in percentage of FFA, as well as peroxides and carbonyl compounds, which harms stability of meat, as storage at high temperatures accelerates this process. Studies have shown that storage at temperatures ranging from 25 to 37°C has led to accumulation of primary and secondary oxidation products and free fatty acids as a result of an increase in rate of chemical reactions, as well as the activity of lipase enzyme, which works to analyze or destroy triglycerides, as free fatty acids are considered products of hydrolysis of fats by lipase enzyme and action of lipolytic bacteria, unlike low temperatures [40,41 .[

Results showed that adding plant sources to product had a significant effect ($P<0.05$) on percentage of free fatty acids in product, as a

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decrease was observed with advancement of storage period and type and concentration of plant sources, and that 1% concentration was lowest percentage compared to 0.5% concentration for treatments to which red cabbage was added. Control treatment had highest percentage of FFA compared to treatments to which red cabbage was added, which had a clear effect in reducing percentage during advancement of storage periods. Storage periods had a significant effect on percentage of free fatty acids FAA in pastrami treatments, and increase in FAA varied according to storage temperature, whether at laboratory temperatures, in refrigeration, or in freezing. Increase in FAA in treatments to which red cabbage was added with advancement of storage period was less compared to control treatment, results in Figure (13) show percentage of free fatty acids in product treatments stored at laboratory temperature (±25°C). Control treatment increased percentage of FFA from 0.22% before storage to 0.91% after 15 days and reached 1.72% after 30 days. At end of storage period, percentage was 1.96%. As for the red cabbage treatments at a concentration of 1%, it increased from 0.16% before storage to 0.32% after 15 days of storage, then to 0.77% after 30 days, reaching 1.08% at end of storage period. [42] indicated that storage at a temperature of 25°C plays an important role in increasing percentage of free fatty acids in meat products. He mentioned in his study on manufacture of pastrami from buffalo meat that percentage of FFA increased from 1.21% to 1.47% after suspending pastrami at laboratory temperature for 6 days, which indicates that temperature worked to decompose fats and led to an increase concentration of free fatty acids in meat.

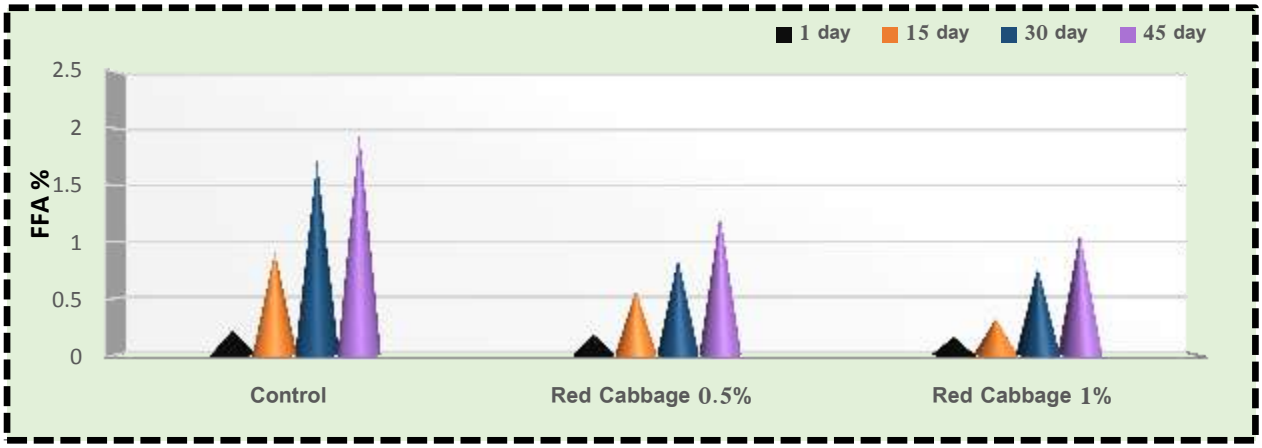

Figure (13): Effect of adding red cabbage powder, temperature, and storage duration on the concentration of free fatty acids (FFA) in the product stored at room temperature. LSD: 0.03193

Results of Figure (14) show percentage of free fatty acids in refrigerated product treatments (±4°C) for 60 days. Results showed an increase in free fatty acid values in cabbage treatments at a concentration of 0.5%, as it rose from 0.18% before storage to 0.58% after 30 days, to reach 0.91% after 45 days, and at end of storage period it reached 1.28%. In control treatment, increase was more evident,

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as it was 0.22% before storage, and reached 0.64% after 30 days, then to 1.06% after 45 days, and at end of storage period to 1.80%. Refrigerated storage at 4°C is generally effective in slowing down It affects process of fat oxidation and hydrolysis, but it does not completely stop these processes. Increase in FFA is affected by factors such as type of meat, presence of additives, duration of storage, and percentage of fat in product.

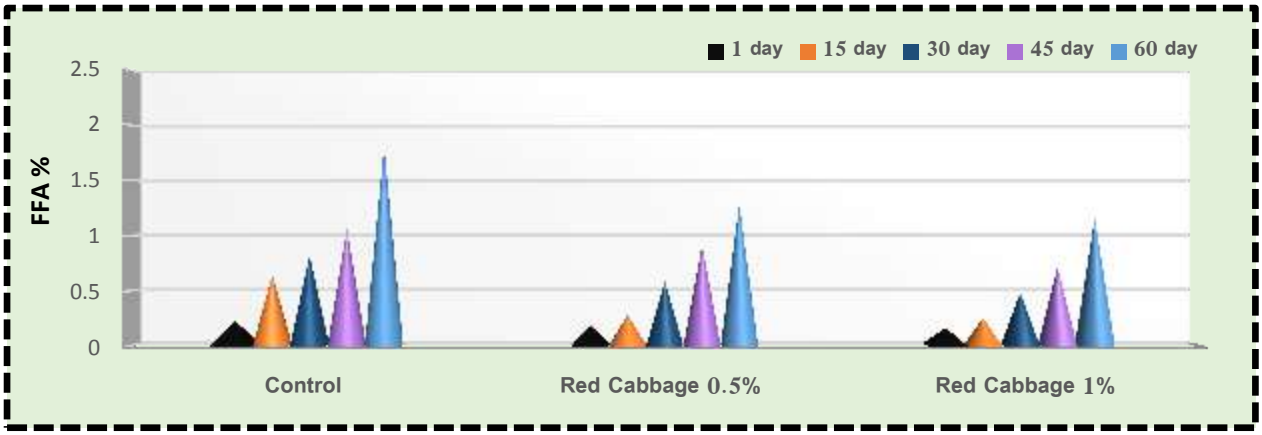

Figure (14): Effect of adding red cabbage powder, temperature, and storage duration on the concentration of free fatty acids (FFA) in the product stored at refrigeration temperature. LSD: : 0.01174

Figure (15) shows percentage of free fatty acids in frozen product treatments (±-18°C) for 75 days. Results showed that freezing storage played a role in reducing percentage of free fatty acids, and concentration and type of plant additives played an important role in limiting increase. FAA percentage in red cabbage treatments at concentrations of 0.5 and 1% increased from 0.18 and 0.16% before storage to 1.06 and 0.89% after 75 days of storage for both concentrations, respectively. In control treatment, increase was more evident, as it increased from 0.22% before storage and reached 1.12% at the end of 75-day storage period .

Freezing meat products at -18°C significantly reduces the rate of lipid oxidation, a key factor in increase of free fatty acids. This process slows down enzymatic activities that lead to breakdown of fat, thus preserving meat quality over time. Initial rapid oxidation phase is a slower stage, keeping overall fatty acid composition relatively stable, which helps control increase in free fatty acids. Combining frozen storage with addition of plant sources can also synergistically reduce increase in free fatty acids. Frozen storage slows oxidation process, while plant sources provide antioxidants that further prevent lipid oxidation [43,44] also mentioned in their study on dried sausage production that the percentage of free fatty acids increased significantly during storage periods at a temperature of 10°C for 7 months.

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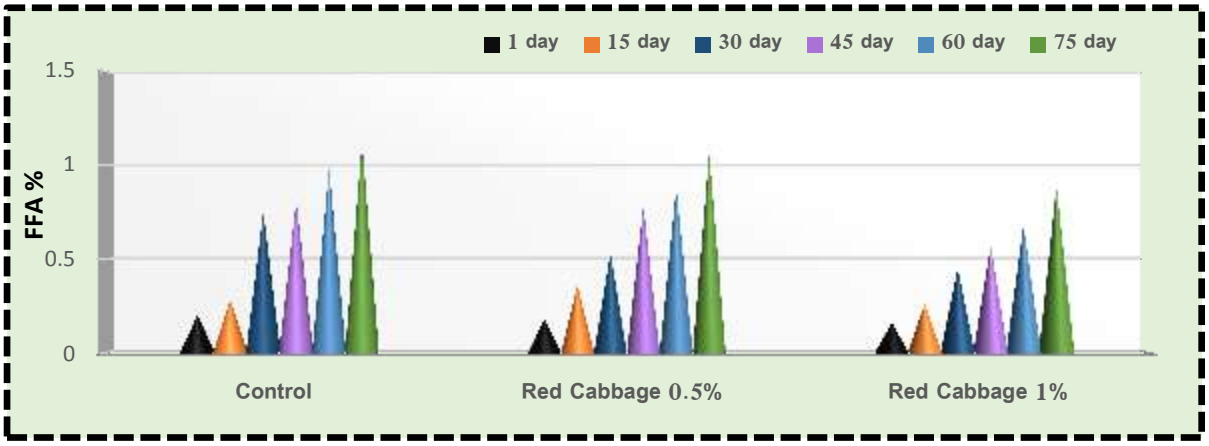

Figure (15): Effect of adding red cabbage powder, temperature, and storage duration on the concentration of free fatty acids (FFA) in the product stored at freezing temperature. LSD: 0.1171

Physical Properties

Water Holding Capacity (WHC (

Storage temperature has an effect on water holding capacity (WHC) of product treatments. Figure (16), (17) and (18) shows a significant decrease ($P<0.05$) in water holding capacity of treatments during storage period at laboratory temperature (±25°C), refrigeration (±4°C), and freezing (±18°C). Results showed that freezing storage had a clear effect in reducing the decrease in treatment's ability to retain water, followed by refrigerated storage and then storage at laboratory temperature. Decrease in water holding capacity during storage period at different temperatures is attributed to changes in nature of proteins, and these changes are largely related to muscle proteins and level of pH value presence of connective tissue proteins such as collagen also affects water-holding capacity of products. These factors are affected by storage temperatures, as low temperatures maintain stability of these proteins. Also, pH and ionic strength values directly affect WHC values [45,46.[

Addition of red cabbage to product had a significant effect ($P<0.05$) on water holding capacity values in product, as a decrease was observed with the advancement of the storage period for the treatments to which plant powder was added at concentrations of 0.5 and 1%, but decrease was less than in control treatment, and WHC values were higher in red cabbage treatments. The reason for high water holding capacity of product treatments treated with plant powder may be attributed to their content of phenolic compounds, which, as antioxidants, contribute to the protection and stability of fats by inhibiting activity of free radicals resulting from oxidation and reducing disruption of cell membranes surrounding muscle fibers and preserving them, which increases the ability of meat to retain water during storage [47], and that these extracts contributed to providing stability to cellular structure of meat and protecting components of the sarcoplasm. And the fluids in the membranes during storage of product from oxidative damage [36.[

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Storage periods had a significant effect on water holding capacity of pastrami treatments, and decrease in WHC varied according to storage temperature, whether at laboratory temperatures, refrigerated, or frozen. Decrease in treatments with added red cabbage was less with advancement of storage period compared to control treatment. The results in Figure (16) show water holding capacity of pastrami treatments stored at laboratory temperature (25 ± 2) C for 45 days, results showed a significant decrease in product parameters as storage period progressed. Decrease was more evident in control sample, as it decreased from 17.5 ml before storage to 14.3 ml after 15 days, then to 13.7 ml after 30 days, and reached 12.9 ml at the end of storage period. As for red cabbage parameters 0.5%, they decreased from 18.4 ml before storage to 16.4 ml after 15 days, to reach 14.06 ml after 30 days, and at end of storage period, they reached 13.9 ml. Decrease in WHC in meat products stored at 25°C may be attributed to changes in structure of proteins due to high temperatures, which in turn affects their ability to retain water. High temperatures can accelerate lipid oxidation and protein degradation, leading to decreased saturability water holding capacity [28.[

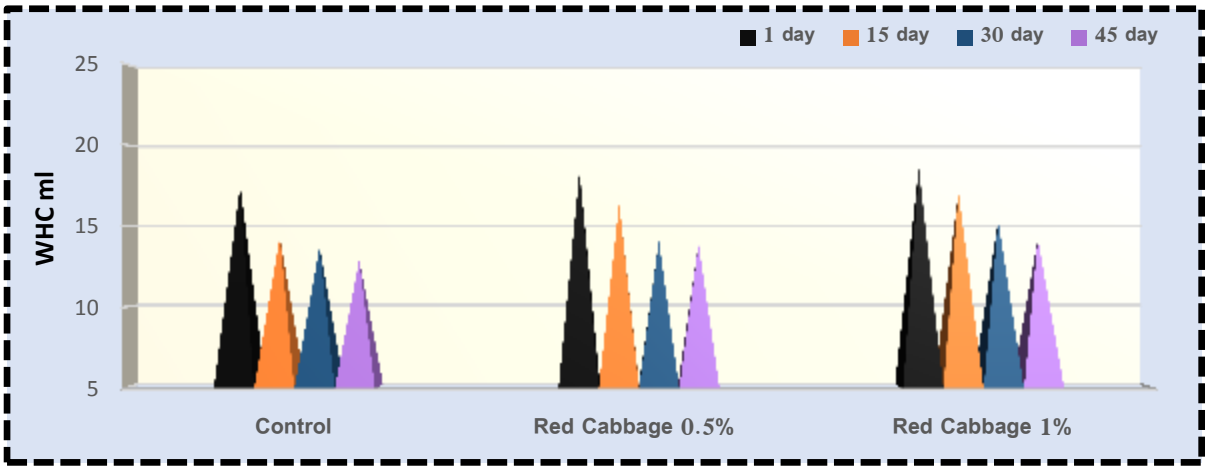

Figure (16): Effect of adding red cabbage powder, temperature, and storage duration on the water holding capacity (WHC) of the product stored at room temperature. LSD = 0.2457

Results in Figure (17) show water holding capacity of refrigerated (4 ± 1) C product treatments. WHC values in 1% red cabbage treatments decreased from 18.6 ml before storage to 16 ml after 30 days of storage, reaching 15.2 ml at end of storage period. In control treatment, water holding capacity was 17.9 ml before storage and decreased to 14.3 ml after 30 days, reaching 12.9 ml at end of storage period. [46] stated that water activity in meat products decreases with decreasing temperature, which affects water holding capacity. Furthermore, decreasing temperature to 4°C during storage affects interactions within protein structures, leading to their breakdown and changing their solubility, which leads to a decrease in water holding capacity of the products.

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Figure (18) shows water holding capacity of pastrami treatments stored in a freezer at (-18 ± 1) °C for 75 days. Results showed a decrease in the water holding capacity of treatments, with highest decrease in control treatment, as it decreased from 18.2 ml before storage to 13.5 ml at end of storage period. In red cabbage treatments at concentrations of 0.5 and 1%, it decreased from 18.4 and 18.6 ml before storage to 14.8 and 15.5 ml for both concentrations, respectively, at end of storage period. Freezing meat products at -18 °C for a long period can lead to protein oxidation and thus a decrease in water holding capacity. Presence of protein carbonyls is an indication of oxidation, which leads to a decrease in WHC of approximately 10-30% over the storage period [50]. Freezing also causes ice crystal formation, which affects muscle fibers and reduces their water-holding capacity. Studies have shown that slow freezing rates exacerbate this effect, leading to further damage to protein structures and a reduction in their water-holding capacity [51]. Results converged with those of [52] when they studied the addition of papaya extract to production of Frankfurt sausages. They indicated that the addition of the plant affected product's qualitative characteristics, including water-holding capacity, which increased with addition of plant. They explained this by plant's content of active compounds that increase water-holding capacity of manufactured product.

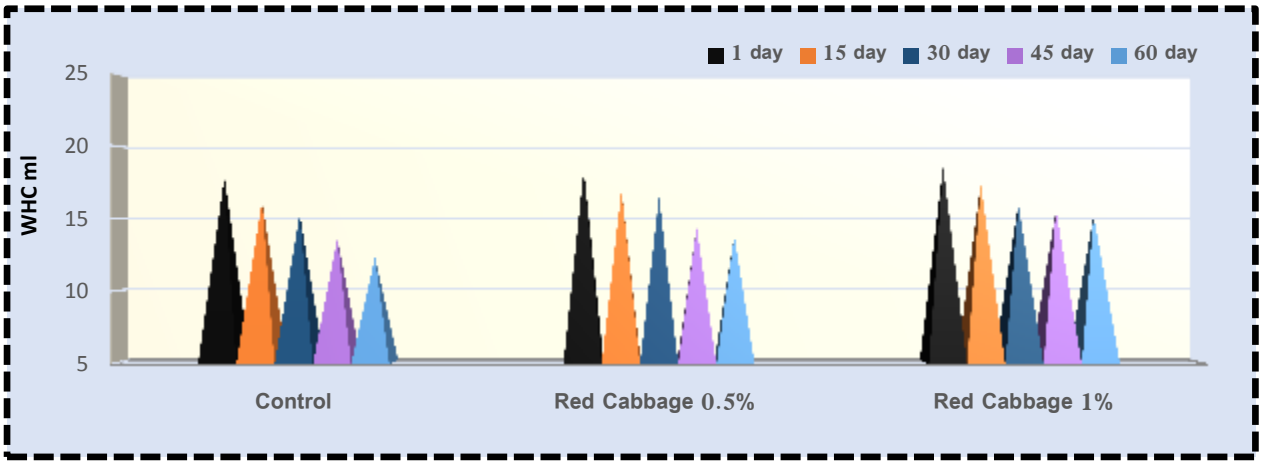

Figure (17): Effect of adding red cabbage powder, temperature, and storage duration on the water holding capacity (WHC) of the product stored at refrigeration temperature. LSD = 0.3205

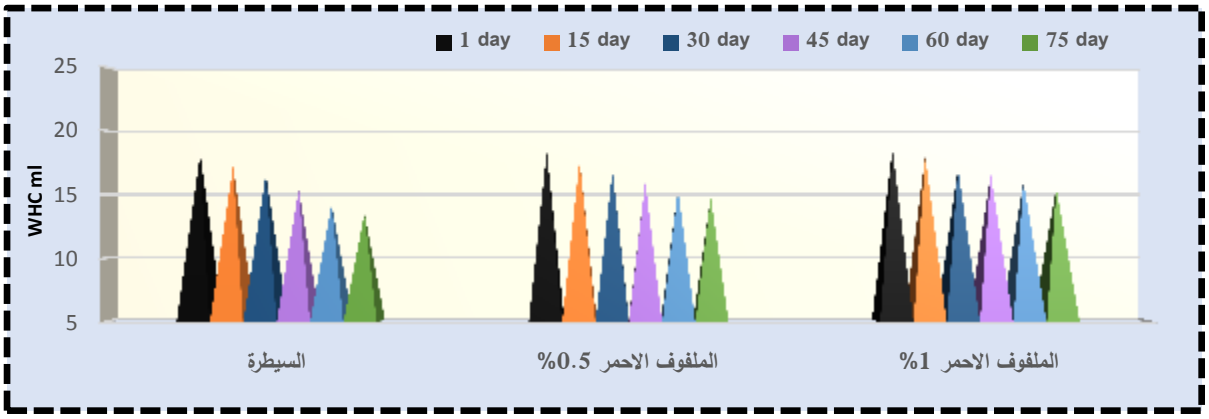

Figure (18): Effect of adding red cabbage powder, temperature, and storage duration on the water holding capacity (WHC) of the product stored at freezing temperature. LSD = 0.117

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Conclusion

Due to high nutritional value and active compounds contained in red cabbage powder, this led to an improvement in chemical indicators and physical properties of pastrami product manufactured in this study. This effect continued throughout different storage periods compared to control treatment, as values of peroxide, thiobarbituric acid, and free fatty acids decreased, and water-holding capacity increased. Therefore, it can be used as a natural preservative instead of artificial ones that affect health of the consumer .

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References

[1]Molina, J. R. G., Frías-Celayeta, J. M., Bolton, D. J., & Botinestean, C. 2024. A comprehensive review of cured meat products in the Irish market: Opportunities for reformulation and processing. Foods, 13(5), 746 .https://doi.org/10.3390/foods13050746.

[2]Smetana, S., Ristic, D., Pleissner, D., Tuomisto, H. L., Parniakov, O., & Heinz, V. 2023. Meat substitutes: Resource demands and environmental footprints. Resources, Conservation and Recycling, 190, 106831 . https://doi.org/10.1016/j.resconrec.2022.106831.

[3]Gokoglu, N. 2019. Novel natural food preservatives and applications in seafood preservation: A review. Journal of the Science of Food and Agriculture, 99(5), 2068-2077 . https://doi.org/10.1002/jsfa.9416 .

[4]Özer, M. Ö. 2021. Morphological variability of red head cabbage (Brassica oleracea L. var. capitata L. subvar. rubra) populations. Genetic Resources and Crop Evolution, 68(3), 1033-1043 . https://doi.org/10.1007/s10722-020-01046-8 .

[5]Drozdowska, M., Leszczyńska, T., Koronowicz, A., Piasna-Słupecka, E., Domagała, D., & Kusznierewicz, B. 2020. Young shoots of red cabbage are a better source of selected nutrients and glucosinolates in comparison to the vegetable at full maturity. European Food Research and Technology, 246(12), 2505-2515 . https://doi.org/10.1007/s00217-020-03593-x.

[6]Park, S., Arasu, M. V., Lee, M. K., Chun, J. H., Seo, J. M., Lee, S. W., Al-Dhabi, N.A. & Kim, S. J. 2014. Quantification of glucosinolates, anthocyanins, free amino acids, and vitamin C in inbred lines of cabbage (Brassica oleracea L.). Food chemistry, 145, 77-85 .https://doi.org/10.1007/s00217-008-1003-y.

[7]Güngören, A. 2025. Historical, Technological, Biochemical, and Microbiological Aspects of Pastirma, an Ethnic Meat Product from Asia to Anatolia: A Narrative Literature Review. Sustainability, 17(7), 2801. https://doi.org/10.3390/su17072801.

[8]Gençcelep, H., İhtiyar, B., & Yüzer, M. O. 2022. Determination of quality properties of Kastamonu pastırma: A dry-cured meat product. Harran Tarım ve Gıda Bilimleri Dergisi, 26(4), 491-500 . https://doi.org/10.29050/harranziraat.1082192

[9]Santé-Lhoutellier, V. 2023. Levers to reconcile cured meat products with health concerns and culinary heritage. Italian Journal of Animal Science, 22(1), 898-910 . https://doi.org/10.1080/1828051X.2023.2237990.

[10]Gürün, G., Değerli, İ. F., & Nazır, S. 2021. The Effect of Reducing Salt in Pastrami Production on Quality and Investigation of Alternative Applications to Salt. International Journal of Food Engineering Research, 7(1), 33-54 . https://doi.org/10.17932/IAU.IJFER.2015.003/ijfer_v07i1003.

[11]Zainy, Z. I., & Alrubeii, A. M. 2021. Determine the manufacturing characteristics of iraqi pasterma. In IOP conference series: Earth and environmental science (Vol. 910, No. 1, p. 012056). IOP Publishing . http://dx.doi.org/10.1088/1755-1315/910/1/012056.

[12]Sinaga, S. M., Lubis, I. Y., & Silalahi, J. 2016. Analysis of Total Protein and Non-Proteinnitrogen in Pakkat (Calamus caesius Blume.) as a Traditional Food of Mandailing Natal by using Kjeldahl Method. Int. J. Pharm. Tech Res, 9(12), 543-549.

[13]Saad, M.S., Islam, Z., Islam, I.S. & Ibrahim I.A. 2021. Chemical evaluation of imported fish. Benha Veterinary Medical Journal, 40(2), 53-55 . https://dx.doi.org/10.21608/bvmj.2021.68335.1379 .

[14]Joseph, S., Chatli, M. K., Biswas, A. K., & Sahoo, J. 2014. Oxidative stability of pork emulsion containing tomato products and pink guava pulp during refrigerated aerobic storage. Journal of food science and technology, 51, 3208-3216 .https://doi.org/10.1007/s13197-012-0820-y.

[15]Libera, J., Latoch, A., & Wójciak, K. M. 2020. Utilization of Grape Seed Extract as a Natural Antioxidant in the Technology of Meat Products Inoculated with a Probiotic Strain of LAB. Foods, 9(1), 103. https://doi.org/10.3390/foods9010103.

[16]Al- Baidhani, A. M. S., Hashim, A. Z., Al- Qutaifi, H. K., Al- Hilphy, A. R., Waseem, M., Madilo, F. K., & Manzoor, M. F. 2024. Ultrasound- assisted extraction of bioactive compounds from Moringa oleifera leaves for beef patties preservation: Antioxidant and inhibitory activities, half-life, and sensory attributes. Food Science & Nutrition, 12(10), 7737-7750 . https://doi.org/10.1002/fsn3.4395.

[17]Munekata, P. E., Pateiro, M., Domínguez, R., Pollonio, M. A., Sepúlveda, N., Andres, S. C., Reyes, J., Santos, E.M. & Lorenzo, J. M. 2021. Beta vulgaris as a natural nitrate source for meat products: A review. Foods, 10(9), 2094 .https://doi.org/10.3390/foods10092094.

[18]Salah, H. M. & Al-Mossawi, A. H. J. 2019. Tenderization of Cow Meat by Using Plant Extracts and Study it's Quality Properties During Frozen Storage. Thi-Qar Univ. J. for Agric. Res. 8 (2.(

[19]Tantamacharik, T., Carne, A., Agyei, D., Birch, J., Bekhit, A.ED.A. 2018. Use of Plant Proteolytic Enzymes for Meat Processing. In: Guevara, M., Daleo, G. (eds) Biotechnological Applications of Plant Proteolytic Enzymes. Springer, Cham. https://doi.org/10.1007/978-3-319-97132-2_3.

[20]Huff-Lonergan, E. 2014. Encyclopedia of Meat Science TENDERIZING MECHANISMS Enzymatic. Encyclopedia of Meat Sciences (Second Edition), (3): pp 1363–1369. https://doi.org/10.1016/B978-0-12-384731-7.00248-8 .

[21]Abellán, A., Salazar, E., Vázquez, J., Cayuela, J. M., & Tejada, L. 2018. Changes in proteolysis during the dry-cured processing of refrigerated and frozen loin. LWT, 96, 507-512 .https://doi.org/10.1016/j.lwt.2018.06.002 .

[22]Al-Zaidan, S. A. A. H., & Al-Hussainy, K. S. J. 2023. Studying the antioxidant activity of oregano and maui rose powders and their effect on lipid oxidation indicatores of cold-

preserved beef luncheon. British Journal of Global Ecology and Sustainable Development, 13, 87-100.

[23]Prylipko, T. M., Fedoriv, V. M., & Kostash, V. B. 2022. Amino acid Composition of Meat Raw Materials During Long-Term Cold Storage. Taurida Scientific Herald. Series: Technical Sciences, (4), 82-87. https://doi.org/10.32851/tnv-tech.2022.4.10.

[24]Al-Shibli, M. A., Al-Ali, R. M., Hashim, A. Z., Altemimi, A. B., Elsayed, N., & Abedelmaksoud, T. G. 2023. Evaluation of meat and meat product oxidation and off-flavor formation: Managing oxidative changes. Теория и практика переработки мяса, 8(4), 302-315 . http://dx.doi.org/10.21323/2414-438X-2023-8-4-302-315.

[25]Orkusz, A., Rampanti, G., Michalczuk, M., Orkusz, M., & Foligni, R. 2024. Impact of Refrigerated Storage on Microbial Growth, Color Stability, and pH of Turkey Thigh Muscles. Microorganisms, 12(6), 1114. https://doi.org/10.3390/microorganisms12061114

[26]Cui, H., Karim, N., Jiang, F., Hu, H., & Chen, W. (2023). Role of temperature fluctuations and shocks during refrigeration on pork and salmon quality. Food Quality and Safety, 7, fyad011 . https://doi.org/10.1093/fqsafe/fyad011.

[27]Qian, S., Li, X., Wang, H., Mehmood, W., Zhang, C., & Blecker, C. 2021. Effects of frozen storage temperature and duration on changes in physicochemical properties of beef myofibrillar protein. Journal of Food Quality, 2021(1), 8836749 . https://doi.org/10.1155/2021/8836749.

[28]Wazir, H., Chay, S. Y., Zarei, M., Hussin, F. S., Mustapha, N. A., Wan Ibadullah, W. Z., & Saari, N. 2019. Effects of Storage Time and Temperature on Lipid Oxidation and Protein Co-Oxidation of Low-Moisture Shredded Meat Products. Antioxidants, 8(10), 486. https://doi.org/10.3390/antiox8100486.

[29]Haque, A., Ahmad, S., Azad, Z. R. A. A., Adnan, M., & Ashraf, S. A. 2023. Incorporating dietary fiber from fruit and vegetable waste in meat products: a systematic approach for sustainable meat processing and improving the functional, nutritional and health attributes. PeerJ, 11, e14977 . http://dx.doi.org/10.7717/peerj.14977.

[30]Domínguez, R., Munekata, P. E., Pateiro, M., Maggiolino, A., Bohrer, B., & Lorenzo, J. M. 2020. Red beetroot. A potential source of natural additives for the meat industry. Applied Sciences, 10(23), 8340 . https://doi.org/10.3390/app10238340.

[31]Stoica, F., Râpeanu, G., Rațu, R. N., Stănciuc, N., Croitoru, C., Țopa, D., & Jităreanu, G. 2025. Red Beetroot and Its By-Products: A Comprehensive Review of Phytochemicals, Extraction Methods, Health Benefits, and Applications. Agriculture, 15(3), 270. https://doi.org/10.3390/agriculture15030270.

[32]Beltrán, J. A., Roncalés, P., & Bellés, M. 2019. Biochemical reactions during fresh meat storage .Encyclopedia of Food Chemistry, p: 224-232,ISBN 9780128140451, https://doi.org/10.1016/B978-0-08-100596-5.21634-X.

[33]Wang, R., Liu, Y., He, Y., Feng, C., & Xia, X. 2025. Changes in basic composition and in vitro digestive characteristics of pork induced by frozen storage. Frontiers in Nutrition, 11, 1511698 . http://dx.doi.org/10.3389/fnut.2024.1511698.

[34]Demirkaya, A. 2013. Tereyağında tiyobarbiturik asit (TBA) testi ile lipid oksidasyonunun değerlendirilmesi. Atatürk Üniversitesi Veteriner Bilimleri Dergisi, 8(3), 237-240 .

[35]Orădan, A. C., Tocai, A. C., Rosan, C. A., & Vicas, S. I. (2024). Fruit Extracts Incorporated into Meat Products as Natural Antioxidants, Preservatives, and Colorants. Processes, 12(12), 2756. https://doi.org/10.3390/pr12122756.

[36]Tomović, V., Jokanović, M., Šojić, B., Škaljac, S., & Ivić, M. 2017. Plants as natural antioxidants for meat products. In IOP conference series: earth and environmental science (Vol. 85, No. 1, p. 012030). IOP Publishing .http://dx.doi.org/10.1088/1755-1315/85/1/012030 [37] Kaczmarek, A., Cegielska-Radziejewska, R., Szablewski, T., & Zabielski, J. 2015. TBARS and microbial growth predicative models of pork sausage stored at different temperatures . http://dx.doi.org/10.17221/591/2014-CJFS.

[38]Widayaka, K., Setyawardani, T., & Sumarmono, J. 2001. The effect of storage and cooking on lipid oxidation of raw and cooked beef and goat meat. Asia Pacific journal of clinical nutrition, 10(4), 548.

[39]Bozhko, N., & Tischenko, V. 2023. Effect of plant extracts rich in polyphenols on lipid oxidation in smoked sausages. In book: The scientific paradigm in the context of technological development and social change. Publishing House "Baltija Publishing ." http://dx.doi.org/10.30525/978-9934-26-297-5-20 .

[40]Soldatova, S., & Korzunov, S. 2021. Effect of Aggravated Temperature on Indicators of Oxidative Texture of Canned Meat. Bulletin of Science and Practice, 7(9), 181-188. (In Russian). https://doi.org/10.33619/2414-2948/70/21.

[41]Salazar, E., Cayuela, J. M., Abellán, A., Bueno-Gavilá, E., & Tejada, L. 2020. Fatty Acids and Free Amino Acids Changes during Processing of a Mediterranean Native Pig Breed Dry-Cured Ham. Foods, 9(9), 1170. https://doi.org/10.3390/foods9091170.

[42]Ibrahim, H. M. 2001. Acceleration of curing period of pastrami manufactured from buffalo meat: II-Fatty acids, amino acids, nutritional value and sensory evaluation. Grasas y Aceites, 52(2), 115-122 . https://doi.org/10.3989/gya.2001.v52.i2.382.

[43]Feng, K., Xing, G. M., Liu, J. X., Wang, H., Tan, G. F., Wang, G. L., Xu, Z. S. & Xiong, A. S. 2021. AgMYB1, an R2R3-MYB factor, plays a role in anthocyanin production and enhancement of antioxidant capacity in celery. Vegetable Research, 1(1), 1-12 . https://doi.org/10.48130/VR-2021-0002.

[44]Šojić, B. V., Petrović, L. S., Mandić, A. I., Sedej, I. J., Džinić, N. R., Tomović, V. M., Tasić, T.A., Škaljac, S. B. & Ikonić, P. M. 2014. Lipid oxidative changes in traditional dry fermented sausage Petrovská klobása during storage. Hemijska industrija, 68(1), 27-34 . https://doi.org/10.2298/HEMIND130118024S

[45]Lucarini, M., Durazzo, A., Sciubba, F., Di Cocco, M. E., Gianferri, R., Alise, M., Santini, A., Delfini, M. & Lombardi-Boccia, G. 2020. Stability of the meat protein type i collagen: Influence of ph, ionic strength, and phenolic antioxidant. Foods, 9(4), 480 . https://doi.org/10.3390/foods9040480.

[46]Li, X., Wei, X., Wang, H., Zhang, C. H., & Mehmood, W. 2018. Relationship between protein denaturation and water holding capacity of pork during postmortem ageing. Food biophysics, 13, 18-24 . https://doi.org/10.1007/s11483-017-9507-2.

[47]Awad, A. M., Kumar, P., Ismail- Fitry, M. R., Jusoh, S., Ab Aziz, M. F., & Sazili, A. Q. 2022. Overview of plant extracts as natural preservatives in meat. Journal of Food Processing and Preservation, 46(8), e16796 . https://doi.org/10.1111/jfpp.16796.

ISSN 2072-3857

[48]Estévez, M., Ventanas, S., Heinonen, M., & Puolanne, E. 2011. Protein carbonylation and water-holding capacity of pork subjected to frozen storage: Effect of muscle type, premincing, and packaging. Journal of agricultural and food chemistry, 59(10), 5435-5443 .https://doi.org/10.1021/jf104995j.

[49]Zhu, M., Zhang, J., Jiao, L., Ma, C., Kang, Z., & Ma, H. 2022. Effects of freezing methods and frozen storage on physicochemical, oxidative properties and protein denaturation of porcine longissimus dorsi. Lwt, 153, 112529 . https://doi.org/10.1016/j.lwt.2021.112529.

[50]Velasco-Arango, V. A., Hleap-Zapata, J. I., & Ordóñez-Santos, L. E. 2023. Effect of carotenoid pigments extracted from papaya epicarp (Carica papaya) on the characteristics of Frankfurt sausages. Revista UDCA Actualidad & Divulgación Científica, 26(1 .(e2167.http://dx.doi.org/10.31910/rudca.v26.n1 .2023.2167.

ISSN 2072-3857