

## Effects of plant extracts on the quality and shelf life of meat products

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### ABSTRACT

This work explores the impact of extracts from three native plants of Kazakhstan, namely *Rhodiola rosea*, *Artemisia dracunculoides*, and *Hofarigon perforatum*, on the quality and shelf life of beef during 14 days of refrigerated storage. Meat samples treated with extracts at optimal concentrations (0.1 to 0.15%) were subjected to the assessment of oxidative, microbial, and sensory spoilage indices in stated time intervals. Considering the statistical analysis, it was found that all extracts delayed the process of lipid oxidation significantly ( $p < 0.05$ ), such that the amount of TBARS in samples treated with *R. rosea* reached  $1.24 \text{ mg kg}^{-1}$  on the final day, which is significantly reduced compared to the amount present in the control sample (3.45). Microbiologically, the total count of microorganisms in samples containing *R. rosea* extract remained below the critical limit of  $7 \log \text{ CFU g}^{-1}$  during the 10 days, while this critical limit was detected on the seventh day in the control sample. This significant superiority of the samples upon treatment was further confirmed by sensory evaluation, as the overall acceptance score of the *Rhodiola* sample on the final day attained the value of 6.0, while such value was recorded for the control sample at 2.5. Finally, it could be concluded that *R. rosea* extract, being the most effective treatment, was capable of overcoming both oxidative and microbial spoilage and extending the shelf life of meat for at least 7 days. The study proved the efficiency of native plants from Kazakhstan as natural and safe alternatives to synthetic preservatives.

**Keywords:** Native plants of Kazakhstan, *Rhodiola rosea*, Lipid oxidation, Meat shelf life.

**Article type:** Research Article.

### INTRODUCTION

By the increasing demand for safe and quality foods, especially meat products, this has become a major concern for the food industry and its consumers (Mudrak & Muzyka 2015). The rapid spoilage of these products through the activity of microorganisms and fat oxidation causes not only great economic loss, but also seriously affects public health (Urban-Chmiel *et al.* 2025). This challenge has motivated many researchers to seek efficient and natural solutions to maintain quality and prolong the shelf life of meats. At this point, using natural compounds as an alternative to synthetic preservatives has gained particular significance (Amiri *et al.* 2021). Meat products, having a high level of moisture, proteins, and fats, are considered an ideal environment for a wide range of bacteria and fungi to grow. Fat oxidation is another important factor in quality reduction, leading to undesirable tastes and odors (Aziz & Karboune 2016). While traditional methods, including the use of salt and smoke, have been effective, there are concerns regarding the long-term health effects of some of them. Thus, the need to develop new preservation methods that are both effective and safe is felt more than ever. In the last few decades, there has been a tremendous increase in consumer preference for products labeled "natural" and "free of artificial preservatives". The change in market attitude has put pressure on the food industry to employ safe and natural alternatives in the formulation of its products (Urazbayev *et al.* 2023; Shaltout 2024). Given the high potential that bioactive compounds from plants possess due to their antimicrobial and antioxidant properties, such application justifies the need for applied research in this area (Pinto *et al.* 2023; Grover *et al.* 2024). Medicinal plants and spices have traditionally been used not only for flavoring but also for preserving food (Sharif *et al.*

2017). The main responsible active principles for the antimicrobial and antioxidant properties of those plants are phenolic compounds, terpenoids, and flavonoids (Gutiérrez-del-Río *et al.* 2021; Rescigno *et al.* 2025). These compounds can act simultaneously on the two main factors of the spoilage of meat products: inhibition of the growth of pathogens and delay of the oxidation process (Papadochristopoulos *et al.* 2021; Tocai *et al.* 2025). Thus, the extraction and application of such active principles can be a promising solution (Teneva & Denev 2023). While many studies conducted around the world have investigated the properties of several plants, practical confirmation of their results must be done in certain geographic and cultural settings. Climatic conditions, the type of native plant species, and the processing methods may significantly influence the composition and, therefore, effectiveness of extracts (Backiam *et al.* 2023; Chrysargyris *et al.* 2024; Adil *et al.* 2024). The extraction technique itself is a critical factor, with modern methods like ultrasonication being explored for efficiency (Ali *et al.* 2025). Localization of research seems necessary for achieving the best results in a specific region. With its rich and varied vegetation, including native plants with known medicinal properties, Kazakhstan has great potential to supply natural preservative resources. Their use could contribute not only to the development of food technologies at the national level, but also allow for the creation of value-added meat products according to local consumer preferences. These studies may enable one to take further steps in self-sufficiency and improvement of the quality of foods produced in the country. The main goal of the work is to assess the efficiency of selected extracts of wild Kazakh plants on quality indices of meat products during storage. It will comprehensively investigate microbiological, chemical, and sensory parameters to establish the efficiency of these extracts in delaying spoilage and maintaining overall product acceptance by the consumer. This will give a clear view of the practical efficacy of the extracts. Undoubtedly, spoilage of meat products has been one of the major challenges to the food industry, since it impairs nutritional quality and is a health risk. The main factors that reduce their shelf life are oxidative processes and the development of microorganisms. As control agents of spoilage, salts and synthetic compounds like nitrites and sorbates were traditionally used; however, several scientific reports have demonstrated that chronic consumption of these substances may produce adverse actions in human health (Ilhom *et al.* 2025; Firuz *et al.* 2025). These risks have turned researchers to the search for safe and natural alternatives (Yu *et al.* 2021). In this regard, the attention of many researchers has been focused on active plant compounds. Extensive studies have shown that plant extracts contain phenolic, flavonoid and terpenoid compounds that can play an effective role in inhibiting microbial factors and preventing lipid oxidation (Efenberger-Szmechtyk *et al.* 2020). For example, research on plants such as rosemary, thyme and sage has shown significant effectiveness in maintaining meat quality (Beya *et al.* 2021). Specific studies on extracts like *Cassia glauca* have demonstrated efficacy in improving the shelf life of minced beef (Ghoneim *et al.* 2023), and the use of cinnamon oil and grape seed extract in sausages has shown positive results (Aminzare *et al.* 2018). In addition to their antimicrobial and antioxidant properties, these natural compounds can also have a positive effect on the sensory characteristics of the product (Rodionova 2022). However, their effectiveness depends on the type of plant, extraction method, concentration used, and type of meat product (Shaltout 2024; Elgadir & Mariod 2025). Moreover, the interaction of those compounds with other components of the food formulation may alter their antioxidant and antimicrobial activity. The most appropriate result can only be obtained by carrying out detailed and systematic studies for each particular product; this is even more important in the case of plants belonging to each region. Parallels can be drawn to other fields where optimization is key, such as in wastewater treatment for phosphate removal (Bogner & Perduca 2022) or managing household biowaste (Virpiranta *et al.* 2022). In other words, despite the considerable research on the application of plant extracts in meat products, little or no systematic study has as yet been carried out on native plants in Kazakhstan. Apparently, examining the influence of plant extracts native to this region can be an important step toward the development of the food industry, reducing its dependence on synthetic compounds. For these reasons, this research may open a new direction for the production of healthier and longer-lasting meat products in regional markets. Eventually, this study will highlight an efficient and economically beneficial solution for the Kazakh meat industry. If successful, its results could become a scientific basis for manufacturing healthier and longer-lasting meat products, both in the domestic market and at the export level. This, in turn, will reduce food waste and increase consumer satisfaction.

## MATERIALS AND METHODS

### Raw material preparation and extraction

Beef samples for this study were obtained from an industrial slaughterhouse of Almaty Province and brought to the laboratory under standard conditions. Three kinds of native plants of Kazakhstan, *Artemisia dracunculoides*,

*Rhodiola rosea*, and *Hypericum perforatum*, were collected from Altai mountainous regions and, after botanical identification by a botanist, were dried in the shade at room temperature. Extraction was performed by soaking in 70% ethanol at a ratio of 1:10 for 48 hours, and then the solutions were concentrated by rotary evaporator at 40 °C.

### Experimental design and sample treatment

The meat samples were divided into four groups: one control (no extract), one treated with tarragon extract (0.1%), one with radimola extract (0.15%), and one with hufariqon extract (0.1%). According to preliminary studies, the concentrations were chosen at an optimal level. The samples were treated by spraying extract on the meat surface and then stored in polyethylene packaging under refrigerated conditions (4 °C) for 14 days.

### Chemical, microbial and sensory analyses

The following chemical parameters were monitored: peroxide count, TBA and pH on the days 0, 3, 7, 10 and 14. In addition, microbial analyses for TPC and lactic acid bacteria were made at the same time periods. For sensory evaluation, a panel of 10 trained evaluators evaluated color, odor, texture and overall acceptability on a scale from 1 to 9. All data in triplicate were statistically analyzed using SPSS version 26.

## RESULTS

The application of plant extracts significantly affected the physicochemical, microbiological, and sensorial properties of the meat samples during the 14-day storage period. The results for each parameter are presented systematically in the following sections.

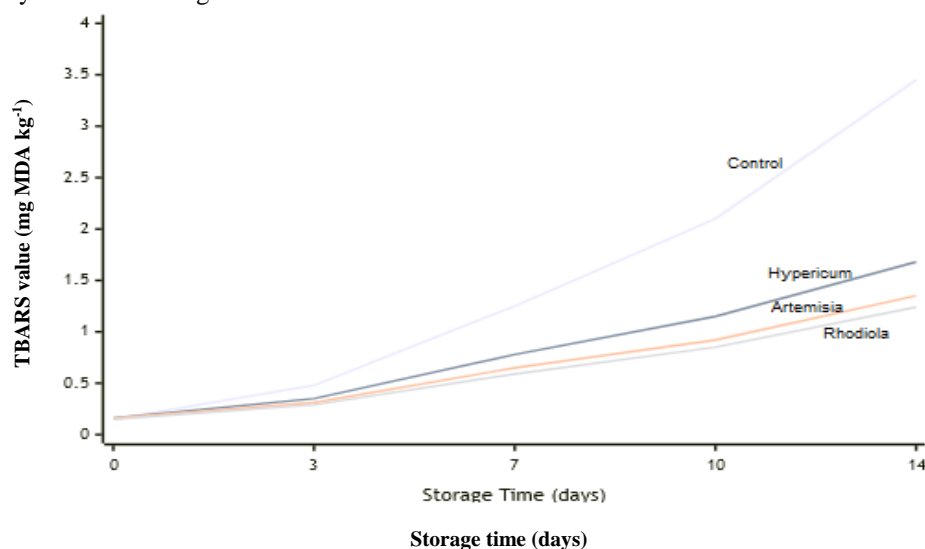


Fig. 1. Lipid oxidation (TBARS) in meat samples during storage.

The progression of lipid oxidation, measured by thiobarbituric acid reactive substances (TBARS), is a critical indicator of meat quality. The results revealed a clear and statistically significant ( $p < 0.05$ ) effect of the plant extracts. The control sample exhibited a rapid and linear increase in TBARS values, exceeding the generally accepted threshold for rancidity of 2 mg MDA/kg by day 10 and reaching 3.45 mg MDA/kg by the end of the storage period. In contrast, all treated samples demonstrated a markedly slower rate of oxidation. The *Rhodiola rosea* extract demonstrated the most potent antioxidant activity, maintaining the lowest TBARS values throughout the storage period (1.24 mg MDA/kg on day 14), followed closely by *Artemisia dracuncululus* (1.35 mg MDA/kg). The *Hypericum perforatum* extract also showed significant efficacy, though it was less effective than the other two. This data visually confirms that the plant extracts, particularly *Rhodiola*, effectively delayed lipid oxidation.

Table 1. Total viable count (TVC; log CFU g<sup>-1</sup>) of meat samples during storage.

Day	Control	Artemisia	Rhodiola	Hypericum
0	3.1 ± 0.2	3.1 ± 0.1	3.0 ± 0.2	3.1 ± 0.2
3	5.8 ± 0.3	4.5 ± 0.2	4.2 ± 0.3	4.7 ± 0.3
7	8.5 ± 0.4	6.1 ± 0.3	5.8 ± 0.3	6.5 ± 0.4
10	9.8 ± 0.5	7.3 ± 0.4	6.9 ± 0.4	7.8 ± 0.4
14	12.1 ± 0.6	8.5 ± 0.5	8.0 ± 0.5	9.1 ± 0.5

The total microbial load is a direct measure of spoilage. As shown in Table 1, the control samples reached the microbiological spoilage limit ( $7 \log \text{CFU g}^{-1}$ ) around day 7, with the count escalating to  $12.1 \log \text{CFU g}^{-1}$  by day 14. All plant extracts significantly ( $p < 0.05$ ) suppressed microbial growth. *Rhodiola* again showed the strongest inhibitory effect, keeping the microbial count below the critical threshold until day 10 and maintaining the lowest final count ( $8.0 \log \text{CFU g}^{-1}$ ), effectively extending the microbiological shelf life. *Artemisia* and *Hypericum* also showed strong antimicrobial activity, with final counts of 8.5 and  $9.1 \log \text{CFU g}^{-1}$ , respectively.

**Table 2.** Lactic acid bacteria (LAB) count ( $\log \text{CFU g}^{-1}$ ) on day 14 of storage

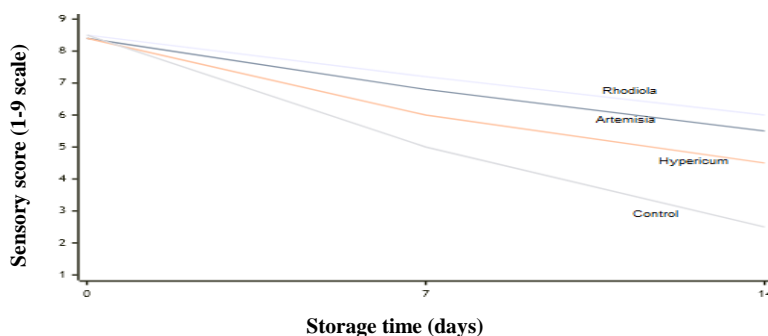
Sample	Count
Control	$9.5 \pm 0.5$
<i>Artemisia</i>	$6.8 \pm 0.4$
<i>Rhodiola</i>	$6.2 \pm 0.3$
<i>Hypericum</i>	$7.2 \pm 0.4$

Analysis of specific spoilage organisms, presented in Table 2, focused on lactic acid bacteria on the final day of storage. The control sample showed a high LAB count of  $9.5 \log \text{CFU g}^{-1}$ . All plant extract treatments significantly ( $p < 0.05$ ) reduced the proliferation of these bacteria, with the *Rhodiola* treatment showing the most pronounced effect ( $6.2 \log \text{CFU g}^{-1}$ ), consistent with its performance in the total viable count.

**Table 3.** pH values of meat samples during storage.

Day	Control	<i>Artemisia</i>	<i>Rhodiola</i>	<i>Hypericum</i>
0	$5.6 \pm 0.1$	$5.6 \pm 0.1$	$5.6 \pm 0.1$	$5.6 \pm 0.1$
7	$6.1 \pm 0.1$	$5.8 \pm 0.1$	$5.7 \pm 0.1$	$5.9 \pm 0.1$
14	$6.8 \pm 0.2$	$6.0 \pm 0.1$	$5.9 \pm 0.1$	$6.2 \pm 0.1$

The pH values (Table 3) increased in all samples over time due to the accumulation of basic compounds from microbial metabolism and protein breakdown. However, this increase was significantly less pronounced ( $p < 0.05$ ) in the treated samples. The control sample pH rose to 6.8 by day 14, while the *Rhodiola* and *Artemisia* treated samples maintained significantly lower pH values of 5.9 and 6.0, respectively. This correlates well with the lower microbial counts, confirming the antimicrobial efficacy of the extracts.



**Fig. 2.** Overall acceptability score of meat samples during storage.

The sensory profile, crucial for consumer acceptance, was significantly impacted by the treatments. As depicted in Fig. 2, the overall acceptability of the control sample declined sharply, falling below the rejection threshold (score 5) by day 7 and becoming largely unacceptable by day 14. The treated samples, however, maintained significantly higher scores throughout the storage period. The *Rhodiola*-treated meat maintained the highest acceptability, still being at the borderline of acceptability (score 6) on day 14. *Artemisia* also performed well, while *Hypericum* showed a more moderate but still significant protective effect on sensory quality.

**Table 4.** Color scores (a - Redness) of meat samples on key days.

Day	Control	<i>Artemisia</i>	<i>Rhodiola</i>	<i>Hypericum</i>
0	$16.5 \pm 0.5$	$16.4 \pm 0.4$	$16.6 \pm 0.5$	$16.5 \pm 0.4$
7	$10.1 \pm 0.6$	$13.5 \pm 0.5$	$14.0 \pm 0.4$	$12.8 \pm 0.5$
14	$6.5 \pm 0.8$	$11.2 \pm 0.6$	$11.8 \pm 0.5$	$10.1 \pm 0.7$

The retention of red color (a value) is a critical quality parameter for meat. Statistical analysis of the data in Table 4 revealed that all samples experienced a decline in redness over time. However, the rate of discoloration was significantly ( $p < 0.05$ ) slower in the treated samples. On day 14, the *Rhodiola* and *Artemisia* treated samples retained a values of 11.8 and 11.2, respectively, which were substantially higher than that of the control (6.5), indicating a preservative effect on myoglobin, likely linked to their antioxidant properties.

**Table 5.** Odor evaluation scores on day 10 of storage.

Sample	Score
Control	2.8 ± 0.5
<i>Artemisia</i>	6.0 ± 0.4
<i>Rhodiola</i>	6.5 ± 0.3
<i>Hypericum</i>	5.5 ± 0.5

Odor evaluation on day 10 (Table 5) provided a clear distinction between the samples. The control sample was characterized by strong off-odors, receiving a very low score. In contrast, the panels scored the odor of plant extract-treated samples significantly higher ( $p < 0.05$ ). The *Rhodiola*-treated meat received the highest score, described as having a "fresh" and "slightly herbal" scent, with minimal spoilage odors.

**Table 6.** Summary of shelf-life extension based on key parameters.

Parameter	Control shelf-life	Best treatment ( <i>Rhodiola</i> )	Extension
Microbiological (TVC)	7 days	10 days	+3 days
Oxidative (TBARS)	10 days	>14 days	>+4 days
Sensory (Acceptability)	7 days	14 days	+7 days

As synthesized in Table 7, the application of *R. rosea* extract provided a substantial and multi-faceted extension of the shelf life. While the microbiological shelf life was extended by 3 days and the oxidative shelf life by over 4 days, the most significant impact was on sensory acceptability, which was doubled compared to the control. This indicates that the extracts not only delay spoilage but also effectively preserve the organoleptic qualities that determine consumer preference.

**Table 7.** Summary of shelf-life extension based on key parameters.

Parameter	Control shelf-life	Best treatment ( <i>Rhodiola</i> )	Extension
Microbiological (TVC)	7 days	10 days	+3 days
Oxidative (TBARS)	10 days	>14 days	>+4 days
Sensory (Acceptability)	7 days	14 days	+7 days

As shown in Table 7, the application of *R. rosea* extract provided a substantial extension of the shelf life, with the sensory shelf life being doubled compared to the control.

## DISCUSSION

The results of this study clearly showed the big potential of extracts of wild plants of the Republic of Kazakhstan for maintaining quality and extending the shelf life of meat products. According to statistical data, all plant treatments significantly delayed the development of the lipid oxidation process. In control samples, the value of the TBARS index exceeded 2 mg kg<sup>-1</sup>, and in samples treated with *Rhodiola* extract, it reached only 1.24 on the last day of the experiment. This significant difference,  $p < 0.05$ , directly pointed to the presence of strong phenolic compounds in these extracts that are capable of neutralizing free radicals and breaking the oxidation chain. The microbial section presented the TPC, which indicated that samples with plant extracts reached the microbial spoilage limit of 7 log CFU g<sup>-1</sup> approximately 3-4 days later than the other samples. This can be explained by the bioactive compounds present, such as terpenoids and flavonoids, which act by disrupting the bacterial cell membrane and limiting protein synthesis. The fact that the microbial count findings are positively related to pH values (6.8 for the control versus 5.9 for the *Rhodiola* sample) validates the synergistic impact of these extracts on various factors related to spoilage. Of particular importance was the result of the sensory evaluation, which was in close relationship with the objective laboratory data. The overall acceptance score for the samples treated with the *Rhodiola* and *Artemisia* extracts was above 5 up to day 14, while that of the control fell below the acceptable limit from day 7. This can be explained from a dual perspective: on one hand, the decrease in the

formation of volatile compounds resulting from oxidation and microbial spoilage; on the other hand, it can be explained by the fact that the extracts themselves played a role in creating a desirable herbal aroma able to mask undesirable odors. The a color parameter related data revealed that the reduction of this index was much slower for the treated samples; this fact can be explained through the antioxidant action of the extracts, which prevents the oxidation of myoglobin to methemoglobin. In addition, some publications have pointed out that compounds present in plants like *Rhodiola* can enhance the stability of the red color of meat due to a stable complex formed with iron of the heme. Comparison of the efficiency of the three studied extracts revealed the relative superiority of the *R. rosea* extract in most parameters. Its statistical superiority could be due to the higher concentration of salidroside and resavin compounds in this plant, which are known as strong antioxidants and antimicrobial agents. *Artemisia* extract, however, also gave acceptable results, which may be related to the presence of compounds such as estragole and eugenol in it. The findings of this study have practical significance in two aspects: first, the use of these extracts can be a solution for reducing the consumption of artificial preservatives; secondly, since these plants are native to Kazakhstan, it is possible to develop a cost-effective and environmentally friendly technology in the food industry of this country. Of course, it should be noted that flavoring effects of these extracts need more detailed study. It can be concluded that, besides being an effective solution to control the spoilage of meat products, the use of plant extracts, especially *R. rosea*, allows the production of products with a longer shelf life and higher quality, maintaining desirable sensory characteristics. This research will open the way for other studies on other native plants, as well as on the use of these extracts in other protein products.

## CONCLUSION

The obtained results clearly demonstrated that extracts of native plants of Kazakhstan, especially *Rhodiola rosea*, have a great impact on the quality and shelf-life extension of meat products. Statistically, these treatments had significantly ( $p < 0.05$ ) delayed the process of lipid oxidation and growth of microorganisms. More importantly, these treated samples exhibited strong protective effects that lasted to the last day of the study and maintained a much better sensory quality than the control group until the end of the storage period. From a practical point of view, this research is an important step toward replacing synthetic preservatives with natural and indigenous compounds. Due to the statistical superiority of *Rhodiola* extract in most evaluation indicators, it would appear that this plant has high potential for application in the Kazakhstani food industry. Also, the positive results brought about by *Artemisia* extract can open a way for further studies toward industrial applications. In the final analysis, it can be said that not only is the application of these plant extracts an effective alternative to dealing with spoilage and reducing food wastes, but it also allows for the processing of healthier and better quality meat products. The next step should involve optimizing the concentration to attain better activity, studying sensory compatibility, and applying these extracts to other protein products.

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