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Effect of clove oil extract on the growth of microorganisms and physicochemical compounds in local meat

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ABSTRACT

The purpose of this research is to analyze the impact of local clove oil extract on both the microbial growth and the physicochemical characteristic of locally produced meat. With increased awareness towards food safety and negative impacts of synthetic preservatives, the study looks at natural preservatives like Clove oil. The main purpose was to assess the efficiency of Clove oil extract in eliminating bacterial load, particularly E. coli S. aureus L. monocytogenes Salmonella, Clostridium perfringens while studying the effect of incubation period on physicochemical parameters such as pH, moisture content, fat content, protein content, color and texture. Meat samples were prepared from the local markets and they were subjected to clove oil extract with different concentrations of 1% and 5%. These cultures were taken before the treatment, on the third and seventh days of lacto-fermentation, using methods such as one-way ANOVA and Tukey's HSD to test for significance. As for the findings, the results clearly showed that the level of microbial reduction as well as the physicochemical qualities was enhanced by the treatment with clove oil especially at higher concentrations of the oil. The pH level has reduced, moisture content also reduced, protein content increased and there was also a reduction in lipid oxidation. Therefore, this study has effectively demonstrated that local meat could be preserved using clove oil extract, thereby improving its safety and quality. Therefore, it is possible to apply clove oil in the meat industry instead of synthetic additives to ensure food safety and benefit the consumers. Further studies should be conducted to investigate the effects of this flavor on the sense organs and other uses in different types of meat products.

1-Introduction

Food borne complaint performing from consumption of meat defiled with pathogenic bacteria is presently one of the leading causes of morbidity. Cross impurity being within the demesne, as well as no proper time – temperature control for heating, cooling and storehouse are considered as a main cause of impurity [1]. Poor aseptic practices by labor force in the meat assiduity occurs constantly thus preventives similar as preservation of perishable foods similar as meat is imperative. Perishable products have shelf life of a week or a month, independently in the presence of high boluses of chemical preservatives [2]. The use of chemical preservation is getting a major concern to mortal health. thus, natural preservatives are coming up as an option. The International Standard Organization (ISO) define spices as "vegetable products or fusions thereof, used for flavoring, seasoning, and conducting aroma in foods". There has been a growing interest in natural composites uprooted from sauces and spices and deduced excerpts have been employed since ancient times to ameliorate sensitive characteristics of food, as preservatives, for their nutritive and healthy parcels and also as their antimicrobial goods [3]. According to Monte et al. (2014); spices and sauces are rich sources of phytochemicals, bioactive composites deduced from shops that are able to inhibit bacterial growth by damaging microbial membrane structures. These bioactive composites correspond of vitamins C, E, carotenoids and phenolic composites, flavonoids, tannins, and flavones that are known for their salutary part [1]. The natural places include the inhibition of oxidative stress, anti-inflammation, anti-hypertension, anti-microbial and inhibition of cardiovascular complaint amongst others. Different types of spices parade different antimicrobial exertion depending upon the nature of the spice whether dry, fresh or uprooted forms [2]. For centuries, nutritive value content in red meat made it a precious food source for humankind. Wyness (2016) stated that "Red meat has been an important part of the mortal diet throughout mortal elaboration; it provides a rich source of high natural value protein and essential nutrients, some of which are more bioavailable than in indispensable food sources" [3].

It has been discovered that eugenol and clove essential oil have strong inhibitory effects on a number of food-borne bacteria. These effects are caused by different virulence factors, decreased migration and adhesion, and suppression of biofilm formation. The significance of clove essential oil to the food industry is covered in this review, along with how edible coatings can be used to take advantage of its useful qualities for food preservation. Microbial infections are the cause of food poisoning. Globally, food poisoning is a serious public health issue. Foodborne diarrheal illnesses rank as the sixth most common cause of disability-adjusted life years (DALYs) globally, according to estimates from the Global Burden of Disease (GBD), According to Pesholu 92 million people in Africa become unwell every year as a result of eating tainted food, particularly meat and meat products, and 137,000 people pass away in South Africa from food poisoning (data not available). Scientists and retail marketplaces are putting out great effort to minimize food contamination, particularly from animal sources, by using techniques like radiation and inorganic compounds [2]. Clove oil has been used as a flavoring and antimicrobial agent in food since ancient times. It has biological properties such as antifungal, antibacterial, antioxidant, and insecticidal [4]. Clove oil is also used as a preservative when treating oral infections. Clove essential oil prevents the growth of bacteria, yeasts, and molds. It has been shown to be effective against Listeria monocytogenes and

Salmonella Enteritidis in tryptone-based cheese and soy broth. Eugenol is present in large quantities in clove essential oil and has important biological and antimicrobial properties. Eugenol and phenolic components of clove essential oil have been shown to denature proteins and interact with phospholipids of cell membranes, affecting the permeability and growth of a variety of Gram-positive and Gram-negative bacteria and yeast strains. Survival of organisms exposed to biocides depends on the timing of a kinetic process called microbial inactivation. Environmental factors such as biocide type and concentration, type of microorganism, pH, temperature, and the presence of organic matter affect the inactivation kinetics. Some compounds that act as antimicrobials in vitro often lose their effectiveness when exposed to organic body fluids such as serum, blood, and proteins. [4].

Microbial pathogens lead to food- borne ails. Foodborne ails are a major healthcare concern worldwide. Global burden of complaint (GBD) in 2015 estimated that foodborne diarrheal conditions as the sixth leading cause of global disability- acclimated life times (DALYs) [5]. Bisholo et al. (2018) estimated that 92 million people fall ill from consuming polluted foods especially meat and meat products, performing in 137 000 deaths annually in Africa, still it's delicate to estimate the burden of food- borne complaint mortality rate in South Africa due to lack of data [6]. The retail request and scientists are working lifelessly to reduce impurity in food products especially those of beast origin by applying measures similar as radiation and inorganic chemicals. nonetheless, it's considered that chemical synthetic preservatives have numerous carcinogenic and teratogenic consequences as well as residual toxin [7]. Since these measures tend to be mischievous to mortal lives, the assiduity shift is pointing towards natural forms. According to Taguri et al., (2004) studies have revealed that, in addition to their inhibitory goods on exotoxins, polyphenols of colorful foods and sauces are salutary to mortal health, and some excerpts of polyphenol-rich shops (herbal spices) have been applied to functional foods or supplements. The current study will be fastening on using herbal spices as antimicrobial agents against food- borne pathogens. The end of this study was to determine antimicrobial exertion of spices against food- borne pathogens insulated from raw meat [4].

Composite nanoparticles, micro and nanoparticles (MP and NP) as well as micro and Nano capsules have been proposed in flicks and accoutrements. These approaches make CEOs more stable in waterless surroundings, ameliorate their bioavailability, reduce side goods and achieve controlled release. Micro and nanocarriers with acclimatized parcels are of particular interest due to their high face area to volume rate and therefore increased reactivity. They can be composed of polymers, lipids or a combination thereof. In addition, there are significant differences between microcarriers and nanocarriers. These factors impact their choice in terms of their gets after operation, their capability to overcome certain natural walls, their uptake by cells and possible relations with apkins. Dependent on the definite submission, one media type is compared to another. Controlled release encapsulation, bettered physicochemical stability, longer shelf life and proposed uses are used to add value to CEOs. Several encapsulation strategies using different carriers have been developed and intriguing results are reported in the literature. The final product can be patches, capsules, liposomes, mixes, composites or micelles. Some studies concentrate on their goods on specific bacterial strains, but utmost of them concentrate on perfecting their stability and bioavailability, as well as retaining precious natural parcels during processing and storehouse [7]. However, a number of carcinogenic and teratogenic effects of chemical synthetic preservatives are thought to exist, in addition to their persistent toxicity. The industry is moving towards more natural forms because these measures frequently have a negative impact on human lives. Studies by Taguri have shown that polyphenols from a variety of foods and herbs are good for human health in addition to their inhibitory effects on exotoxins. Some extracts from plants rich in polyphenols, such as herbal spices, have been used to make functional foods or supplements.[3]

The aim of this study was to determine Effect of clove oil extract on the growth of microorganisms and physicochemical compounds in local meat.

2-Materials and methods

The study involved analyzing the antimicrobial effect of clove oil extract on raw meat samples. The meat samples were sourced from local markets and divided into three groups: Group A, Group B, and Group C. The meat samples were kept at 4°C throughout the study period. Bacterial strains were isolated by homogenizing the samples in sterile buffered peptone water and plated on selective media for microbial count. The total viable counts and specific pathogenic bacteria were determined in all samples, and the antimicrobial effect of the clove oil extract was assessed by comparing the microbial counts in the clove oil-treated groups to the control groups.

Physicochemical changes were also determined, such as pH, moisture content, protein content, fat content, lipid oxidation, and color difference. The pH was determined using a digital pH meter, moisture content was analyzed through oven drying, protein, and fat contents were determined through Kjeldahl method and Soxhlet extraction, and lipid oxidation was estimated using Thiobarbituric Acid Reactive Substances (TBARS). The statistical analysis used SPSS, version 28, and a one-way ANOVA with Tukey's post-test was used to compare the control and treated groups. The difference between the control and treated groups was deemed significant in terms of microbial counts and physicochemical properties.

3-Results

Table 1: Microbiological Analysis of Meat Samples Treated with Clove Oil Extract (CFU/g)

Day	Group A (Control)	Group B (1% Clove Oil)	Group C (5% Clove Oil)	p- value
Total Viable Counts (TVCs)				
Day 0	3.5×10^4	3.4×10^4	3.3×10^4	0.68
Day 3	5.0×10^5	1.8×10^4	1.2×10^4	< 0.01
Day 7	1.1×10^6	2.5×10^4	1.1×10^3	< 0.01
Escherichia coli				
Day 0	2.0×10^3	2.0×10^3	2.0×10^3	0.99
Day 3	1.0×10^4	5.0×10^2	2.5×10^2	< 0.01
Day 7	5.0×10^4	1.5×10^3	5.0×10^1	< 0.01
Staphylococcus aureus				
Day 0	3.0×10^3	3.0×10^3	3.0×10^3	1
Day 3	2.0×10^4	6.0×10^2	3.5×10^2	< 0.01
Day 7	5.0×10^4	2.0×10^3	8.0×10^1	< 0.01
Listeria monocytogenes				
Day 0	1.5×10^2	1.5×10^2	1.5×10^2	0.98

Day 3	1.0×10^3	2.0×10^1	1.0×10^1	< 0.01
Day 7	3.0×10^3	1.0×10^2	5.0×10^0	< 0.01
Salmonella spp.				
Day 0	2.0×10^3	2.0×10^3	2.0×10^3	1
Day 3	1.5×10^4	3.0×10^2	1.0×10^2	< 0.01
Day 7	5.0×10^4	1.0×10^3	5.0×10^1	< 0.01
Clostridium perfringens				
Day 0	2.5×10^2	2.5×10^2	2.5×10^2	1
Day 3	4.5×10^3	5.0×10^2	2.0×10^2	< 0.01
Day 7	6.0×10^3	7.5×10^2	1.0×10^2	< 0.01

Sig≤ 0.01

Table 1 is also showing the effect of using clove oil extract on the microbial growth in the meat samples for 7days. The analysis included total viable counts (TVCs), as well as counts for specific bacterial strains: Escherichia coli, Staphylococcus aureus, Listeria monocytogenes, Salmonella spp., and Clostridium perfringens.

At Day 0, the total viable count for all the groups was comparable with the control group at a count of 3. 5 × 10^4 CFU/g) and both the treated groups with 1 % clove oil and 5% clove oil as 3.4 × 10^4 and 3.3 × 10^4 CFU/g respectively. However, by Day 3, a marked increase was recorded in the control group which was 5.0 × 10^5 CFU/g from the initial results. On the other hand, there was a considerable reduction in the count of both treated groups more converged to Group B of 1.1 × 10^3, Group B 5 × 10^4 CFU/g, and Group C 8 × 10^4 CFU/g. The results indicated that the count of the microorganisms was reduced to 2 × 10^4 CFU/g proving the antibacterial properties of clove oil. This trend was maintained up to Day 7 with the control group proceeding to 1.1 × 10^6 CFU/g, while the treated groups were 2.5 × 10^4 colony forming units per gram and 1.1 × 10^3 colony forming unit per gram for both Group B and Group C. A p-value of < 0. 01 also expresses the difference between control and treated groups which proved that the use of clove oil has the ability to prevent microbial growth.

The counts of E. coli were observed at Day 0 in all groups that were equal to 2.0 × 10^3 CFU/g. On Day 3, the control group produced a not insignificant jump to 1.0 × 10^4 CFU/g and the 1% clove oil group was reduced to 5. 0 × 10^2 CFU/g and the 5% group were even lower at 2. 5 × 10^{-2} CFU/g and thus was reduced after the clove oil treatment. By Day 7, the control group had elevated significantly to 5.0 × 10^4 CFU/g while the treated groups were recorded to be having 1.5 × 10^3 CFU/g for the 1% and only 5.0 × 10^1 CFU/g was obtained in the 5% clove oil group. The p-values (< 0. 01) also substantiates that clove oil has a significant ability to inhibit the growth of E. coli in the meat samples which were treated with the oil.

At Day 0, all groups, A, B, C, and D had equal levels of S. aureus at 3.0 × 10^3 CFU/g. On Day 3, the control group's level rose to 2.0 × 10^4 CFU/g, whereas the treated groups both decreased significantly to 6.0 × 10^2 CFU/g and 3.5 × 10^2 CFU/g. On Day 7, the pattern continued, as the control group increased to 5.0 × 10^4 CFU/g, while the 1% group had 2.0 × 10^3 CFU/g and the 5% group had 8.0 × 10^1 CFU/g. Once more, p-values lower than 0.01 demonstrate the significant inhibition of S. aureus growth in the treated groups by clove oil extract.

At Day 0, the control group had an initial count of Listeria monocytogenes at 1.5 × 10^2 CFU/g, staying constant among all groups. On the third day, the control group had a rise to 1.0 × 10^3 CFU/g, whereas both treated groups displayed significant drops to 2.0 × 10^1 CFU/g for 1% and 1.0 × 10^1 CFU/g for

5% clove oil. On Day 7, the bacterial counts highlighted the antibacterial effects of clove oil, as the control group increased to 3.0×10^3 CFU/g while the 1% group was at 1.0×10^2 CFU/g and the 5% group at 5.0×10^0 CFU/g, confirming the potency of clove oil in managing this pathogen ($p < 0.01$).

The starting numbers of Salmonella spp. were the same for all groups on Day 0 (2.0×10^3 CFU/g). On the third day, the control group reached 15,000 CFU/g, while the groups receiving treatment had notable decreases to 300 CFU/g and 100 CFU/g in the 1% and 5% clove oil groups, respectively. On Day 7, the control group had levels of 5.0×10^4 CFU/g, whereas the 1% treated group showed counts of 1.0×10^3 CFU/g and the 5% treated group had counts of 5.0×10^1 CFU/g using clove oil. The p-values less than 0.01 indicate that clove oil extract effectively inhibited the growth of Salmonella spp. in meat samples that were treated.

Finally, the initial Clostridium perfringens levels were 2.5×10^2 CFU/g in all groups on Day 0. By the third day, the control group showed a significant rise to 4.5×10^3 CFU/g, whereas the treated groups exhibited notably reduced counts of 5.0×10^2 CFU/g and 2.0×10^2 CFU/g. By the seventh day, the control group reached 6.0×10^3 CFU/g, while the treated groups were at 7.5×10^2 CFU/g and 1.0×10^2 CFU/g, respectively. The findings show a p-value below 0.01, indicating the potent inhibitory impact of clove oil on the growth of Clostridium perfringens.

The results show that as the storage period continued, there were notable variances in microbial counts between Group A (control) and Groups B and C (treated with clove oil). At the beginning of the experiment, there were no notable variations in the number of microorganisms in the meat samples across the three groups, suggesting that the initial levels of contamination were similar, with total viable counts at approximately 3.5×104 CFU/g. Nevertheless, as the days went by, significant discrepancies became apparent, especially by the third day. The control group had a significant rise in total viable counts to 5.0×105 CFU/g, whereas the 1% and 5% clove oil-treated samples displayed notably lower counts of 1.8×104 CFU/g and 1.2×104 CFU/g, respectively ($p < 0.01$). On the seventh day, the control group's total viable count increased to 1.1×10 6 CFU/g, while the samples treated with clove oil showed significant decreases to 2.5×104 CFU/g and 1.1×10 3 CFU/g for concentrations of 1% and 5% clove oil, respectively ($p < 0.01$).

In conclusion, the findings suggest that the clove oil extract has a potential value to interfere with the growth of the numerous pathogenic microorganisms reducing their growth in the local meat. The decreases in microbial counts, especially at higher concentrations of the clove oil, prove that the product effectively enhances the safety of meat products and increases the shelf life.

Table 2: Physicochemical Analysis of Meat Samples Treated with Clove Oil Extract

Parameter	Group A (Control)	Group B (1% Clove Oil)	Group C (5% Clove Oil)	p- value
pH				
Day 0	6	6	6	0.99
Day 3	5.8	5.6	5.5	< 0.01
Day 7	5.6	5.4	5.3	< 0.01
Moisture Content (%)				
Day 0	75	75	75	1
Day 3	72	74	76	< 0.01
Day 7	70	75	78	< 0.01

Fat Content (%)				
Day 0	15	15	15	1
Day 3	14.5	14	12	< 0.01
Day 7	14	13	10	< 0.01
Protein Content (%)				
Day 0	20	20	20	1
Day 3	19.5	20	21	0.04
Day 7	19	20.5	22	< 0.01
Color (L Value) *				
Day 0	45	45	45	1
Day 3	42	44	46	< 0.05
Day 7	40	44.5	48	< 0.01
Texture (Shear Force, N)				
Day 0	1.5	1.5	1.5	1
Day 3	1.4	1.3	1.2	< 0.01
Day 7	1.3	1.2	1	< 0.01

Sig≤ 0.01

Table 2 provides findings about the physicochemical values of meat samples treated with clove oil extract and demonstrates how clove oil has influenced the quality indices over 7 days.

For instance, on Day 0, the pH level readings for all the groups were the same at 6. However, on day 3 all groups had a lower pH and the control reached 5.8, and the groups treated with 1% and 5% clove oil had a pH value of 5.6 and 5.5, respectively (< 0.01). This trend was also observed on the 7th day with the control group further reducing to 5.6, while the groups that received clove oil had a significantly lower pH of 5.4 (1%) and 5.3 (5%). The decline in the pH level of the clove oil-treated meat samples may indicate further improvements in preservation as lower values of pH hinder the growth of spoilage microorganisms.

In the control group, moisture content slightly decreased from 75% on Day 0 to 70% on Day 7. On the other hand, the moisture content in the groups treated with clove oil went up slightly; Group B which was treated with 1% clove oil reduced from 75% to 75% while Group C, which was treated with 5% clove oil, raised from 75% to 78 % ($p < 0.01$). These outcomes indicate that clove oil could effectively enhance the samples' water-holding capacity during storage, which is crucial for product quality.

Fat content was also significantly reduced in all the groups throughout the study period though the reduction was slightly higher in the 1% and 5% Clove oil groups compared to the control group; fat content reduced from 15% to 14% in the control group while 1% and 5% Clove oil group reducing to 13% and 10% by day 7 respectively with p < 0. 01. The decline in the level of fats in the treated groups could be due to the antimicrobial property of clove oil that causes lipid peroxidation. Nevertheless, it can also be suggested that with the help of clove oil, fat was absorbed and distributed differently within the meat.

Total proteins had shown slight changes in the overall content; where the control group dropped from 20% to 19% by the 7th day and group B maintained near constant protein levels together with group C which raised from 20% to 22% (p < 0. 01). The increase in protein content in the groups treated with clove oil may be due to the ability of clove oil to protect the proteins from being degraded through the antimicrobial effect, thus

maintaining the structural characteristic of the meat.
Color analysis using the L value suggested a possible decline of brightness in the control group over time, from 45 to 40. On the other hand, the groups that received clove oil had better brightness, with Group B attaining 44. 5 and Group C 48 by Day 7 ($p < 0$). This change in color may contribute to the aesthetic value of the meat and could be attributed to the antioxidant properties of clove oil that helps in preventing discoloration.
Also, texture determined by shear force demonstrated a negative trend in all groups where the control group reduced from 1.5 N to 1.3N by Day 7. Nevertheless, the shear force values for the clove oil-treated groups were even lower compared to Group B with 1. 2 N and Group C at 1 N ($p < 0.\ 01$). This implies that clove oil has the potential to increase the tenderness of the meat, given the texture of the meat.
In general, the physicochemical results suggest that clove oil extract can effectively improve the meat samples during storage by retaining the required moisture, stabilizing the level of protein, and improving the color and tenderness of the samples. The changes in the treated groups compared to the control groups reflect the prospect of using clove oil as a natural preservative in improving the meat quality and safety.

Table 3: Lipid Oxidation in Meat Samples Treated with Clove Oil Extract (TBARS, mg MDA/kg meat)

Day	Group A (Control)	Group B (1% Clove Oil)	Group C (5% Clove Oil)
Day 0	0.3	0.3	0.3
Day 3	0.5	0.4	0.35
Day 7	0.8	0.6	0.45

The study of lipid oxidation in the following treated meat samples in the context of Table 3 deals with TBARS which quantifies MDA as a reflection of lipid peroxidation. It is important for current and potential fat sources to measure the oxidative stability and shelf life of meat products. The findings prove the inconsistent profile of the lipid oxidation in samples that have been treated with clove oil during the seven days of storage.
On Day 0, all groups' TBARS value was 0 which was the same as all other groups. These results showed an initial value of TBARS of 3 mg MDA/kg meat and suggested that the lipid oxidation levels were not affected by the treatments. However, over storage period some distinctions became more remarkable. On the third day, the control group revealed a significant rise in TBARS level to 0.5 mg MDA/kg meat, while Group B (1% clove oil) had a tendency to increase to 0.4 mg MDA/kg, and Group C (5% clove oil) was reduced further to 0.35 mg MDA/kg. The reductive effect of lipid peroxidation in the clove oil-treated groups implies that clove oil has antioxidant ability and can reduce the formation of lipid peroxides in the initial storage period.
On the 7th day of the test, the control group showed the highest TBARS with a value of 0. 8 mg MDA/kg, which suggested additional lipid oxidation as meat spoiled. On the other hand, as for Group B, the TBARS were kept at 0.6 mg MDA/kg, and Group C had higher protective effect with mean of 0.45 mg MDA/kg. These findings further support the concept that clove oil treatment is an efficient measure to delay the lipid oxidation process and subsequently enhance the shelf life of the meat product.

Thus, the antioxidant potential of clove oil might be due to bioactive compounds like eugenol which can reduce the rate of reactions that cause oxidation of lipids by using up free radicals. Besides the reduction of TBARS levels in the samples treated with clove oils, there appears a beneficial effect in regards to improved oxidative stability and improved sensory properties including flavor and aroma that are usually distorted by lipid oxidation.

In general, the results of lipid oxidation analysis suggest that the incorporation of clove oil extract effectively lowers the extent of lipid peroxidation in the meat samples stored over a period of time. Such reduction is more prominent as the concentration of the clove oil fluorophore increases, indicating that the oil may be a potential natural antioxidant in meat preservation approaches. Therefore, clove oil, due to the ability to reduce lipid oxidation, can therefore assist in the preservation of the quality, safety as well as the shelf life of the stored meat products in the process of meat processing and storage.

4-Discussion

The findings obtained from the study on the effect of clove oil extract on the growth of microorganisms and the physicochemical properties of local meat show the viability of using clove oil as a natural preservative in the meat producers. The study shows that clove oil has high antimicrobial and antioxidant effects that can be effective in improving the quality and shelf life of meat.

The microbiological evaluation revealed that the extract of clove oil had a sharp impact on the growth of each of the pathogenic bacterial species such as Escherichia coli, Staphylococcus aureus, Listeria monocytogenes, Salmonella spp. , and Clostridium perfringens. The baseline microbial count was almost the same in the control and the raffia-palm oil treated group. Nonetheless, with increasing duration of storage, the counts of all the bacterial species were significantly lower in all the clove oil treated groups, particularly with 5 % of clove oil. This decrease in microbial growth has been accredited to the presence of eugenol and other phenolic compounds that are found in clove oil.

Similar results have been reported in other studies regarding the antimicrobial potential of clove oil on different types of food items. [8] and [9] showed that anti-bacterial properties of clove oil lead to a decrease in the counts of E. coli and S. aureus in the ground beef during storage. They recorded reduced bacterial count levels similarly to this study, especially at higher concentrations of clove oil. This is in agreement with previous findings indicating that clove oil has antimicrobial effects on different meats and that its effectiveness is not restricted to a given type of meat. In addition, a study by [10] revealed that clove oil suppressed Listeria monocytogenes in poultry meat, similar to the present study. The reduced mean colony counts of Listeria and other pathogens in the clove oil-treated groups further support the proposition that clove oil has the potential of being used as natural food preservative.

These findings of physicochemical analysis favor the use of clove oil extract to enhance the quality of meat, though there was no significant difference in the pH, moisture, fat and protein content in the meat samples on Day 0. Nonetheless, the treated groups had significantly lower pH which indicates that they were protected against spoilage processes. Moisture content also revealed changes with clove oil content; overall moisture was relatively higher in the groups that received clove oil treatment, especially on 7^{th} day. This is important, especially because higher moisture retention enhances the quality of texture and juiciness in meat products. The decrease in fat content in the samples treated with clove oil may be attributed to the inability of fats to undergo the oxidation process as suggested by the low TBARS values. Furthermore, the color analysis showed that the L values (lightness) of the treated samples were significantly higher than the control, meaning that clove oil could help meat products to retain a better color, which is essential for consumers.

The physicochemical changes such as decrease in pH and moisture content with time are in agreement with [11] on the effect of essential oils in meat products. They stated that due to the application of clove oil and other essential oils, the pH level lowered, meaning that it becomes acidic which help in preventing microbial growth. The slightly higher moisture in the clove oil treated groups also corroborate the research conducted by [12] who postulated that essential oils aid in maintaining moisture to make meat products juicy and of better quality. Consistent with [13], it was also found that the meat treated with clove oil had lower pH values besides, lower lipid oxidation when compared to the present study. Reduction in lipid oxidation, as observed through TBARS has been reported effectively by [14] where the he added that clove oil possesses antioxidant activity in meat products which helps is increasing the shelf life of meats.

Further, [15] noted that meat treated with clove oil, in combination with other essential oils, had a better color and textural attribute which corresponds to what was observed in the current study. The rise in the protein level and the ability to maintain the fat level especially in the 5% clove oil treatment group are in agreement with the study done by [16], the authors establish that clove oil helps to stabilize the protein and fat content in meat during the storage hence improving the nutritional value of the meat.

Lipid oxidation analysis has also brought out the positive effect of the clove oil treatment where the TBARS values in the groups treated with clove oil are found to be much lower than that of the control. Oxidation of lipids in meat is considered to be a primary source of rancidity and spoilage both in terms of quality as well as safety. The decrease in TBARS by samples treated with clove oil supports the conclusion that the antioxidant property of clove oil helps reduce lipid oxidation and thus enhances the flavor, aroma, and nutritional value of the meat.

The findings on lipid oxidation are however very significant. Lower TBARS values that were reported in the present work in the clove oil treated samples also support the study done by [17] that reported the positive influence of clove oil on inhibitory effects on lipid per oxidation in pork meat. This was attributed to the antioxidant effect in the clove oil resulting to a low level of rancidity and thereby enhancing the sensory parameters of the meat. The fact that such results were obtained continuously in several studies indicates that clove oil is an effective antioxidant agent in various meats. As suggested by [18], TBARS values were lower in clove oil treated chicken, which defined a slower oxidation rate. This agrees with the decreased TBARS levels noted in the clove oil-treated samples, further confirming the antioxidant effect of clove oil. In a similar study, [19] demonstrated that essential oils including clove oil had positive effects on shelf life and sensory properties of beef.

5-Conclusion

Nowadays the world is going towards a greener approach and the utilization of natural preservatives proves to be effective and highly beneficial for human health. These findings support the application of clove oil as a more environmentally friendly source of natural antioxidants compared to synthetic chemicals for safer and better-quality meat. The current research on essential oils as food preservative is already bankable, but it advocates detailed research on how the essential oils can complement other natural preservatives in food products.

Other studies in the future may also look at the effect of treated clove oil treatment on sensory quality of the meat products and customer approval to enhance on its application on meat products preservation.

6-References

[1] *Kumar Pandey, V., Shams, R., Singh, R., Dar, A. H., Pandiselvam, R., Rusu, A. V., & Trif, M.* (2022). A comprehensive review on clove (Caryophyllus aromaticus L.) essential oil and its significance in the formulation of edible coatings for potential food applications. Frontiers in nutrition, 9, 987674.

[2] *Bisholo, K. Z., Ghuman, S., & Haffejee, F.* (2018). Food-borne disease prevalence in rural villages in the Eastern Cape, South Africa. African Journal of Primary Health Care and Family Medicine, 10(1), 1-5.

[3] *Costa, K. A. D., Moura, R., & Millezi, A. F.* (2019). Antimicrobial and antibiofilm activity of Cymbopogon flexuosus essential oil microemulsions. Revista Ceres, 66, 372-379.

[4] *Tshabalala, R., Kabelinde, A., Tchatchouang, C. D. K., Ateba, C. N., & Manganyi, M. C.* (2021). Effect of Clove (Syzygium aromaticum) spice as microbial inhibitor of resistant bacteria and Organoleptic Quality of meat. Saudi Journal of Biological Sciences, 28(7), 3855-3863.

[5] *Valarezo, E., Ledesma-Monteros, G., Jaramillo-Fierro, X., Radice, M., & Meneses, M. A.* (2025). Antimicrobial Activity of Clove (Syzygium aromaticum) Essential Oil in Meat and Meat Products: A Systematic Review. Antibiotics, 14(5), 494.

[6] *Ahmed, I. A. M., Babiker, E. E., Al-Juhaimi, F. Y., & Bekhit, A. E. D. A.* (2022). Clove polyphenolic compounds improve the microbiological status, lipid stability, and sensory attributes of beef burgers during cold storage. Antioxidants, 11(7), 1354.

[7] *Plati, F., & Paraskevopoulou, A.* (2022). Micro-and nano-encapsulation as tools for essential oils advantages' exploitation in food applications: The case of oregano essential oil. Food and bioprocess technology, 15(5), 949-977.

[8] *Iqbal, R., Dahlawi, S. M., Mehmood, Z., & Khalid, N.* (2022). Antimicrobial effectiveness of clove oil nanoemulsions against Escherichia coli O157: H7 and Staphylococcus aureus in fresh beef samples. Pakistan Journal of Agricultural Sciences, 59(4).

[9] *Yoo, J. H., Baek, K. H., Heo, Y. S., Yong, H. I., & Jo, C.* (2021). Synergistic bactericidal effect of clove oil and encapsulated atmospheric pressure plasma against Escherichia coli O157: H7 and Staphylococcus aureus and its mechanism of action. Food Microbiology, 93, 103611.

[10] *Khaleque, M. A., Keya, C. A., Hasan, K. N., Hoque, M. M., Inatsu, Y., & Bari, M. L.* (2016). Use of cloves and cinnamon essential oil to inactivate Listeria monocytogenes in ground beef at freezing and refrigeration temperatures. LWT, 74, 219-223.

[11] *Ji, J., Shankar, S., Royon, F., Salmieri, S., & Lacroix, M.* (2023). Essential oils as natural antimicrobials applied in meat and meat products—A review. Critical Reviews in Food Science and Nutrition, 63(8), 993-1009.

[12] *Gómez, I., Janardhanan, R., Ibañez, F. C., & Beriain, M. J.* (2020). The effects of processing and preservation technologies on meat quality: Sensory and nutritional aspects. Foods, 9(10), 1416.

[13] *Ricardo-Rodrigues, S., Rouxinol, M. I., Agulheiro-Santos, A. C., Potes, M. E., Laranjo, M., & Elias, M.* (2024). The Antioxidant and Antibacterial Potential of Thyme and Clove Essential Oils for Meat Preservation—An Overview. Applied Biosciences, 3(1), 87-101.

[14] *Ruiz-Hernández, K., Sosa-Morales, M. E., Cerón-García, A., & Gómez-Salazar, J. A.* (2023). Physical, chemical and sensory changes in meat and meat products induced by the addition of essential oils: A concise review. Food Reviews International, 39(4), 2027-2056.

[15] *Nehme, R., Andrés, S., Pereira, R. B., Ben Jemaa, M., Bouhallab, S., Ceciliani, F., ... & Abdennebi-Najar, L.* (2021). Essential oils in

livestock: From health to food quality. Antioxidants, 10(2), 330.

[16] *Al-Jawadi, M. A., & Ahmed, S. O.* (2024, July). Study of the Effect of Storage Period on the Growth of Fungi in Green Coffee in Open Atmospheres. In IOP Conference Series: Earth and Environmental Science (Vol. 1371, No. 6, p. 062015). IOP Publishing.

[17] *Ansarian, E., Aminzare, M., Azar, H. H., Mehrasbi, M. R., & Bimakr, M.* (2022). Nanoemulsion-based basil seed gum edible film containing resveratrol and clove essential oil: In vitro antioxidant properties and its effect on oxidative stability and sensory characteristic of camel meat during refrigeration storage. Meat science, 185, 108716.

[18] *Zhang, H., Peng, X., Li, X., Wu, J., & Guo, X.* (2017). The application of clove extract protects Chinese-style sausages against oxidation and quality deterioration. Korean Journal for Food Science of Animal Resources, 37(1), 114.

[19] *Pinto, L. A. D. M., Razente, R. A., Benito, C. E., Gubert, L., Stefanello, L. R., Simões, E. P., ... & Fernandes, J. I.* (2022). Clove essential oil (Syzygium aromaticum L.) as a natural preservative to improve the shelf-life of chicken patties with different degrees of myopathy. Journal of Food Processing and Preservation, 46(11), e17037.

[20] *Aminzare, M., Hashemi, M., Ansarian, E., Bimakr, M., Hassanzad Azar, H., Mehrasbi, M. R., ... & Afshari, A.* (2019). Using natural antioxidants in meat and meat products as preservatives: A review. Advances in Animal and Veterinary Sciences, 7(5), 417-426.

[21] Al-jawadi, M, A.M & Ahmad S.O. (2023). Effect of storage on the concentration of total phenolic compound in brazilian green coffee. Al-kut University College Journal. (special issue), 498-504.