

Enhancing oxidative stability and consumer acceptance of beef burgers with dill (*Anethum graveolens* L.) on refrigerated storage

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Abstract

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Processed meat products, particularly bovine burgers, have gained significant popularity in Iraq over the past decade due to increased demand for high-nutritional diets and the expansion of fast-food restaurants. However, meat product producers face challenges related to oxidation, which affects quality, flavor, and nutritional value during storage. This study investigates the impact of dill powder and dill extract as natural additives on the qualitative and sensory characteristics of bovine burgers stored under frozen conditions for varying periods (1, 15, 30, and 45 days).

Six treatments were prepared: T1 (control), T2 (0.5% dill powder), T3 (1% dill powder), T4 (2% dill powder), T5 (0.050 ppm dill extract), and T6 (0.075 ppm dill extract). The samples were analyzed for pH, free fatty acid (FFA) content, total volatile nitrogen (TVN), and peroxide value (PV). Results showed that T5 and T6 treatments significantly reduced oxidative degradation markers (FFA and PV), and maintained better quality during extended storage compared to the control group. The pH values of treated samples declined progressively over the storage period but remained within acceptable limits, highlighting their potential for preserving meat quality.

The findings underscore the potential of dill, a widely used culinary and medicinal herb in Iraq, as a natural preservative and flavor enhancer in processed meat products. By mitigating oxidation and improving sensory characteristics, dill-based additives offer a promising solution for enhancing the shelf life and consumer acceptance of bovine burgers.

Keywords: oxidation; meat; power outages; dill; Tailored Preservation Strategies

Introduction

Over the past ten years, processed meat, particularly bovine burger, has become more popular in Iraq due to the need for high-nutritional diets, in addition to the spread of fast food restaurants specializing in selling burger at competitive prices.

Burger is a chopped meat product used in dishes that are processed quickly. Its circulation and industry have lately expanded, and it has a wealth of inventions and unique additions that cater to various tastes to boost marketing and promotion. The ingredients in beef burger include chopped meat, fillers, natural enhancers, and allowed preservatives,

whether they are added or not. At least 60% of the dish must be meat, and no more than 20% may be fat (Tham-sorn et al., 2024). Burger is produced in units with regulated dimensions and thickness, and it is then frozen and packaged appropriately. While other meat products are frequently harsher and, in certain cases, may have a very dominant meat flavor, burger goods are softer, juicier, and have a meat flavor (Sogari et al., 2024).

Oxidation is one of the biggest problems facing meat product producers (Baquer et al., 2024). It happens more quickly in minced meat than in intact meat, because grinding greatly increases the surface area of the flesh exposed to air (Haque et al., 2024). Additionally, foods with a high

fat content, such as processed meats, are more prone to oxidation, which can lead to unpleasant smells and odours as well as nutrient loss (Zhang et al., 2024). Lipid oxidation is a crucial factor in the degradation of muscle food (Wu et al., 2024). Variable storage durations and unpredictable events, such as power outages, can cause factory burgers to thaw and refreeze, changing their flavor and oxidation. The morphological, chemical, physical, biochemical, microbiological, sensory, technological, sanitary, nutritional, and culinary qualities of meat are all considered to be part of its overall quality. There have been several attempts to increase the quality of the processed meat without compromising production efficiency by altering its diet (Xu and Falsafi, 2024). Researchers and manufacturers are interested in using various types of phytochemicals in burger processes. These additions contain substances and components that are essential for protecting the created product from deteriorating over time, protecting it from changes in taste, and helping to create new flavors.

Dill is an aromatic annual plant that self-seeds. The species name, *graveolens*, means to release a strong odour, while the scientific name *Anethum*, is derived from the Greek meaning to soothe or calm (Bhattacharya et al., 2025). One of the most used in Iraq “dill plant” or “chibitt” in Arabic and ‘chbint’ in Iraq. Dill has long been used as a culinary and medicinal herb, and it was thought to help with digestion (Das et al., 2025). It is thought to have originated in the Mediterranean. It is used as a natural taste enhancer in a variety of dishes, primarily pickles, but also sauces, salads, soups, shellfish, and meats. Minerals such as phosphate, potassium, and magnesium can be found in dill leaves (Vishvakarma et al., 2022). Numerous studies have looked into dill’s scent composition, and it was found that carvone, limonene, and dill apiole were its key constituents (Kaur et al., 2021).

Materials and Methods

Minced beef, pelvic fat and kidneys were purchased from local markets in the city of Najaf, Iraq. The spices of Marsin (Turkish type) were purchased and added at 1%. The beef mixture and beef fat were mixed at 70% minced meat, 30% fat, and 1.5% sodium chloride for 5 min in a meat mixer (Havant, UK). Burgers of 62±1 g with a 9 cm diameter were formed by a hand press maker (Chinese), and the following treatments were prepared: T1: control without any coating, T2: 0.5% dill powder, T3: 1% dill powder, T4: 2% dill powder, T5: 0.050 ppm dill, T6: 0.075 ppm dill. The sample was kept in the freezer at -18 °C for varying periods of time (1, 15, 30, and 45 days).

pH determination

Burger samples’ pH values are determined using (Zainy and Alrubeii, 2021) as follows: 5 g of sample was blended with 45 mL distilled water for 1 min, and then the pH of the homogenate was measured using a pH meter (Hanna HI6221-01 USA).

Peroxide value (p.v)

5 g of ground meat was kept in an iodine flask and 25 mL of the solvent (2:1, acetic acid: chloroform v/v) was added. 1 mL of saturated potassium iodide solution was mixed and left for 1 min (with gentle shaking). 35 mL of water was added with some drops of the starch indicator to note the presence of free iodine (blue color appears). Titration of liberated iodine was done with 0.1N sodium thiosulphate till the blue color vanished. The same procedure was carried out for the blank and the peroxide value was determined using Eq.

$$PV \text{ (meq / kg)} = N \times (VS - VB) \times 1000 \text{ Weight of sample (g)}$$

where: N = normality of sodium thiosulfate, VS = sodium thiosulfate consumed by sample (mL), and VB = sodium thiosulfate consumed by blank (mL).

Total volatile nitrogen (TVN)

At the 45th day, the concentration of total volatile nitrogen in the prepared burger samples was measured according to the following procedure: a sample (100 g) was homogenized in 300 mL of trichloroacetic acid solution (5%), and the mixture was filtered to get a clear filtrate. Then, 5 mL of the filtrate was distilled in a micro Kjeldahl distillation system (RapidStill-I, Labconco, USA) after adding 15 mL of sodium hydroxide (2N). Boric acid solution (15 mL, 4%) was used as a receiver solution for the condensed ammonia gas, which was titrated against HCl solution (0.01M). Concentration of TVN was calculated according to the following equation:

$$\begin{aligned} \text{TVN (mg nitrogen/100g meat)} &= \\ &= (14 * (\text{MO} + 300) * V) / 500 \text{ mg} \end{aligned}$$

where: TVN = total volatile nitrogen; V = Volume (mL) of hydrochloric acid; MO = moisture content of the meat sample.

Statistical analysis

The effect of treatment and storage duration on various attributes was investigated using a completely randomized design (CRD) in a factorial experiment (4×10). Data were statistically analyzed using the SAS software (2012).

Results and Discussion

pH

Table 1 shows how the pH value of the bovine burgers is affected by overlap between various treatments and freeze storage periods. It also shows that the T6 treatment had a significantly higher value ($P < 0.01$) in the pH (6.05) value during the 1-day freeze storage period than the T1 treatment, which had the lowest value (5.37) during the 15-day period.

Table 1 shows that, with the exception of the T1 treatment, which recorded the lowest pH value (5.67), there are no significant differences ($P < 0.01$) among the rates of the additional treatments.

Regarding storage periods, the statistical analysis's findings showed a significant difference ($P < 0.01$) between them, because pH peaked on the first day and then began to decline in the next 15 and 30 days, reaching its lowest value in the 45-day period. The reason for the pH decrease in the early storage periods can be attributed to the rapid activity of calpain- μ and Cathepsins, or due to the low water holding capacity (WHC) of meat (Cheng, 2021), as well as to the degradation of meat proteins with the advanced storage period causing the rise of nitrogen compounds (Chen et al., 2022).

Table 1 Changes in pH value

Treatment	pH				Average
	Day 1	Day 15	Day 30	Day 45	
T1	5.95±0.05 ^d	5.37±0.32 ^l	5.75±0.05 ^g	5.61±0.01 ^k	5.67±0.1 ^B
T2	5.98±0.02 ^c	5.90±0.05 ^c	5.80±0.05 ^{fg}	5.70±0.05 ^j	5.84±0.04 ^A
T3	6.02±0.02 ^b	5.91±0.01 ^c	5.82±0.02 ^f	5.73±0.03 ^h	5.87±0.04 ^A
T4	5.97±0.02 ^d	5.90±0.05 ^c	5.80±0.1 ^{fg}	5.71±0.01 ⁱ	5.84±0.04 ^A
T5	6.02±0.02 ^b	5.92±0.07 ^c	5.81±0.01 ^f	5.70±0 ^j	5.86±0.04 ^A
T6	6.05±0.05 ^a	5.97±0.02 ^d	5.83±0.03 ^f	5.75±0.05 ^g	5.90±0.04 ^A

The averages that bear different letters, differ significantly ($P < 0.01$) among them (large letters are a main effect of treatment and storage duration and low-case letters are the effect of the interaction between treatment and storage duration).

Source: Authors' own elaboration

Table 2 Changes in FFA

Treatment	FFA%				Average
	Day 1	Day 15	Day 30	Day 45	
T1	0.35±0.05 ^h	0.80±0.05 ^g	1.10±0.05 ^c	1.30±0.05 ^a	0.88±0.13 ^A
T2	0.25±0.05 ^o	0.60±0.05 ^j	0.90±0.05 ^c	1.15±0.05 ^b	0.72±0.12 ^B
T3	0.25±0.05 ^o	0.65±0.05 ⁱ	0.93±0.03 ^c	1.10±0.05 ^c	0.73±0.12 ^B
T4	0.15±0.05 ^q	0.40±0.05 ^l	0.65±0.05 ⁱ	0.93±0.03 ^c	0.53±0.11 ^C
T5	0.10±0 ^f	0.37±0.02 ^m	0.72±0.02 ^h	0.95±0.05 ^d	0.53±0.12 ^C
T6	0.10±0 ^f	0.20±0.05 ^p	0.50±0.05 ^k	0.85±0.05 ^f	0.41±0.11 ^D

The averages that bear different letters, differ significantly ($P < 0.01$) among them (large letters are a main effect of treatment and storage duration and low-case letters are the effect of the interaction between treatment and storage duration).

Source: Authors' own elaboration

FFA

Table 2 illustrates how the percentage of FFA of the bovine burgers is affected by various treatments and freeze storage periods. It shows a significant increase ($P < 0.01$) in the FFA ratio (1.3%) of the T1 treatment during the 45-day freeze storage period, while we also note a significant decrease ($P < 0.01$) in treatments T5 and T6, the differences between treatments and storage times varied over period one.

The significant superiority in the average of treatments ($P < 0.01$) shows that the T1 treatment is as high as 0.88% compared to T6 (0.41%), followed by T3 corresponding to T2 then T5 and T4 treatments, which different from the control. This indicates that there are significant differences between additive treatment rates, as shown in Table 2.

The statistical analysis revealed a significant difference ($P < 0.01$) between the storage periods, with the FFA ratio reaching its maximum ratio in the 45-day period after having been at its lowest in the 1-day period, and then increasing as the storage period progressed. The percentage of FFA is based on Iraqi standards.

When it surpasses 1.5%, it is discarded. The presence of lipolytic enzymes, such as lipase and phospholipase, may be the cause of the high percentage of FFA with increasing storage period. These enzymes cause the release of FFA and greatly contribute to the production of an unpalatable odour

that reflects the deterioration of flavor, lowering the nutritional value and edibility of meat (Wu et al., 2021).

TVN

There were varying differences between treatments and different storage periods. Table 3 shows the effect of overlap between different treatments and freeze storage periods in the TVN concentration of the bovine burgers. Table 3 shows the effect of overlap between different treatments and freeze storage periods in TVN concentration of bovine burgers, and notes a significant rise ($P < 0.01$) in T.V.N concentration (13.25 mg N/100 g meat) for T1 in the 45-day freeze storage period, and we noted a significant decrease ($P < 0.01$) for T6, and in the 1-day period, there were varying differences between treatments and different storage periods.

Table 3 notes that there are significant differences between additionality rates, as it has been noted that there is significant superiority ($P < 0.01$) in favor of the T1 treatment up to (9.31 mg N/100g meat) compared to T6 (5.08 mg N/100g meat), followed by T3, which corresponds to T2, then T5 and T4 treatments.

As for storage periods, the results of the statistical analysis indicated a significant difference ($P < 0.01$) between periods as the concentration of T.V.N was at its lowest level in the 1-day period, and then began to rise over the storage period, until

it reached its highest concentration in the 45-day period. The high concentration of TVN with increasing storage periods is the result of an increase in the effectiveness of protein-analyzing enzymes (Motaghifar et al., 2020). The concentration of TVN also includes a range of compounds such as trimethylamine (TMA) resulting from bacterial degradation, Diethylamine (DMA), which includes self-degradation enzymes during refrigerated storage and ammonia (NH_3) resulting from amino acid deacidification resulting from meat spoilage. This aligns with the findings of Zainy et al. (2025).

P.V

Table 4 shows the effect of interaction between different treatments and freeze storage periods in the peroxide value of the bovine burgers, and notes a significant rise ($P < 0.01$) in the peroxide value (7.65 mg/kg lipid) for the T1 treatment. The T5 treatment recorded (1.75 mg/kg fat) and the T6 treatment recorded (1.88 ml/kg fat) in the 1-day period caused a significant decline ($P < 0.01$) during the 45-day frozen storage period.

Significant distinctions exist between additive treatment rates. For example, it has been found that the average of T1 treatment has a significant superiority ($P < 0.01$) over T6 treatment, which has a significant superiority of up to 5.47 mEq/kg lipid (3.22 mEq/kg lipid).

Table 3 Changes in total volatile nitrogen (mg N/100 g meat)

Treatment	TVN				Average
	Day 1	Day 15	Day 30	Day 45	
T1	4.88±0.05 ⁿ	8.77±0.12 ^c	10.35±0.05 ^c	13.25±0.05 ^a	9.31±1.14 ^A
T2	3.87±0.05 ^a	5.93±0.03 ^k	8.20±0.1 ^h	10.85±0.05 ^c	7.21±0.98 ^C
T3	3.94±0.06 ⁱ	5.9±0.05 ^k	8.36±0.04 ^g	11.23±0.12 ^b	7.35±1.03 ^B
T4	3.03±0.03 ^s	5.12±0.13 ^m	6.54±0.21 ⁿ	8.57±0.07 ^f	5.81±0.76 ^E
T5	3.28±0.07 ^r	5.25±0.05 ^l	6.70±0.1 ^j	8.78±0.11 ^c	6.00±0.76 ^D
T6	2.27±0.05 ^t	4.38±0.07 ^o	5.89±0.13 ^k	7.79±0.06 ⁱ	5.08±0.76 ^F

The averages that bear different letters, differ significantly ($P < 0.01$) among them (large letters are a main effect of treatment and storage duration and low-case letters are the effect of the interaction between treatment and storage duration).

Source: Authors' own elaboration

Table 4 Changes in peroxide values

Treatment	p.v				Average
	Day 1	Day 15	Day 30	Day 45	
T1	3.18±0.07 ^p	4.97±0.12 ^g	6.10±0.1 ^c	7.65±0.05 ^a	5.47±0.61 ^A
T2	2.90±0.05 ^r	4.20±0.05 ^k	5.52±0.02 ^f	6.80±0.05 ^b	4.85±0.55 ^C
T3	2.94±0.04 ^{qr}	4.60±0.05 ⁱ	5.82±0.02 ^d	6.95±0.05 ^b	5.04±0.55 ^B
T4	2.23±0.03 ^u	3.36±0.09 ^o	4.88±0.07 ^h	5.78±0.04 ^{de}	4.06±0.51 ^D
T5	1.75±0.05 ^v	2.60±0.05 ^t	3.52±0.02 ⁿ	4.12±0.03 ^l	2.99±0.34 ^F
T6	1.88±0.08 ^v	2.85±0.05 ^{sr}	3.71±0.01 ^m	4.45±0.05 ^j	3.22±0.36 ^E

The averages that bear different letters, differ significantly ($P < 0.01$) among them (large letters are a main effect of treatment and storage duration and low-case letters are the effect of the interaction between treatment and storage duration).

Source: Authors' own elaboration

According to the statistical analysis, there was a significant difference ($P < 0.01$) between the periods, where the PV value was at its lowest in one day and then started to increase as the storage period went on, reaching its highest in forty-five days, as explained by Wasli et al. (2018). Dill leaves decreased oxidation indicators and demonstrated high antioxidant activity. Our results matched that. According to Iraqi standards, the amount of peroxide permitted for oil or fat cannot be greater than 10 mEq/kg fat according to the specifications of the Central Instrument for Measurement and Quality Control, 1987 (Saleh and Mohammed, 2020).

Conclusions

Particularly, treatments T5 and T6 showed exceptional effectiveness in lowering lipid oxidation, stabilizing pH, and minimizing the buildup of FFA and TVN. According to these results, bovine burgers' shelf life can be considerably increased, while maintaining their nutritional value and sensory appeal by carefully choosing and optimizing the ingredients.

The study emphasizes how crucial it is to regulate storage conditions in order to reduce microbial and enzymatic activity that causes a pH fall, FFA buildup, and TVN increase. Modified atmosphere packaging (MAP) or more stringent temperature controls could improve the stability of bovine burgers during longer storage times.

The association between enzymatic activity and quality parameters appears to be a strong association between enzymatic activity and quality degradation, as seen by the reported decrease in pH and increase in FFA and TVN levels. Future research could look at the precise enzymes that break down proteins and fats, allowing for tailored interventions to stop their activity and extend the shelf life of products.

The results have wider ramifications for the meat industry, especially in terms of cutting down on food.

Customized preservation techniques for varying storage times: The study shows that treatment efficacy varies with storage time. For example, T5 demonstrated steady effectiveness in lowering oxidation over long periods of time, while T6 was very successful in preserving pH during early storage. This implies that depending on the anticipated storage time, customized preservation techniques combining various treatments or additives could be created.

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