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Research Article

The effects of different herbs on the quality characteristics of Sucuk (Turkish dry-fermented sausage)

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ABSTRACT

The effects of thyme, rosemary, and dill as a natural antioxidant alternative to nitrite on some quality characteristics of Turkish type dry-fermented sausage (Sucuk) were investigated. Samples were prepared with the addition of powder forms of these herbs and ripened for 15 days. According to the results, the addition of herbs did not result in a significant difference in pH, water activity (a_w), ash and dry matter values, and lightness (L*) of the products. The significant decrease in instrumental a* values with the addition of herbs and the decrease in color scores in the sensory analysis were similar, and all groups containing natural antioxidants (herbs) scored higher in odor evaluation than the control group. Considering TBARS values, significantly higher results were observed in all herb added groups during the ripening period. However, the addition of herbs caused a decrease in the hardness, adhesiveness, and cohesiveness values of Sucuks compared to the nitrite added groups.

Keywords: Sucuk, Thyme, Rosemary, Dill, Nitrite

Introduction

Drying and fermentation processes can be considered the oldest and the most common methods for preservation in the meat industry, and thanks to these techniques, a wide variety of meat products can be produced, such as sausages, ham, and salami. In the fermentation process, preservative effects are generally achieved by mixing the minced meat and fatty tissue with curing agents, carbohydrates, and spices. Then, considering the sausages production, the mixture is stuffed into natural or synthetic casings and allowed to ripening and drying. The difference and quality of raw material, various curing agents, fermentation and drying conditions enable the production of a wide variety of fermented meat products (Ercoskun & Özkal, 2011; Kaban, 2013; Demirgül & Tuncer, 2017).

Sucuk, a dry-fermented sausage, is one of the traditional foods that widely produced and consumed in Turkey. Production of Sucuk consists of mixing the beef, sheep or water buffalo meat and sheep tail fat and/or beef fat with the curing agents (nitrite and/or nitrate), various spices including cumin, garlic, salt, and black and red pepper, stuffing this mixture into a casing (mostly cattle small intestines), hung for fermentation (ripening) at 22-23 °C by natural meat microbiota or added starter cultures and allowing to dry for several weeks at ambient temperature and humidity (Kilic, 2009). Although the initial microbiota of the mixture is dominated by microorganisms originating mainly from raw meat, such as *Pseudomonas spp.*, *Enterobacteriaceae*, and *Escherichia coli*, the microbiota shifts toward the lactic acid bacteria (LAB) and *Micrococcaceae* due to ripening, moisture loss, and oxygen consumption. Therefore, these products are mainly stabilized by acidification via LAB and reduction in water activity (a_w) during ripening and drying (Vignolo et al., 2010; Paramithiotis et al., 2010).

Nitrites and/or nitrates are the most commonly used curing agents in dry-fermented sausage production because of the interactions between these compounds and meat myoglobin, as well as their antioxidant properties contributing to desired meat flavor, and antimicrobial properties, especially against *Clostridium botulinum* (Martin, 2012; Hospital et al., 2014, 2016; Bonifacie et al., 2021). However, ingestion of high amounts of nitrite can cause various adverse effects on human health, both due to the residual content in cured meat and/or excessive consumption of cured meat (Parthasarathy & Bryan, 2012; Waga et al., 2017). Nitrite can interact with secondary amines to produce nitric oxide, which forms N-nitrosamines, which is reported to cause gastric cancer (De Mey et al., 2017; Flores et al., 2019; Flores & Toldrá, 2020). Thus, the amount of these compounds added to foods is being limited, and only the lowest concentrations are consistent in terms of food safety and health (Cammack et al., 1999). And also consumers demand safe meat products without chemical additives (Fraqueza et al., 2021). For this purpose, the replacement of nitrite/nitrate with natural antioxidants and antimicrobials in meat products is gained attraction by many researchers (Riel et al., 2017; Jin et al., 2018; Sucu &Turp, 2018; Pini et al., 2020; Tang et al., 2021).

Culinary herbs and spices have been used since ancient times for taste and shelf-life purposes (Bishov et al., 1977). Thyme (*Thymus vulgaris* L.), which belongs to the genus *Thymus* of the Lamiaceae family, is an aromatic and well-known herb that is widely cultivated worldwide (Morales, 2002). It is a good source of a vast variety of bioactive materials, such as lutein, apigenin, naringenin, luteolin, thymol and carvacrol, possessing significant antioxidant properties (El-Guendouz et al., 2019). Rosemary (*Rosmarinus officinalis* L.) is a wild shrub, which generally grows in the Mediterranean basin, belonging to the Lamiaceae family. Owing to antioxidant, antimicrobial, anti-inflammatory, antimutagen, anti-tumor, and aromatic properties, it is widely used in different foods and traditional medicine (Al-Sereiti et al., 1999; Moreno et al., 2006). *Anethum graveolens* L., commonly known as dill, is an annual herb that belongs to the family Apiaceae, widely cultivated in Mediterranean countries. Besides the fact that it is a good source of essential oils, calcium, potassium, magnesium, phosphorus, sodium, vitamin A, and niacin, it exhibits antioxidant, antimicrobial, anticancer and anti-inflammatory effects (Oshaghi et al., 2015; Sintim et al., 2015; Sendijani et al., 2020).

In the literature, the effects of thyme and rosemary on dry fermented sausages have been reported by different authors (Oz et al., 2011; Jin et al., 2016), but studies in this topic are limited. There is, however, no report about the effects of dill on the properties of dry-fermented sausages. Therefore, the aim of the present study was to determine the effects of thyme, rosemary, dill, and combination of these herbs on the chemical, color, textural and sensory properties as well as lipid oxidation values of Sucuk products.

Materials and Methods

Materials

The materials used for the production of Sucuk (beef, tail fat, spices) were purchased from a local meat processing plant in Kırklareli, Turkey. On the other hand, $NaNO_2$ was purchased from Merck (Germany). The production and analysis of the samples were carried out in the laboratories of Kırklareli University, Department of Food Engineering.

Preparation of Rosemary, Thyme, and Dill Powder

Thyme and rosemary were taken as dried. Dill was taken as fresh and dried (25±2°C) in laboratory conditions. Then, they were ground into powder form using a grinder (Siemens, Germany) and added to sucuk samples in powder form.

Production of Sucuks

Beef (80%) and tail fat (20%) constituted the main components of sucuk. For this purpose, the frozen meat and the fat were first thawed for 24 hours at 4±2 °C, and then the meat was cleaned of impurities such as visible fat, tendon, cartilage, nerves, connective tissues, blood, and dirt. Afterward, the meat and the fat were separately minced through a 12 mm plate using a meat grinder (Ari Makina, Istanbul). Five batches were prepared depending on the antioxidant source used in the formulations, namely nitrite (control), thyme, rosemary,dill-containing groups, and a group that containing a combination of these herbs (mixed). The amounts of these compounds and other additives such as salt, garlic, sugar, etc. showed in Table 1. Each group of prepared sausage dough was minced again and made ready for stuffing. The sucuk doughs was stuffed in pre-soaked natural bovine intestines, tied, and hanged. The prepared sucuks were ripened first by keeping them at 25 ± 1°C and 90% RH for 3 days and then at 20 ± 1°C and 80-85% RH for 12 days. All treatments were replicated independently twice. For each replicate, 5 Sucuks were produced per treatment. Sucuk samples at days 5, 10, and 15 of ripening were taken for pH, aw, TBARS, while samples at day 15 of ripening (end of ripening period) for dry matter, ash, color, textural and sensorial analysis.

Table 1. The formulations of the Sucuks.

Ingredients (%)	**Sample groups**				
	Nitrite AS	Thyme AS	Rosemary AS	Dill AS	Mixed Herbs AS
Meat	80	80	80	80	80
Fat	20	20	20	20	20
Salt	2.5	2.5	2.5	2.5	2.5
Garlic	1	1	1	1	1
Sugar	0.4	0.4	0.4	0.4	0.4
Sweet paprika	0.5	0.5	0.5	0.5	0.5
Black pepper	0.6	0.5	0.5	0.5	0.5
Cumin	0.6	0.5	0.5	0.5	0.5
$NaNO_2$	0.0015	-	-	-	-
Thyme	-	0.5	-	-	0.5
Rosemary	-	-	0.5	-	0.5
Dill	-	-	-	0.5	0.5

Abbreviation: AS, Added Sucuk

Chemical and Physicochemical Analysis

The dry matter content of sucuk was determined by drying the sample in an oven at 105 °C until a constant weight was obtained (AOAC, 1990). Ash content was determined by dry ashing in a furnace oven at 525 °C for 24 h (AOAC, 1990). Ten grams of sucuk was homogenized in 90 mL of distilled water for 1 min and the pH value of sucuk was determined by immersing the probe of the pH meter (Hanna, Germany). Water activity (a_w) was measured using a water activity measuring device (Novasina LabSwift, Switzerland) after the samples stabilized for 30 min at 25 °C (Cetin et al., 2019). The method of Gokoglu et al. (2010) was employed for the determination of the extent of lipid oxidation (TBARS) in Sucuk samples using a spectrophotometer (Shimadzu, Japan). Results were expressed as mg malonaldehyde/kg.

Color Measurement

The color of the sucuks that sliced to the approximately same sizes was determined using a colorimeter (CR-400, Minolta, Japan). Five consecutive readings were taken from the insides of the samples using the CIE L* (lightness), a* (redness), and b* (yellowness) system and the results were averaged. In the measurements, the device was adjusted that illuminator D65, aperture size of 8 mm and an observer angle of 10°.

Texture Profile Analysis

The sucuk samples were subjected to texture profile analysis (TPA) using the Texture Analyzer (TA.HD Plus Stable Micro Systems LTD., Surrey, England). Sucuk samples were given a cubic shape with 2x2x2 cm^3. A double compression cycle test was performed up to 50% strain compression of the original portion height using an aluminum cylinder probe (SMS P/36, 36 mm diameter, TA.HD Plus Stable Micro Systems LTD., Surrey, England). A time of 3 s was allowed to elapse between the two compression cycles. Force-time deformation curves were obtained with a 30 kg load cell applied. Pretest, test, and posttest speeds were 1, 5, and 1 mm/s, respectively. The force-distance curves were recorded and force and distance of maximum force peak and the area under the curve were evaluated as representative mechanical parameters, i.e., hardness, chewiness, gumminess, adhesiveness, springiness, cohesiveness, and resilience. All measurements were repeated five times and mean values were recorded (Dertli et al., 2016).

Sensory Evaluation

Sensory parameters (color, odor, flavor, texture, and overall acceptance) of the samples were evaluated by ten panelists. The panelists were chosen especially from people who habitually consume Sucuk and had experience in sensory analysis of various meat products. All panelists were informed about the study at the beginning of panel. Panelists participated in one session and ten samples (two pieces for each sample group) were presented to each panelist. Before the assessment, Sucuk samples were sliced to approximately 0.5 cm and cooked for 3 minutes at 180 °C via the preheated grill. After cooking, the samples were coded using letters and randomly presented to the panelists. Trained panelists evaluated the effects of the addition of different spices on the sensory attributes of sucuk. Water has been consumed before the assessment of each sample. Responses were recorded using a hedonic scale, where the panelists scored from 0 (dislike extremely) to 10 (like extremely) for corresponding attributes (Uran & Gokoglu, 2014).

Statistical Analysis

A one-way analysis of variance (ANOVA) design were performed using with SPSS 18 (SPSS Statistics/IBM, Armonk, NY) software. As random and fixed factors, replications and five different treatments (Nitrite, Thyme, Rosemary, Dill and Mixed Herbs AS) were used, respectively. TBARS, aw and pH analysis were applied as a repeated factor for four levels of ripening period (Day 1, 5, 10 and 15) and one level (after ripening, day 15) were used for the determination of dry matter, ash, TPA and color of Sucuks. Also the treatments were identified as a fixed effect for the statistical evaluation of sensory data, while panelists were accepted as a random effect. When there were differences among the samples, Duncan's Multiple Comparison Test was used to compare differences between means. The significance level was set at 0.05 ($p < 0.05$). All data were expressed as mean values ± standard error of the mean (SEM) in tables.

Results and Discussion

Proximate Composition and pH Values

As shown in Table 2, the incorporation of different herbs did not influence the dry matter and ash content of Sucuk samples significantly ($p>0.05$). Similar results were reported in the literature for the proximate composition of Sucuk by different authors (Kayaardı & Gök, 2004; Ekici et al., 2015). According to the Turkish Standard Institute (TS 1070, 2002), the moisture content of sucuk must be reduced below 40% in the ripening period.

Table 2. Proximate composition and pH values of the Sucuks.

Sample	Dry Matter	Ash	pH			
			Day 1	Day 5	Day 10	Day 15
Nitrite AS	62.52±1.28^{a}	5.99±0.27^{a}	5.46±0.04^{aA}	4.57±0.12^{aB}	4.19±0.08^{aB}	4.31±0.11^{aB}
Thyme AS	62.76±1.15^{a}	5.54±0.01^{a}	5.45±0.00^{aA}	4.26±0.05^{abB}	4.26±0.10^{aB}	4.17±0.06^{aB}
Rosemary AS	65.04±2.22^{a}	5.84±0.05^{a}	5.34±0.01^{bA}	4.21±0.00^{bB}	4.31±0.12^{aB}	4.22±0.05^{aB}
Dill AS	62.09±0.33^{a}	6.20±0.18^{a}	5.45±0.00^{aA}	4.30±0.01^{abB}	4.20±0.14^{aB}	4.25±0.06^{aB}
Mixed herbs AS	65.48±0.14^{a}	6.12±0.01^{a}	5.39±0.01^{abA}	4.26±0.03^{abB}	4.16±0.08^{aB}	4.45±0.01^{aB}

Note: Means with different superscript lowercase letters at the same column show the significant differences between the samples ($p < 0.05$). Means with different superscript uppercase letters at the same line show the significant differences between the samples ($p < 0.05$).
Abbreviation: AS, Added Sucuk.

As can be seen from the dry matter values in Table 2, the moisture content of sucuk samples at day 15 of the ripening period was acceptable. Bozkurt and Bayram (2006) reported that the reduction in moisture content of sucuk is associated with the moisture loss at high ripening temperature and low relative humidity. Furthermore, the authors found a significant relationship between moisture content and sensorial properties, and thus stated that the decreased moisture content has led to an increase in the sensory scores. Similarly, no significant difference was observed in the moisture content of Sucuk samples with the addition of thyme, while the moisture content decreased from 58.63% to 36.74% after 14 days of ripening (Oz et al., 2011).

Fermentation and drying are the most crucial processes for the development of the main quality attributes of Sucuk. pH values of the samples were identical for the first day of the fermentation period except for the rosemary added group and showed a similar trend during fermentation, where the pH decreased sharply at day 5, due to organic acid production by microorganisms, and then no statistical differences were observed (Table 2). After the 10th day, a slight increase observed towards the 15th day in the nitrite and mixed herbs containing groups can be attributed to the decomposition of acids and production of basic nitrogenous compounds (Ercoskun & Ozkal, 2011). These results are in agreement with the literature (Bozkurt, 2006; Kurt, 2016), where a sharp decrease reported at first days followed by an increase. The decrease in pH due to glycolysis and LAB provides some serious advantages, including selective inhibition of undesirable microbial flora and growth, promoting the texture development due to a decrease in water-retention capacity, as well as the drying process and gelation mechanisms, avoiding the enzymatic and chemical reactions associated with flavor, odor, and color (Ordóñez et al., 1999). The Turkish Standard Institute (TS 1070, 2002) states that the pH value of high-quality Sucuk must be in the range of 4.7-5.4. However, our samples were found to be lower than this range, which might be due to the initial pH value and general microbiota of raw meat and/or ripening conditions. Similarly, Gök et al. (2011) reported that the storage time of 60 days gave better results in terms of pH rather than Sucuks stored for 0, 30, or 90 days, which had lower or higher pH values than standard range.

Water Activity (a_w) Values

According to Table 3, although the highest aw value was observed for the thyme added group, it was not statistically different from other groups (p>0.05). During ripening period, aw values decreased seriously due to the gradual drying of Sucuk samples, and the minimum aw values were obtained at day 15.

Table 3. Water activity values of the Sucuks.

Sample	Water Activity (a_w)			
	Day 1	Day 5	Day 10	Day 15
Nitrite AS	0.950±0.001^{aA}	0.919±0.000^{aB}	0.898±0.001^{aC}	0.878±0.000^{aD}
Thyme AS	0.952±0.000^{aA}	0.915±0.002^{aB}	0.894±0.004^{aC}	0.873±0.004^{aD}
Rosemary AS	0.950±0.000^{aA}	0.907±0.003^{aB}	0.894±0.004^{aB}	0.874±0.000^{aC}
Dill AS	0.944±0.005^{aA}	0.914±0.003^{aB}	0.888±0.000^{aC}	0.872±0.004^{aC}
Mixed herbs AS	0.950±0.001^{aA}	0.913±0.001^{aB}	0.888±0.003^{aC}	0.867±0.001^{aD}

Note: Means with different superscript lowercase letters at the same column show the significant differences between the samples ($p < 0.05$). Means with different superscript uppercase letters at the same line show the significant differences between the samples ($p < 0.05$).
Abbreviation: AS, Added Sucuk.

Similar results were reported in the literature (Soncu et al., 2018, 2020). This reduction caused by dehydration helps to the evolution of characteristic texture and to stabilization of Sucuk (Ordóñez et al., 1999). Decreasing the a_w values to 0.90 or below exhibits a significant hurdle effect and inhibits bacterial growth (Lücke, 1998). Furthermore, there might be a relation between a_w and pH values of Sucuk samples. This relation has been explained as a characteristic property of Sucuk by Gökalp et al. (1999), where the decreasing pH values to the isoelectric points of the meat proteins on the first days has led to an increase in moisture loss. In addition, a decrease in a_w of the dry-fermented sausages exhibits a significant inhibitory effect on the cathepsin B, L, H, and D activities (Toldrá et al., 1992).

Thiobarbituric Acid Reactive Substances (TBARS) Values

Nitrites and nitrates are often incorporated into dry-fermented sausages due to their ability to interact with meat components and providing color, flavor, antibacterial and antioxidant properties to the product (Zubillaga et al., 1984; Hospital et al., 2014, 2016; Bonifacie et al., 2021). However, health-related concerns of these chemical antioxidants, such as chemical toxicity, formation of carcinogens in food or after ingestion, and reproductive and developmental toxicity, as well as increasing consumer demands towards more natural and organic foods have led to intensive research for substituting these compounds with natural ones (Sebranek & Bacus, 2007). Compounds present in various plant products, such as flavonoids, tannins, coumarins, curcuminoids, xanthones, phenolics, lignans, and terpenoids, exhibit significant antioxidant properties (Roby et al., 2013) and thus they may be an alternative to nitrate/nitrite in sucuk. In this context, owing to the carnosol, carnosic acid, ursolic acid, rosmarinic acid in rosemary (Rašković et al., 2014), thymol and carvacrol in thyme (Kulisic et al., 2005), and chlorogenic acid and myricetin in dill (Shyu et al., 2009), the use of these herbs would have been expected to show antioxidant activity. However, TBARS values of sucuk samples were higher than the control group for the entire ripening period (p<0.05). In our study, TBARS values of the control group significantly increased with ripening time (Table 4). Moreover, the rate of TBARS formation was faster during the first 5 days, which might be an indication of the lipid oxidation started from the first 5 days for all groups as reported by Bozkurt and Erkmen (2007), but remained almost the same after day 10 for natural antioxidant incorporated groups.

Although the TBARS values of the control group were lower at the end of the ripening period, it may be concluded that herbs showed higher stability than nitrite in terms of lipid oxidation, as can be seen in Table 4, which indicates a 245% increase in the control group compared to 167%, 148%, 131%, and 130% in thyme, rosemary, dill, and mixed groups, respectively. These results are in agreement with the findings of Tsoukalas et al. (2011), who reported that the TBARS values of freeze-dried leek powder added fermented sausages were higher than nitrite added ones, but they suggested that nitrite combined with the freeze-dried leek powder must be added to fermented sausages for suppressing the lipid oxidation. Similarly, Jin et al. (2016) found that the addition of thyme and rosemary powder did not affect the TBARS values of sausages, while the DPPH radical scavenging capacity of the sausage samples was significantly improved with the addition of these spices. In contrast, Soncu et al. (2020) applied the thyme or rosemary essential oil containing chitosan to dry-fermented sausages as an antifungal approach and found that the thyme or rosemary essential oils combined with the chitosan resulted in lower TBARS values than control groups. The differences between TBARS results may be due to different application methods (e.g., the extracts or essential oils might contain higher amounts of phenolic components than powder form and thus exhibit better antioxidant activity), ripening conditions, salt concentration, fat contents, and incorporation of different spices and additives. In addition, it should be noted that these spices possess various health-promoting and therapeutic effects, which are important factors in terms of consumer perception and advantages over nitrite.

Table 4. TBARS values of the Sucuks.

Sample	TBARS (mg malonaldehyde/kg)			
	Day 1	Day 5	Day 10	Day 15
Nitrite AS	0.040 ± 0.002^{bD}	0.079 ± 0.002^{bC}	0.086 ± 0.000^{bB}	0.098 ± 0.001^{bA}
Thyme AS	0.073 ± 0.008^{aC}	0.101 ± 0.001^{aB}	0.110 ± 0.004^{aAB}	0.122 ± 0.003^{aA}
Rosemary AS	0.080 ± 0.009^{aB}	0.106 ± 0.001^{aA}	0.110 ± 0.000^{aA}	0.118 ± 0.002^{aA}
Dill AS	0.090 ± 0.001^{aC}	0.102 ± 0.003^{aB}	0.111 ± 0.001^{aAB}	0.118 ± 0.004^{aA}
Mixed herbs AS	0.095 ± 0.004^{aC}	0.106 ± 0.000^{aBC}	0.113 ± 0.002^{aAB}	0.124 ± 0.003^{aA}

Note: Means with different superscript lowercase letters at the same column show the significant differences between the samples (p < 0.05). Means with different superscript uppercase letters at the same line show the significant differences between the samples (p < 0.05).

Abbreviation: AS, Added Sucuk.

Texture Properties

Textural properties of Sucuk significantly influence the commercial value of the product. It has been reported that the most important textural properties are hardness, springiness, and cohesiveness in dry-fermented sausages, and high values of these parameters may have a negative impact on the sensory evaluation. Furthermore, significant correlations were found between sensory chewiness and these parameters (Chorbadzhiev et al., 2017). Hardness, which is defined as a maximum force to compress a sample, is the most important parameter as it is one of the factors that determines the commercial value of Sucuk. Cohesiveness is an indicator of the strength of internal bonds and it represents the viscoelastic properties of Sucuk together with the springiness. Adhesiveness is the work needed to overcome the attractive forces between the surface of the sucuk and the surface of other materials, which come into contact with the food, such as the mouth, lips, and teeth. Chewiness, which is an indicator of the ease of the chewing process, represents the total time for the reduction of Sucuk into a state ready for swallowing, while gumminess is defined as the chewing energy required to disintegrate Sucuk before swallowing. Resilience defines how well the Sucuk regains its original height following the removal of deformation (Kilcast, 2004; Pandey et al., 2014).

In our study, the textural properties of Sucuk samples produced with different herbs in terms of hardness, adhesiveness, cohesiveness, springiness, gumminess, chewiness, and resilience were determined and the results were given in Table 5. In the ripening period, the initial meat mixture, which has weak internal bonds and hence exhibits soft behavior, is converted into a semisolid/solid product due to protein coagulation at low pH, moisture loss, and gelation of proteins, with an increase in the hardness, gumminess and chewiness, and a decrease in adhesiveness and springiness (Bozkurt & Bayram, 2006; Kargozari et al., 2014).

As seen in Table 5, the addition of herbs caused a significant decrease in the hardness and adhesiveness values of the Sucuk samples ($p<0.05$). Especially rosemary and dill made the Sucuks softer. However, the addition of spices did not cause any significant difference between samples in terms of cohesiveness, springiness, chewiness and resilience ($p>0.05$) and thus, it can be concluded that no negative effect was observed on textural properties. Furthermore, the texture of our Sucuk samples was elastic and easily sliceable, and they did not stick to the knife during slicing. Similar to our findings, Sucu and Turp (2018) found no significant changes in textural properties of Sucuk with the addition of beetroot powder, but higher values for these parameters (hardness and gumminess) were determined in our study. In another study, although no significant changes were observed for hardness values of Sucuks prepared with the black carrot concentrate, other textural properties were found to be significantly lower, especially with the addition of 2% black carrot concentrate + 150 mg/kg sodium nitrite (Ekici et al., 2015).

Table 5. Texture profile (TPA) of the Sucuks at day 15 of the ripening period.

Sample	Hardness (N)	Adhesiveness (g.sec)	Cohesiveness	Springiness	Gumminess (Nxmm)	Chewiness (Nxmm)	Resilience
Nitrite AS	52.45 $\pm1.78^{a}$	-15.32 $\pm0.78^{a}$	0.66 $\pm0.00^{a}$	0.56 $\pm0.00^{a}$	30.42 $\pm1.53^{a}$	13.76 $\pm1.39^{a}$	0.25 $\pm0.00^{a}$
Thyme AS	45.41 $\pm0.28^{ab}$	-26.95 $\pm0.53^{b}$	0.58 $\pm0.00^{a}$	0.55 $\pm0.00^{a}$	26.55 $\pm0.46^{ab}$	14.87 $\pm0.52^{a}$	0.21 $\pm0.00^{a}$
Rosemary AS	40.52 $\pm1.22^{b}$	-36.67 $\pm1.52^{c}$	0.58 $\pm0.00^{a}$	0.60 $\pm0.00^{a}$	23.59 $\pm0.55^{b}$	14.23 $\pm0.45^{a}$	0.19 $\pm0.00^{a}$
Dill AS	40.11 $\pm1.54^{b}$	-39.04 $\pm1.04^{c}$	0.62 $\pm0.00^{a}$	0.59 $\pm0.00^{a}$	25.05 $\pm0.64^{b}$	14.85 $\pm0.34^{a}$	0.23 $\pm0.00^{a}$
Mixed herbs AS	50.18 $\pm0.49^{a}$	-47.05 $\pm1.57^{d}$	0.60 $\pm0.00^{a}$	0.56 $\pm0.00^{a}$	30.44 $\pm0.51^{a}$	17.21 $\pm0.22^{a}$	0.23 $\pm0.00^{a}$

Note: Means with different superscript lowercase letters at the same column show the significant differences between the samples ($p < 0.05$).
Abbreviation: AS, Added Sucuk.

Color and Sensorial Properties

Color is one of the most important properties of Sucuk, which generally shows a brick-red color in Turkey, in terms of quality and consumer perception. Color of Sucuk develops in the first days of ripening due to the production of nitrosomyoglobin and moisture loss and starts to decrease following days as a consequence of denaturation of nitrosomyoglobin via lactic acid generation (Bozkurt & Bayram, 2006). Thus, to protect this desired red color for a longer period, antioxidants such as nitrate/nitrite are generally used. In the present study, the replacement of nitrite with natural antioxidants did not influence the lightness (L*) and b* values of Sucuk samples, while the a* values were found to be significantly different from the control group ($p<0.05$) (Table 6). However, the dill added group had dramatically higher b* values than the thyme added group, which indicated that the color of Sucuk slightly more blue rather than yellow in the thyme added group ($p<0.05$). This might be due to the difference in pigment intensity between the two spices.

Table 6. Color characteristics of the Sucuks at day 15 of the ripening period.

Sample	*L**	*a**	*b**
Nitrite AS	48.71 ± 0.74^{a}	16.84 ± 0.35^{a}	9.66 ± 0.37^{ab}
Thyme AS	48.62 ± 0.77^{a}	10.41 ± 0.89^{b}	8.18 ± 0.67^{b}
Rosemary AS	50.01 ± 0.88^{a}	9.60 ± 0.36^{b}	8.65 ± 0.48^{ab}
Dill AS	46.81 ± 0.85^{a}	2.60 ± 0.37^{c}	10.67 ± 0.55^{a}
Mixed herbs AS	49.41 ± 0.33^{a}	4.57 ± 0.11^{c}	10.14 ± 0.06^{ab}

Note: Means with different superscript lowercase letters at the same column show the significant differences between the samples ($p < 0.05$).
Abbreviation: AS, Added Sucuk.

Table 7. Sensory properties of the Sucuks at day 15 of the ripening period.

Sample	Color	Odor	Flavor	Texture	Overall Acceptance
Nitrite AS	$7{,}18\pm0{,}04^{a}$	$6{,}29\pm0.20^{a}$	$7{,}13\pm0.14^{a}$	$7{,}08\pm0.15^{a}$	$6{,}98\pm0.14^{a}$
Thyme AS	$5{,}58\pm0.10^{b}$	$6{,}39\pm0.02^{a}$	$7{,}08\pm0.13^{a}$	$6{,}24\pm0.16^{ab}$	$6{,}51\pm0.23^{a}$
Rosemary AS	$5{,}15\pm0.10^{bc}$	$6{,}11\pm0.02^{ab}$	$5{,}48\pm0.11^{b}$	$5{,}87\pm0.10^{b}$	$5{,}02\pm0.33^{b}$
Dill AS	$4{,}76\pm0.10^{c}$	$5{,}44\pm0.10^{b}$	$5{,}10\pm0.11^{b}$	$6{,}14\pm0.27^{ab}$	$5{,}17\pm0.35^{b}$
Mixed herbs AS	$5{,}02\pm0.20^{bc}$	$5{,}63\pm0.24^{ab}$	$5{,}22\pm0.10^{b}$	$6{,}26\pm0.15^{ab}$	$5{,}51\pm0.47^{ab}$

Note: Means with different superscript lowercase letters at the same column show the significant differences between the samples ($p < 0.05$).
Abbreviation: AS, Added Sucuk.

Conclusion

In the present study, the use of various herbs (dill, thyme, rosemary) as a replacement of nitrite in Sucuk production was performed and it has been seen that these herbs can be an alternative to nitrite as natural antioxidants. To the best of our knowledge, this is the first study on the use of dill as a natural antioxidant on Sucuk, a traditional fermented sausage. According to the results, the pH and a_w values were not affected by the addition of herbs, these values dramatically reduced as the ripening continued, due to lactic acid production and moisture loss, respectively. The addition of thyme, rosemary, and dill to the samples did not effectively reduce the TBARS values compared to nitrite. According to the color analysis, herbs addition decreased the *a** values of samples and this decrease negatively affected the panelist scores for sensory attributes. However, it has been understood that the addition of herbs has positive contributions in terms of flavor and odor. In the texture analysis, the use of herbs showed the softer structure compared the control group produced with nitrite. Considering all these results, herbs can be used as a good natural source of dietary bioactive components to reduce the amount of nitrate/nitrite in Sucuk at optimized concentrations without affecting the quality properties.

Compliance with Ethical Standard

Conflict of interests: The author declares that for this article they have no actual, potential, or perceived conflict of interests.

Ethics committee approval: The author declares that this study does not include any experiments with human or animal subjects; therefore, no ethics committee approval is needed.

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