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# Investigation of Pulsed UV Light Effects on Turkey Salami

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ABSTRACT

Pulsed UV light application has been a method used frequently in ensuring food safety recently. UV treatment is used in many areas including the food industry through UV treatment and high inactivation power. Pulsed UV light, which is an effective microbial inactivation method that takes place in a shorter time in solid and liquid foods, as it is accepted as an alternative to continuous UV light application, is a promising alternative to both chemical and thermal decontamination methods in the food industry. In this study, pulsed UV light was applied on ready-to-consumption packaged turkey salami samples. In order to ensure food safety and reduce consumer anxiety, the effect of pulsed UV light application of different time and distance on turkey salami slices contaminated with *Listeria monocytogenes* in equal thickness in order to use UV light was investigated. The effect of pulsed UV application on the microbial inactivation efficiency of the salami surface and the quality of the salami were evaluated. In pulsed UV light system, 3 different distances of quartz glass to samples will be 5-8-13 cm and sliced salami in 3 different periods of 15-30-60 sec. The results of the study showed that pulsed UV light method could be used effectively in inactivation against *L. monocytogenes* on the salami surface as an alternative to thermal and chemical methods. It was determined that *L. monocytogenes* inactivation increased as the distance to the quartz lamp decreased and the application time and total energy dose increased. The highest inactivation was obtained after 5 cm 60 sec pulsed UV light treatment.

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# Hindi Salama Uygulanan Atımlı UV Işık Etkilerinin İncelenmesi

MAKALE BİLGİSİ

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Et ürünleri

ÖZ

Atımlı UV ışık uygulaması gıda güvenliğinin sağlanmasında son dönemlerde sıklıkla uygulanan bir yöntem olmuştur. UV işleminin kolaylığı ve yüksek inaktivasyon gücü sayesinde gıda endüstrisi dahil birçok alanda kullanılmaktadır. Sürekli UV ışık uygulamasına da alternatif olarak kabul edildiği gibi katı ve sıvı gıdalarda daha kısa sürede gerçekleşen etkili bir mikrobiyal inaktivasyon yöntemi olan atımlı UV ışık, gıda sanayisinde hem kimyasal hem de ısıl dekontaminasyon yöntemlerine karşı ümit verici bir alternatiftir. Bu çalışmada, tüketime hazır ambalajlı hindi salam örnekleri üzerinde atımlı UV ışık uygulaması yapılmıştır. Gıda güvenliğinin sağlanması ve tüketicilerin kaygılarının azaltılmasında UV ışık kullanımı amacıyla *Listeria monocytogenes* ile kontamine edilmiş eşit kalınlıktaki hindi salam dilimlerine farklı süre ve uzaklıktaki atımlı UV ışık uygulamasının etkisi araştırılmıştır. Atımlı UV uygulamasının salam yüzeyindeki mikrobiyal inaktivasyon etkinliği ve salamın kalitesi üzerine etkisi değerlendirilmiştir. Atımlı UV ışık sisteminde kuvars camın örneklere uzaklıkları 5-8-13 cm olacak şekilde 3 farklı mesafe ve 15-30-60 s olacak şekilde 3 farklı sürede dilimli salamlara uygulama yapılmıştır. Çalışma sonuçları, atımlı UV ışık yönteminin ısıl ve kimyasal yöntemlere alternatif olarak salam yüzeyinde *L. monocytogenes*'e karşı inaktivasyonda etkili bir şekilde kullanılabileceğini göstermiştir. Kuvars lambaya olan mesafe azaldıkça, uygulama süresi ve toplam enerji dozu arttıkça *L. monocytogenes*'in inaktivasyonunun arttığı belirlenmiştir. En yüksek inaktivasyon 5 cm 60 s atımlı UV ışık işlemi sonrası elde edilmiştir.

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## Introduction

Salami is preferred for both cold kitchen products and long journeys due to its high nutritional properties and long shelf life. In addition, it carries a risk on food safety since it is generally consumed without heat treatment. This risk may arise from personnel or poor hygiene conditions after completing the product process. Various preservation techniques developed and renewed may be preferred in order to avoid microbial problems that may occur in salami, processing and storage. Pulsed UV light, one of the food preservation techniques, is a promising alternative to both chemical and thermal decontamination methods in the food industry (Manzocco et al., 2015).

Due to its microbial inactivation feature, UV light, which provides decontamination on surfaces, uses short-time, intense pulses in the wavelength range of 100-1100 nm, which is rich in UV-C light. This technology is an effective microbial inactivation method that takes place in a shorter time in solid and liquid foods, as it is accepted as an alternative to continuous UV light application (Oms-Oliu, 2010). The electrical energy accumulated in a high power capacitor during pulsed UV light application is released as intermittent, intense, short pulses of light on the inert gas (eg xenon) lamp. These pulses often take a few seconds (Krishnamurthy, 2007). Pulsed UV light application, the working principle of which is explained by several mechanisms, has a lethal effect on microorganisms. Microbial reduction with this technique; damage to microorganism DNA with the formation of thymine dimers (photochemical effect) occurs through localized overheating of microbial cells (photothermal effect) and structural damage (photophysical effect) due to pulses (Takeshita et al., 2003). There are study reports on decontamination of vegetables, fruits, food powders and seeds, dairy products, fish, honey and instant milk powder, apple and orange juice, poultry meat products using pulsed UV light (Keklik et al., 2009). In addition, pulsed light has different applications on equipment surfaces and packaging materials.

In this study, the effect of pulsed UV light application of different time and distance on turkey salami slices contaminated with *Listeria monocytogenes* in order to ensure food safety in ready-to-eat meat products and to reduce consumer concerns was investigated. The effect of pulsed UV application on the microbial inactivation efficiency of the salami surface and the quality of the salami were evaluated.

## MATERIAL AND METHOD

### Preparation of Salami Samples

Sliced turkey salami stored in vacuum packs was purchased from a local market. All of the salami are the same size and have a smooth surface. It was brought to Sivas Cumhuriyet University Food Engineering Laboratory in the cold chain (+ 4°C).

*L. monocytogenes Inoculation to Salami Samples*

In order to revive the culture of *Listeria monocytogenes* (CECT 935, Spanish Type Culture Collection, Spain) in Sivas Cumhuriyet University Food Engineering Laboratory, a small amount of the culture was taken under sterile conditions to Tryptic Soy Broth (TSB, Merck 1.05459, Darmstadt, Germany) and incubated at 37°C for 24 hours. Turbidity was observed in the tubes after the incubation. In order to determine whether the turbidity is caused by *L. monocytogenes*, a sample of microorganisms was taken from TSB and transferred to Palcam Agar (Liofilchem, Italy) and left for incubation under the same conditions. Incubation showed black zoned colonies and the presence of *L.monocytogenes* was detected (Halkman, 2005).

A loopful of microorganisms were taken from the working culture in Palcam agar and transferred to 10 mL TSB (Biokar Diagnostics, Beauvais, France). After incubating at 37°C for 24 hours, in order to remove the medium from the TSB culture obtained in the centrifuge (2-16 PK, Sigma, Germany) at 3000 rpm (1448 xg) for 12 minutes centrifuge has been done. The upper liquid part of the tube was removed and the cells were washed by shaking with 10 mL of 0.85% sterile physiological saline solution (Daejung, Korea). The inoculum solution was prepared by rinsing the cells in 10 mL of physiological saline solution by pouring the supernatant after centrifugation of the suspended cells under the same conditions (Halkman, 2005).

Salami slices of equal size and thickness were placed on sterile aluminum foils. 100 µL of *L.monocytogenes* inoculum liquid added to the surfaces of all salami slices was spread over the surface with a sterile pipette tip, and homogeneous distribution of the pathogen was achieved on the salami surface. Since the treatment of *L.monocytogenes* inoculated salami until the decontamination application is of great importance in terms of ensuring an effective process and reflecting the reality of the result achieved, the salami surface was kept at room temperature for 20 minutes in order to allow microorganisms to adhere.

*Pulsed UV Light Treatment*

Steri-Pulse XL 3000 Pulsed UV-Light Sterilization System (Xenon C1orporation, MA, USA) was used in the inactivation application. The system consists of a stainless steel sterilization cabinet, control module, lamp unit and cooling unit. Xenon lamp is a system with a pulse duration of 360 µs (time per pulse) that releases 1.27 J/cm$^2$ light energy 1.5 cm below the lamp surface by using 3800 V energy at a frequency of 3 Hz. The UV lamp makes 3 pulses per second (one pulse at 360 µs). The distance between the quartz glass and the lamp is 5.8 cm.

Each sliced salami sample inoculated with *L. monocytogenes* and positioned on sterile aluminum foils was exposed to pulsed UV light treatment for 15, 30, 60 sec at a distance of 5, 8, 13 cm from the quartz glass in a pulsed UV light system (Shi et al., 2010). Control group was not applied pulsed UV, A, B and C samples were applied pulsed UV as distance 5 cm for 15, 30 and 60 sec respectively, K, L and M samples were applied pulsed UV as distance 8 cm for 15, 30 and 60 sec respectively, X, Y and Z samples were applied pulsed UV as distance 13 cm for 15, 30 and 60 sec respectively,

In pulsed UV light application, the process that takes 60 sec at 5 cm is described as “severe”, the process that takes 30 sec at 8 cm is described as "moderate" and the process that takes 5 seconds at 13 cm as "light". Temperature and energy measurements were made for 5 cm-60 sec (severe), 8 cm-30 sec (moderate) and 13 cm-15 sec (light) process steps (Ancos et al., 2002).

*Temperature Measurements in Pulsed UV Light Application*

Temperature changes occurring during the application were kept at a distance of 2-2.5 mm from the surface of salami before and immediately after the process with an infrared thermometer (Extech Instrument, America), and temperature changes were investigated by measuring from the surface (Ancos et al., 2002).

***Microbiological Analysis***

For microbial analysis, 25 grams of treated and untreated salami slices are placed in sterile plastic bags (SM2-01, Gosselin, France) containing 225 ml of buffered peptone water (Lab M, UK) in a stomacher (Bag Mixer 400 P, Interscience, France) and was made homogeneous for one min. Serial dilutions were prepared for samples that became homogeneous in tubes with buffered peptone water. 100 µL of the prepared dilutions were taken under aseptic conditions and carefully planted in ready-made Palcam agar (Liofilchem, Italy) with the spreading method with a drigalski spatula. Then, petri dishes were left to incubate for 24 hours at 37°C. After incubation, typical colonies with a diameter of 1-1.5 mm in black zones formed on Palcam agar were counted and expressed as colony forming units per slice (cfu/g) (Keklik et al., 2009).

***Instrumental Colour Analysis***

Measurements were made using a colorimeter (CR-600, Konico Minolta, Japan) using the CIELAB color method. In this method, which gives numerical values of three color scales L (lightness), a (redness), b (yellowness); These parameters were measured at two randomly selected points on the salami surface and the average differences between the obtained L*, a*, b* values were determined (Candogan & Kolsarici, 2003).

***Thiobarbutyric Acid (TBA) Analysis***

Thiobarbutyric acid (TBA) number has been determined by the spectrophotometric method by modifying methods of Tarladgis et al. (1960) and Jin et al. (2014). According to the method, 25 mL of distilled water and 10 mL of 15% trichloroacetic acid (TCA) were added on 5 g of salami sample and homogenization was performed for 60 h. The mixture obtained was filtered through filter paper and 4 mL of filtrate was taken into a test tube, 1 mL of 0.06 N TBA solution was placed on it and incubated in a water bath for 90 minutes at 80°C. It was quickly cooled to room temperature and read against the standard solution in a Genesys 10S-UV VIS brand spectrophotometer with an absorbance value of 520 nm.

TBA number was calculated as (mg malonaldehyde/kg sample) = 7.8 ×Absorbance value.

***Statistical Analysis***

All analyses in the study were carried out with 3 parallel. ANOVA was used to determine the interactions of independent variables among themselves and their effects on the dependent variable with the obtained data, SPSS 17.0 package program. Whether the differences between the means of values were significant at 95% confidence interval (P<0.05) was tested by Tukey method.

## Results and Discussion

***Microbial Inactivation***

The number of *L.monocytogenes* after application of turkey salami samples contaminated with *L.monocytogenes* and applied with pulsed UV light at different time and distance was expressed in log cfu/g and is given in Table 1. The microbial density of the inoculum solution was determined as an average of $6\times10^8$ cfu/mL.

It was observed that the *L. monocytogenes* count of turkey salami was in the range of 0.36 - 1.50 log cfu/g in the process performed in pulsed UV light system at a distance of 5 cm from the quartz glass. The highest inactivation value was obtained at the closest (5 cm) and the longest (60 cm) UV applied C sample, and an increasing inactivation was observed in direct proportion to the application time. 15 and 30 sec applications are not statistically different from each other (P>0.05). 60 sec application differed significantly from 15 and 30 sec applications (P<0.05).

The distance of K, L and M samples from quartz glass is 8 cm, and the number of *L.monocytogenes* detected is in the range of 1.48-0.29 log cfu/g. As the application time increased, the logarithmic inactivation level increased and consequently the highest inactivation value was obtained in 60 sec application. It was observed that the 15, 30 and 60 sec applications were significantly different from each other (P<0.05).

With the effect of pulsed UV light applied at a distance of 13 cm from the quartz glass, the *L.monocytogenes* count of the samples was determined to be in the range of 0.35-1.44 log cfu/g. There was no significant difference between 15 and 30 sec in applications performed at this distance (P>0.05). 60 sec application differed significantly from 15 and 30 sec applications (P<0.05).

In a study, microbial inactivation efficiency was investigated for various chicken products with pulsed UV light technology. For *Salmonella typhimurium*, a log reduction in the range of 0.8-2.4 cfu/cm$^2$ was achieved in vacuum packed chicken breast meat and 1.2-2.4 cfu/cm$^2$ in packed chicken breast (Keklik et al., 2010). Less inactivation (0.3-1.9 cfu/cm$^2$) was observed in breast meat inside *L. monocytogenes* in unpackaged chicken sausages compared to *S.* Typhimurium. In our study, it is seen that the log reduction in 5 cm-15 sec application is more than 8 cm-15 sec and 13 cm-15 sec applications. The reason for this is that as the proximity of the samples to UV light increases, the efficiency of inactivation increases. In addition, it is seen that microbial inactivation at 5 cm-60 sec application is higher than 8 cm-60 sec and 13 cm-60 sec applications. As seen from these results, microbial inactivation increases as the proximity of the samples to UV light and the exposure time to UV light increases. It was observed that the microbial reduction we obtained from salami and decontamination results on chicken sausages were similar.

Ha and Kang (2015) showed that the near infrared and UV-C light combination applied to sliced hams for 70 sec was 3.62 log cfu/g in *E. coli*, 4.17 log cfu/g in *S.* Typhimurium and 3.43 log cfu/g in *L.monocytogenes*. In our study, it was observed that decontamination results were similar on *L.monocytogenes* in sliced salami with a high rate of microbial reduction in long-term UV applications (5 cm-60 sec, 8 cm-60 sec and 13 cm-60 sec) in turkey salami.

Table 1. *L.monocytogenes* count (cfu/g) after pulsed UV treatment on turkey salami surface

| Groups | Distance (cm) | Time (sec) | *L.monocytogenes* count after pulsed UV application (cfu/g) |
|---|---|---|---|
| A | | 15 | 1.5090±0.1756[c] |
| B | 5 | 30 | 1.2960±0.1781[c] |
| C | | 60 | 0.3616±0.1247[a] |
| K | | 15 | 1.4842±0.1587[c] |
| L | 8 | 30 | 0.8513±0.1521[b] |
| M | | 60 | 0.2993±0.1844[a] |
| X | | 15 | 1.4401±0.0840[c] |
| Y | 13 | 30 | 1.6217±0.1542[c] |
| Z | | 60 | 0.3531±0.1079[a] |

Table 2. Temperature changes on the salami surface after pulsed UV light application in turkey salami (°C)

| Groups | Distance (cm) | Time (sec) | Before Pulsed UV Application | After Pulsed UV Application |
|---|---|---|---|---|
| A | | 15 | 3.8±0.5 | 12.30 |
| B | 5 | 30 | 3.8±0.5 | 30.03 |
| C | | 60 | 3.8±0.5 | 35.60 |
| K | | 15 | 3.8±0.5 | 13.20 |
| L | 8 | 30 | 3.8±0.5 | 22.30 |
| M | | 60 | 3.8±0.5 | 33.20 |
| X | | 15 | 3.8±0.5 | 9.08 |
| Y | 13 | 30 | 3.8±0.5 | 20.20 |
| Z | | 60 | 3.8±0.5 | 29.60 |

Bottino et al. (2017) found that low (55.83 mJ/cm$^2$) and high (160.97 mJ/cm$^2$) doses of UV-C light applied to vacuum-packed fish fillets decreased both the number of colonies formed and the growth rates of these colonies compared to the vacuum-packed fillets alone have reported.

Fernández et al., (2019) studied on different Spanish dry-cured ham samples treated with pulsed light and found similar results as our study that the higher the UV light power used, the higher the level of *Listeria* inactivation. Besides this, in a study, it was shown that pulsed light treatments allow reductions of *Listeria innocua* by about 1 log on the surface of sliced boiled ham and chicken cold cuts while 3–4 log can be achieved on frankfurter sausages (Kramer et al., 2019).

***Temperature and Energy Levels in Pulsed UV Light Application***

After pulsed UV light application, detecting temperature changes in samples is important in determining the use potential of pulsed UV light on salami as a decontamination technique (Hilton et al., 2017).

The starting temperatures of the salami used in the measurement are 3.8 ± 0.5°C (Table 2). There was an increase of 9.8°C, 22.3°C and 35.6 on the surfaces of the samples in applications of 13 cm-15 sec (mild), 8 cm-30 sec (moderate) and 5 cm-60 sec (severe), respectively. As a result of the statistical analysis, it was determined that there was a significant difference between the applications under these three different conditions ($P<0.05$).

The maximum temperature increase with an average of 35.6°C occurred in the closest distance and the longest processing time (5 cm-60 sec). Only an average temperature increase of 9.8°C was experienced in light-intensity operations. In the 5 cm-60 sec process, it was observed that the samples were lightened due to the temperature from time to time. These temperatures occurring on salami are below the inhibition effect. This supports the fact that pulsed UV light is a non-thermal decontamination technique.

Hilton et al. (2017), *L. innocua, E. coli* and *P. fluorescens* pathogenic bacteria were exposed to 5-50°C temperatures and then to pulsed UV light in the energy range of 1.02-12.29 J/cm$^2$. The high inactivation obtained for *E. coli* and *P. fluorescens* (mean 6.66 and 6.15 log cfu/g, respectively), while the temperature has no effect, in *L. innocua* pathogen (mean 6.27 log cfu/g) pulsed at 50°C in UV light application, the synergistic effect of temperature and light pulses has been observed. However, it has been stated that the temperature has no effect on the inactivation that occurs in bacteria exposed to pulsed UV light in the 5-40°C temperature range. In order to increase inactivation in target microorganisms, if the synergistic effect is to be used, it has been supported by other studies that the temperature should be at least 50-60°C. Gayan et al. (2015) also reported that the lethal effect of continuous UV rays for *L.monocytogenes* increased with synergistic effect at least 50-60.

The energy released by pulsed UV light in the system and, more importantly, the amount of energy absorbed by the sample are important for the inactivation process. As the total amount of energy released in all process steps of pulsed UV light application increased, log decreases also increased (Table 3). While more energy was released in the 5 cm application, which was considered as the most severe process in terms of parameters, less energy was released in the application at 13 cm, which is the lightest process.

As the distance to the light source increased in the same process times, the temperature difference occurred after the application on the salami surface decreased due to the decrease in energy density. However, as the process time increased in applications performed at the same distance for different durations, temperature and total energy values also increased. This increase is due to the fact that there is more energy accumulation in the capacitor over time and this accumulated energy is released in the system during application. Temperature values are expected to increase with the increase in energy density.

Table 3. Energy changes on the salami surface after pulsed UV light application in turkey salami ($J/cm^2sec$)

| Distance (cm) | Energy changes after pulsed UV application ($J/cm^2sec$) |
|---|---|
| 5 | 1.61±0.01[a] |
| 8 | 1.20±0.00[b] |
| 13 | 0.83±0.00[c] |

Table 4. L values measured on turkey salami surface after pulsed UV applications

| Groups | Distance (cm) | Time (sec) | L values after pulsed UV application |
|---|---|---|---|
| Control | - | - | 67.955±1.6792[c] |
| A | | 15 | 67.7854±2.3630[bc] |
| B | 5 | 30 | 67.3173±2.1864[bc] |
| C | | 60 | 66.5129±2.4012[b] |
| K | | 15 | 64.2781±1.5662[ab] |
| L | 8 | 30 | 65.8641±1.6403[ab] |
| M | | 60 | 66.6666±2.1556[ab] |
| X | | 15 | 66.4548±2.3938[ab] |
| Y | 13 | 30 | 65.0713±1.5270[ab] |
| Z | | 60 | 62.022±2.0671[a] |

Table 5. a values measured on turkey salami surface after pulsed UV applications

| Groups | Distance (cm) | Time (sec) | a values after pulsed UV application |
|---|---|---|---|
| Control | - | - | 18.0457±0.4459[b] |
| A | | 15 | 16.1707±0.5637[a] |
| B | 5 | 30 | 16.1361±0.5240[a] |
| C | | 60 | 16.3467±0.5901[a] |
| K | | 15 | 16.6644±0.3938[ab] |
| L | 8 | 30 | 16.5578±0.4187[a] |
| M | | 60 | 16.5181±0.5422[a] |
| X | | 15 | 17.5399±0.6318[ab] |
| Y | 13 | 30 | 16.2653±0.3816[a] |
| Z | | 60 | 16.9207±0.5633[ab] |

Table 6. b values measured on turkey salami surface after pulsed UV applications

| Groups | Distance (cm) | Time (sec) | b values after pulsed UV application |
|---|---|---|---|
| Control | - | - | 10.6779±0.2638[a] |
| A | | 15 | 13.2195±0.4608[b] |
| B | 5 | 30 | 13.7337±0.4460[bc] |
| C | | 60 | 16.2160±0.5854[f] |
| K | | 15 | 14.4665±0.3419[bcd] |
| L | 8 | 30 | 15.1604±0.3833[def] |
| M | | 60 | 16.2037±0.5319[ef] |
| X | | 15 | 14.8994±0.5367[cde] |
| Y | 13 | 30 | 14.9645±0.3511[cdef] |
| Z | | 60 | 16.1958±0.5392[ef] |

***Effects of Pulsed UV Application on the Quality of Turkey Salami***

*Colour Parameters*

The $L*$, $a*$ and $b*$ values measured on the salami surface after pulsed UV applied turkey salami samples are given in Tables 4, 5 and 6, respectively. The average $L*$, $a*$, $b*$ values of the control group were 67.95 ± 1.67, 18.04 ± 0.44 and 10.67 ± 0.26 respectively.

The colour changes of salami samples applied pulsed UV light, the values of all treatment groups are different from the control groups ($P<0.05$); It is seen that the $L*$ value in the 5 cm – 60 sec procedure is significantly different from the 8 cm – 30 sec and 13 cm – 5 sec procedures ($P<0.05$); There is a significant difference between the 13 cm-5 sec procedure ($P<0.05$). Also; $b*$ values are different from each other in all three processing steps ($P<0.05$). The colour change occurring in the salami sample exposed to pulsed UV light for 60 sec at a distance of 5 cm from the quartz lamp is given in the figure, with each application made from different distances to UV light (5, 8 and 13 cm), the decrease in the colour intensity of the samples was determined. As the exposure time to UV light increases, the amount of energy absorbed by the samples increases, causing a decrease in colour parameters (Guerrero-Beltran et al., 2008). In addition, the fact that the absorbed energy and therefore the temperature increases of the samples in applications performed at different times than 5 cm distance according to the distances were higher, causing the damage of colour pigments to be observed in a shorter time.

The difference between *a** values is insignificant in 5 cm-15 sec and 5 cm-30 sec applications where the temperature increase is the highest (P>0.05). Although the difference is insignificant in the applications at 8 and 13 cm distance at 15 sec, it is seen that the redness (*a**) increases, and the redness value of all groups decreases in the applications of 8 cm for 30 sec and 13 cm 60 sec. The fact that turkey salami has intense red colour pigments, the measurement of the absorbance at high values, the change in yellow and blue, not the redness, has been effective on the colour parameters until the applications where a decrease in absorbance is observed. It can be said that in applications performed from a distance of 5 cm, which is the closest application to the UV lamp, the temperature change increases suddenly and is higher than in other applications, causing the same effect at 5 cm distance. The sudden increase in temperature change caused colour pigmentation in turkey salami, causing lighter colour. One of the most important factors that make salami attractive is colour. The lightening in colour may reduce the attractiveness of the salami, creating a negative perception for consumers.

Allende et al. (2006) 7.11 kJ/m$^2$ dose of pulsed-UV induced tissue softening and browning on red oak leaves after 7 days of storage at 5°C. Erdoğdu and Ekiz (2013) reported that UV does not cause significant changes in the colour of cumin seeds and black pepper because it is a non-thermal method. It has been reported that UV applications on chicken breast meat and chicken carcass have no negative effect on the colour of the products (Wallner-Pendleton et al., 1994, Chun et al., 2004). In our study, a decrease in red color was observed with the effect of UV light.

Murugesan et al. (2012) stated that UV light applied to strawberry samples causes an increase in application time and closeness of anthocyanins and this causes an increase in yellow colour. In our study, yellow colour increases with the increase in the application time and proximity of UV light. Koutchma (2009) stated that UV light can cause up to 50% reduction in orange juice carotenoids.

As it can be seen in Table 6, with the predominance of blue colour in 5 cm applications, it is seen that the blue colour generally increases as the application time increases. It is seen that the blue colour content increases as the proximity to the UV lamp decreases in all applications except 13 cm-15 sec applications.

*TBA Values*

Thiobarbituric acid (TBA) values of salami samples are given in Table 7. The chemical reaction that occurs when food components react with oxygen, heat, light and metal ions is called oxidation (Shahidi et al., 2010). The expression of the oxidation of oils in terms of malonaldehyde refers to the number of TBA (Schmedes et al., 1989). It has been reported that the maximum accepted value in turkey salami should be 3 mg malonaldehyde/kg sample (Melton, 1983). TBA values of all samples from turkey salami samples are below this limit. The TBA values of the samples varied in the range of 0.53-2.17 mg malonaldehyde/kg sample. The lowest TBA value was found in group K and it was determined that it was 0.99 mg malonaldehyde/kg sample.

The difference between the TBA values obtained in the samples was found to be significant (P<0.05). When the TBA values of the experimental samples were compared, the difference between the K and L samples and the X and Y samples was found to be insignificant (P>0.05), and the difference between C and L was found to be significant (P<0.05). The difference between the other samples was found to be insignificant (P>0.05). It was seen that the highest TBA value belonged to the C sample and the lowest TBA values to the K and X samples after the control sample. In all sample groups, as the UV application time increased, TBA values increase with the effect of temperature increase.

In a study conducted on fresh and smoked turkey meats, it was reported that the malonaldehyde levels increased from 0.90 to 1.19 malonaldehyde/kg sample in fresh meats and from 0.63 to 0.71 malonaldehyde/kg sample in smoked meats at the end of this period when meats were stored at -18°C for 6 months. Lipid oxidation is one of the most important parameters showing the degradation degree of raw or cooked meat products in refrigerator and frozen conditions. Lipid oxidation products can occur in meat and other foods under storage and cooking conditions. Lipid oxidation can easily occur in turkey meats with high unsaturated fatty acids and heat applied. Therefore, it is important to determine the amount of malonaldehyde in turkey meats and the risks that may arise in terms of the health of people consuming these meats. In addition, aerobic oxidation products of meat and meat products give a colour reaction with TBA. This causes changes in quality, colour, odour and taste, as well as breakdown of some compounds and the formation of toxic compounds. Changes in colour, smell, taste and quality decrease create an undesirable situation for consumers.

In a study, pork loin samples treated pulsed UV between 1-30 sec and TBA values of samples were not statistically affected from pulsed UV neither different duration nor different distance unlike our study (Koch et al., 2019).

Table 7. TBA values measured on turkey salami surface after pulsed UV applications (mg malonaldehyde/kg)

| Groups | Distance (cm) | Time (sec) | TBA values after pulsed UV application (mg malonaldehyde/kg ) |
|---|---|---|---|
| Control | - | - | $0.5323 \pm 0.0664^{a}$ |
| A | | 15 | $1.2363 \pm 0.1530^{b}$ |
| B | 5 | 30 | $1.2571 \pm 0.1914^{b}$ |
| C | | 60 | $2.1757 \pm 0.2957^{c}$ |
| K | | 15 | $0.9964 \pm 0.2102^{ab}$ |
| L | 8 | 30 | $1.3091 \pm 0.2746^{b}$ |
| M | | 60 | $1.4706 \pm 0.1980^{b}$ |
| X | | 15 | $1.1303 \pm 0.2593^{ab}$ |
| Y | 13 | 30 | $1.3187 \pm 0.1792^{b}$ |
| Z | | 60 | $1.5893 \pm 0.4174^{bc}$ |

## Conclusion

In the food industry, by showing the necessary care at every stage from production to consumption, the main goal should be to deliver unprocessed, minimal changes in their nutritional and sensory properties or ready-to-eat food products in a microbiologically safe manner, thereby protecting and improving the health of the society. Besides safe food, another factor to consider is the quality characteristics of the food. In our country and in the world, the demand for sliced foods ready for consumption is increasing day by day. The use of preservatives used in salami, which is one of the ready-to-eat sliced foodstuffs, in different and excessive amounts than those specified in the standard is both harmful to health and undesirable by consumers.

In our study, the effects of pulsed UV light from new technologies were investigated in order to prevent the negativities that threaten the ready-to-cook sliced salami, to present the beneficial properties of the salami to the consumer with the least loss and to ensure the microbiological quality, and the changes in the specific quality characteristics of the salami were investigated.

The results of the study showed that pulsed UV light method can be used effectively in inactivation against *L. monocytogenes* on salami surface as an alternative to thermal and chemical methods. It is thought that the pulsed UV light technology, which is among the non-thermal methods applied to salami, will meet the expectations of the consumers because it can be applied to the end product, does not leave toxic residues and no microorganisms develop resistance against irradiation. Thus, the loss of some nutritive elements such as vitamins can be prevented by heat treatment and the risk of chemical residue in salami can be prevented.

It was determined that *L. monocytogenes* inactivation increased as the distance to the quartz lamp decreased and the application time and total energy dose increased. The highest inactivation was obtained after 5 cm 60 sec pulsed UV light treatment. However, in this severe processing phase, more change was observed in colour compared to other distances and processing times. This situation may negatively affect consumer choice. Therefore, it can be used at a distance of 5 cm from the light source by reducing the processing time of 60 sec to 30 sec, or a 30 sec application at a distance of 8 cm may be preferred. However, considering that the highest inactivation values are obtained in 5 cm-60 sec process, it would be more preferable to optimize these application conditions by preventing colour loss.

The loss of colour is thought to be caused by the temperature rise in the sample cabinet during application. In this case, filtering the infrared rays responsible for temperature formation before they reach the salami sample in the system can reduce the colour losses on the salami surface observed in the processes applied at a distance of 5 cm to the lamp. However, in addition to the lamp cooling system available in the system we use, temperature increases can be prevented by a system that allows the cabinet to cool down.

As a result; Pulsed UV light was effective in the inactivation of L. *monocytogenes* pathogen, which has the potential to be transmitted to salami from meat products in various ways. How the physical and chemical properties of salami, which attracts consumers with its colour and taste, are affected by pulsed UV light. It has been determined that the pulsed UV light application, which has been successful in the inactivation studies of many microorganisms that have been inoculated into different food samples until today, is effective on *L. monocytogenes* inoculated with salami, and it has been observed that UV light is a successful application in solid foods

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