Research Article / Araştırma Makalesi GU J Sci, Part A, 9(1): 25-32 (2022) https://doi.org/10.54287/gujsa.1082957

Gazi University
Journal of Science
PART A: ENGINEERING AND INNOVATION
http://dergipark.org.tr/gujsa

An Approach for Color Measurement of Irradiated Fresh Cilantro

Pelin YÜCEL[1*]

[1]*Turkish Energy, Nuclear and Mineral Research Agency, Ankara, Turkey.*

Keywords

Cilantro

Irradiation

Image Analysis

Color Coordinates

Abstract

Food irradiation is widely accepted as a proven and effective postharvest treatment to reduce the bacterial contamination, extend the shelf life and maintain the food quality. Spices and herbs are the most commonly irradiated commercial products. Low dose irradiation causes no adverse effects on the visual quality of fresh herbs and spices. The appearance and color of food influence the consumer's product choice. Numerous studies are performed on the use of computer vision and image processing for the color evaluation in the food industry. In the present study, fresh cilantro was chosen as a model to estimate the change in the color parameters of gamma irradiated fresh cilantro leaves. Image analysis method was proposed as an alternative to conventional colorimeters for color measurement of irradiated fresh herbs and spices.

Cite

Yucel, P. (2022). An approach for color measurement of irradiated fresh cilantro. *GU J Sci, Part A*, *9*(1), 25-32.

Author ID (ORCID Number)

P. Yucel, 0000-0002-1581-8388

Article Process

Submission Date	04.03.2022
Revision Date	11.03.2022
Accepted Date	24.03.2022
Published Date	28.03.2022

1. INTRODUCTION

Food irradiation is a technology applicable for all groups of foods, as functional properties, nutritional quality and sensory acceptability of foods are slightly affected. In a food system, there is an interaction between radiation and water and other biological systems, resulting in radiolytic products as oxidizing agents and changes are observed in the molecular structure of organic matter. Deoxyribonucleic Acid (DNA) is damaged by radiation, preventing reproduction of microorganisms, insects and gametes (Chauhan et al., 2009). Gamma rays of nucleides ^{60}Co and, to a lesser extent, ^{37}Cs or X-rays with energies up to 5 MeV, or accelerated electrons with energies up to 10 MeV are the sources of ionizing radiation for food processing. These sources are feasible for commercial use of irradiation as desired food preservative effects are achieved and no radioactivity is observed in foods or packaging materials (Farkas, 2004). Gray (Gy) is the international unit for the absorbed radiation dose; generally pasteurization doses are smaller than 10 kGy and sterilization doses are greater than 10 kGy. Irradiation is suitable for packaged products, as it causes minimum rise in the temperature of the product, hereby preventing recontamination or reinfestation of the product. Ionizing radiation treatment of foods is approved by World Health Organization, Food and Agricultural Organization, International Atomic Energy Agency and many countries for producing better and safer foods. Space foods for astronauts are sterilized by irradiation (Acheson & Steele, 2001).

Microbial decontamination of herbs and spices have been achieved by irradiation for more than 40 years. CODEX and most countries have allowed the use of irradiation (WHO, 1994; Chmielewski & Migdal, 2005). Doses greater than 10 kGy should not be applied to a food, except application of higher doses for technological purpose. In Turkey, radiation processing of food is controlled by Food Irradiation Legislation of Republic of Turkey Ministry of Agriculture and Forestry (URL1, 2019).

*Corresponding Author, e-mail: pelin.yucel@tenmak.gov.tr

Irradiation, compared with thermal treatment, leaves no chemical residues and is proven to be more effective against bacteria (Tjaberg et al., 1972; Loaharanu, 1994; Thayer et al., 1996; Olson, 1998; Sádecká, 2007). As heat sterilization of spices result in the loss of thermolabile aromatic volatiles and/or thermally induced changes, ionizing radiation is less harmful to the spices and can be applied in place of ethylene oxide and methyl bromide treatment. Minimal modifications on the quality attributes of food are observed.

The most suitable way for microbial safety of spices and herbs seemed to be gamma irradiation, resulting in no change in the quality (Lee et al., 2005). Extensive research is available on the application of irradiation for spices, herbs and vegetable seasonings. Andrews et al. (1995) observed a significant reduction at a dose of 5 kGy and total elimination of microbial contamination at 10 kGy, with no effect on flavor quality of dry ginger. Of nine aromatic herbs and spices irradiated at 10 kGy, quinone radical content of all samples increased while some samples showed significant decrease in total ascorbate and carotenoids content (Calucci et al., 2003).

Despite being well known decontamination method, less study has been performed for the treatment of fresh herbs. Electron beam irradiation can be applied for fresh herbs, like *Salvia Officinalis* and *Calendula Officinalis* (Minea et al., 2004). Electron beam treatment can be cost effective due to high throughput of e-beam processing (Khade et al., 2020). *Escherichia coli* O157:H7 inoculated on cilantro was effectively reduced by irradiation and chlorination while maintaining product quality (Foley et al., 2004). Low irradiation doses were shown to have a smaller effect on sensory quality of parsley leaves than drying and freezing. Irradiation doses up to 1.4 kGy extended the shelf-life of minimally processed parsley leaves to 30 days (Cătunescu et al., 2019). The visual quality of fresh mint was not affected by low irradiation doses and samples showed good quality for up to 9 days of storage (Hsu et al., 2010). A study of methanolic extracts of ten commercial herbs and spices irradiated in the range 0 - 30 kGy done by Polovka & Suhaj (2013) showed that the observed changes in antioxidant activity induced by γ-irradiation were without practical significance and would have no negative effect on the health of the consumer.

Consumer’s choice and preferences are generally influenced by color. Visual, instrumental and machine vision systems are applied for color measurement of many food products, including fruits and vegetables, spices and flavors, cereals and grains. Compared to the colorimetry and spectrophotometry, machine vision with digital imaging has advantages, namely analysis of the whole sample surface and objective evaluation of irregular color or surface (Giese, 2003). Machine vision with image processing has been found increasingly useful in the food industry. Brosnan & Sun (2004) reviewed the application of computer vision system and image processing in the food industry, mainly fruits and vegetables, meat, fish, pizza, cheese, bread and grain. There is an increasing trend in the use of machine vision system for the measurement of color. Machine vision system has the following parts; a camera linked to a computer, controlled lighting and software for camera settings, image capture and image processing. The image can be evaluated immediately or stored for further analysis (Balaban & Odabasi, 2006). Minz & Saini (2021) suggested computer vision system to measure the color of mozzarella cheese as an option to spectrophotometer. Although color spectrophotometer limits the measuring area, computer vision system permits the user to measure the color over the whole surface. Computer vision system is recommended as a rapid and low-cost quantification instrument.

Generally, fresh herbs, such as fresh cilantro, parsley and basil, are eaten raw and widely used as seasoning in many meals without any treatment step for microbial treatment. Herbs, which are grown low to the ground, can be contaminated easily from irrigation water (US FDA, 2022). Cilantro (*Coriandrum sativum*) is annual and herbaceous plant from the Apiceae family, originating from Mediterranean region. The leaves and stems are used to flavor dishes. The mature seeds are called coriander and used for flavoring (Abascal & Yarnell, 2012). Cilantro is a herb consumed worldwide and shows a wide range of health benefits from antibacterial to anticancer effects (Mauer & El-Sohemy, 2012). Khade et al. (2020) studied the effect of combined treatment of washing with potable water, sodium hypochlorite and radiation at 2 kGy to ensure safety and to eliminate the microbial load of coriander, mint and spinach. Shelf life was extended up to 15 days at 4-6°C by the developed combination. Irradiation of spices and herbs has a high potential application in many countries. The objective of this study was to determine a relationship between color parameters of fresh cilantro leaves subjected to irradiation with a simple computer vision system. The color of irradiated fresh cilantro was compared with non-irradiated cilantro.

2. MATERIALS AND METHODS

Fresh cilantro samples were supplied by commercial grade and placed in polyethylene bags. 0, 1, 2 and 3 kGy (at a dose rate of 0,626 kGy/h from a Cobalt-60 source) irradiation doses were applied at Turkish Energy, Nuclear and Mineral Research Agency, Ankara, Turkey. Non- irradiated samples were used as controls. The absorbed doses were controlled by alanine dosimetry.

The measurements were made with a simple computer vision system (CVS). Image analysis is the core of this system. The objects are distinguished from the background and quantitative information is produced to be used in the control systems (Brosnan & Sun, 2004). Images of samples were captured by a scanner in jpeg format with a resolution of 300 dpi and a region of interest (ROI) was selected to obtain color information (Figure 1). Intensity values of ROI were read from the image for each color coordinate system (CIE XYZ, CIE L*a*b*, Hunter Lab and RGB). The programme BAB BS200ProP was used to process the color parameters. BAB BS200ProP image analysis system enables the user to acquire images from external sources, such as camera, scanner and keep the images in a database.

Figure 1. *Color measurement from image of scanned cilantro leaves*

Of the color parameters, the ratio of white to black, red to green, and yellow to blue are represented by L* value, a* value and b* value, respectively. Positive values of a* indicate red color and negative values indicate green color. Positive values of b* are measured for yellow color and negative values are for blue color. Color saturation or intensity is measured by chroma. Hue angle (h°) defines the comparative amount of redness and yellowness, where angle of 0°/360°, 90°,180° and 270° indicates red/magenta, yellow, green and blue color or purple or intermediate color between neighboring pair of basic colors (McGuire,1992). Hue angle and chroma were calculated from a^* and b* color space, done by using the formulae (Wrolstad & Smith, 2010).

$$hue\ angle\ (°) = \arctan(\frac{b^*}{a^*}) \quad (1)$$

$$chroma = \sqrt{(a*^2 + b*^2)} \quad (2)$$

3. RESULTS AND DISCUSSION

Color is an important quality index and plays a main role for consumer preferences and consumer acceptability. *RGB* (red, green, blue), Hunter Lab, *CIE* (Commission Internationale de l'Eclairage) *L*a*b**, *CIE XYZ, CIE Yxy* and *CIE LCH* are the color coordinate systems used to define color a sample (Giese, 2003). Of the color spaces, most commonly used system in the food industry is *CIE L*a*b**, owing to its uniform color distribution, as well as the perception system is very near to the human eye (Markovic et al., 2013). In this study, color changes observed after irradiation were evaluated by image analysis system in *L*a*b** model system of fresh cilantro (Table 1).

Table 1. *Color parameters of non-irradiated and irradiated fresh cilantro*

Dose (kGy)	RGB			CIE L*a*b*			Hunter Lab		
0	111	155	79	59.33	-28.86	34.9	52.33	-24.4	23.4
1	105	147	73	56.44	-27.99	34.4	49.35	-23.1	22.4
2	102	144	71	55.3	-27.92	34.0	48.19	-22.8	21.9
3	99	141	70	54.18	-27.72	33.1	47.06	-22.5	21.3

L* value, which is the color coordinate characterizing the lightness, decreased upon irradiation (Figure 2a). During irradiation, L* values showed a decrease in all treatments, being higher in control compared to irradiated samples (Table 1). The observed values were of the range 59.33-54.18. No significant effect was observed on aroma, amount of total volatile compounds, color or overall visual quality of fresh cilantro leaves irradiated at doses up to 2 kGy (Fan et al., 2003). L* value decreased as radiation dose increased in dry smoked shrimp. Increasing radiation dose resulted in a trend of decrease in whiteness (Akuamoah et al., 2018). Significant decrease was monitored in the appearance, color and texture of fresh spinach after irradiation (Al-Suhaibani & Al-Kuraieef, 2016). Undesirable changes in the sensory quality of foods can be prevented by the selection of suitable dose. Irradiation of fresh-cut iceberg lettuce and spinach at doses of 1 and 2 kGy enhanced the microbial safety while maintaning quality (Fan et al., 2012).

Chroma value, proportional to the strength of the color, shows the degree of saturation of color. A change was observed in the chroma between the non-irradiated and irradiated samples. The highest chroma value was observed for non-irradiated sample (Figure 2b). The observed chroma values were of the range 45.29-43.17. A general trend of decrease was noted in chroma values (Table 2). Control quince fruits, either due to browning or chlorophyll degradation, showed higher chroma values compared to irradiated fruits (Hussain et al., 2019). When gamma irradiation and low energy electron beam treatment were compared for allspice berries, caraway seeds, oregano and rosemary leaves, no difference was found in color, water activity, chlorophyll and caretonoid contents and terpenoic compounds for storage time up to 105 days (Schottroff et al., 2021). Irradiation would have no adverse effect on the acceptability of fresh herbs.

The hue angle (h°), where values above 100°C representing green color and values below 90°C yellow color, is often used for color determination. In our study, the highest value was obserbed for 3 kGy irradiation. (Figure 2c). The hue angle range was within the 120° region, suggesting green color. The observed hue angle values were of the range 129.13-129.95. The lower the irradiation dose employed the less undesired effects were observed for products containing organic colors (Reid, 1995). For fresh mushrooms and dried mushrooms, good linear correlations were reported by Kortei et al. (2015) between the hue angle and the lightness after irradiation. Irradiation had no adverse effect on product quality. Knowledge of the effect of irradiation on the color of the food products can be used to decide the optimum irradiation dose for the food.

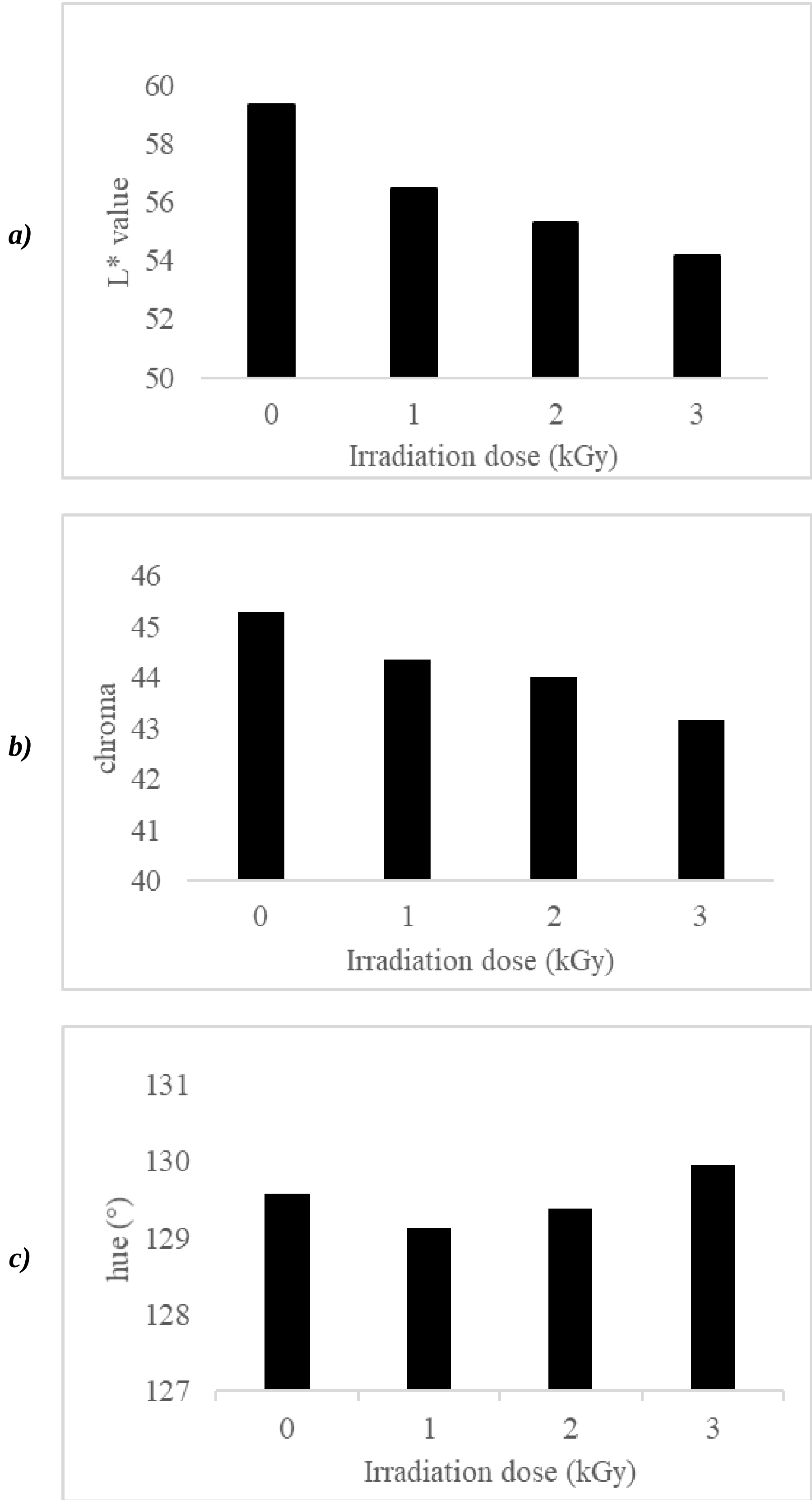

Figure 2. a) *Color lightness,* ***b)*** *chroma and* ***c)*** *hue angle, for non-irradiated and irradiated fresh cilantro*

Table 2. *Chroma and hue angle values of non-irradiated and irradiated fresh cilantro*

Dose (kGy)	L* value	chroma	hue (º)
0	59.33	45.29	129.59
1	56.44	44.35	129.13
2	55.30	43.99	129.39
3	54.18	43.17	129.95

4. CONCLUSION

Food quality and safety are important for the food industry. Food irradiation is a suitable technology for fresh herbs and spices, as ionizing radiation effectively inhibits physical changes during postharvest deterioration and maintains a fresh product appearance. Instrumental color measurement combined with image processing eliminates the limitations of the subjective human sensory analysis In this study, computer vision system with image processing is utilized to measure the color of irradiated fresh cilantro. The study has been conducted on the images of fresh cilantro which are captured before and after irradiation. This study proposes that color can be measured only by using a simple scanner, avoiding the use of an expensive colorimeter. Tristimulus values can be converted into other color systems. The color lightness (L*) decreased when fresh cilantro was irradiated. A change in chroma value was observed between the fresh and irradiated cilantro; fresh cilantro showing the highest chroma value (45.29). The hue angle (h°) was highest at 2 kGy. Image analysis can be a viable technique to measure the color of irradiated foods, providing better characterization of irradiated foods and improving irradiated food quality.

ACKNOWLEDGEMENT

Author would like to thank to the Turkish Energy, Nuclear and Mineral Research Agency.

CONFLICT OF INTEREST

No conflict of interest was declared by the author.

REFERENCES

Abascal, K., & Yarnell, E. (2012). Cilantro-Culinary Herb or Miracle Medicinal Plant?. *Alternative and Complementary Therapies*, *18*(5), 259-264. doi:10.1089/act.2012.18507

Acheson, D., & Steele, J. H. (2001). Food Irradiation: A Public Health Challenge for the 21st Century. *Clinical Infectious Diseases*, *33*(3), 376-377. doi:10.1086/321899

Akuamoah, F., Odamtten, G. T., & Kortei, N. K. (2018). Influence of gamma irradiation on the colour parameters of dry smoked shrimps (*Penaeus notialis*). *Food Research*, *2*(4), 350-355. doi:10.26656/fr.2017.2(4).0271

Al-Suhaibani, A. M., & Al-Kuraieef, A. N. (2016). The Effects of Gamma Irradiation on the Microbiological Quality, Sensory Evaluation and Antioxidant Activity of Spinach. *International Journal of Chem Tech Research*, *9*(6), 39-47.

Andrews, L. S., Cadwallader, K. R., Gronder, R. M., & Chung, H. Y. (1995). Chemical and microbial quality of irradiated ground ginger. *J. Food Sci.*, *60*(4), 829-832. doi:10.1111/j.1365-2621.1995.tb06240.x

Balaban, M. O., & Odabasi, A. Z. (2006). Measuring color with machine vision. *Food Technology*, *60*(12), 32-36. (makalenin son haline eklenmeyecek – makale yılını kontrol etmek için bağlantı adresi)

Brosnan, T., & Sun, D-W. (2004). Improving quality inspection of food productsby computer vision—a review. *Journal of Food Engineering*, *61*(1), 3-16. doi:10.1016/S0260-8774(03)00183-3

Calucci, L., Pinzino, C., Zandomeneghi, M., Capocchi, A., Ghiringhelli, S., Saviozzi, F., Tozzi, S., & Galleschi, L. (2003) Effects of gamma-irradiation on the free radical and antioxidant contents in nine aromatic herbs and spices. *J Agric Food Chem*., *51*(4), 927-34. doi:10.1021/jf020739n

Cătunescu, G. M., Muntean, M., Marian, O., David, A. P. & Rotar, A. M. (2019). Comparative effect of gamma irradiation, drying and freezing on sensory and hygienic quality of parsley leaves. *Lebensmittel-Wissenschaft und-Technologie, 115*, 108448. doi:10.1016/j.lwt.2019.108448

Chauhan, S. K., Kumar, R., Nadanasabapathy, S., & Bawa, A. S. (2009). Detection Methods for Irradiated Foods. *Comprehensive Reviews in Food Science and Food Safety*, *8*(1):4-16. doi:10.1111/j.1541-4337.2008.00063.x

Chmielewski, A. G. & Migdal, W. (2005). Radiation decontamination of herbs and spices. *Nukleonika*, *50*(4): 179-184.

Fan, X., Niemira, B. A., & Sokorai, K. J. B. (2003). Sensorial, nutritional and microbiological quality of fresh Cilantro leaves as influenced by ionizing radiation and storage. *Food Research International*, *36*(7), 713-719. doi:10.1016/S0963-9969(03)00051-6

Fan, X., Guan, W., & Sokorai, K. J. B. (2012). Quality of fresh-cut iceberg lettuce and spinach irradiated at doses up to 4 kGy. *Radiation Physics and Chemistry*, *81*(8), 1071-1075. doi:10.1016/j.radphyschem.2011.11.022

Farkas, J. (2004) Food Irradiation. In: A. Mozumder, Y. Hatano (Eds.), *Charged particle and photon interactions with matter* (pp. 785-812). Marcel Dekker Inc., New York-Basel.

Foley, D., Euper, M., Caporaso, F., & Prakash, A. (2004). Irradiation and chlorination effectively reduces *Escherichia coli* O157:H7 inoculated on cilantro (*Coriandrum sativum*) without negatively affecting quality. *J. Food Prot.*, *67*(10), 2092-2098. doi:10.4315/0362-028X-67.10.2092

Giese, J. (2003). Color Measurement in Foods. *Food Technology*, *57*(12), 48-49+54.

Hsu, W-Y., Simonne, A., Jitareerat, P., & Marshall Jr., M. R. (2010). Low-dose irradiation improves microbial quality and shelf life of fresh mint (Mentha piperita L.) without compromising viual quality. *J. Food Sci.*, *75*(4), M222-M230. doi:10.1111/j.1750-3841.2010.01568.x

Hussain, P. R., Rather, S. A., Suradkar, P. P., & Ayob, O. (2019). Gamma irradiation treatment of quince fruit (*Cydonia oblonga* Mill): effect on post-harvest retention of storage quality and inhibition of fungal decay. *Journal of Radiation Research and Applied Sciences*, *12*(1), 118-131.

Khade, H. D., Hajare, S. N., Sarma, K. S. S., & Gautam, S. (2020). A combination process including ionizing radiation for hygienization and shelf life extension of leafy vegetables. *Indian Journal of Experimental Biology*, *58*, 474-486.

Kortei, N. K., Odamtten, G. T., Obodai, M., Appiah, V., & Akonor, P. T. (2015). Determination of color parameters of gamma irradiated fresh and dried mushrooms during storage. *Croatian Journal of Food Technology*, *Biotechnology and Nutrition*, *10*(1-2), 66-71.

Lee, J. H., Lee, K-T., & Kim, M. R. (2005). Effect of Gamma-Irradiated Red Pepper Powder on the Chemical and Volatile Characteristics of Kakdugi, a Korean Traditional Fermented Radish Kimchi. *Journal of Food Science*, *70*(7), 441-447. doi:10.1111/j.1365-2621.2005.tb11466.x

Loaharanu, P. (1994). Status and prospects of food irradiation. *Food Technology*, *52*, 124-131.

Markovic, I., Ilic, J., Markovic. D., Simonovic, V., & Kosanic, N. (2013) Color Measurement of Food Products Using CIE L*a*b* and RGB Color Space. *Journal of Hygienic Engineering and Design*, *4*, 50-53.

Mauer, L., & El-Sohemy, A. (2012). Prevalence of cilantro (Coriandrum sativum) disliking among different ethnocultural groups. *Flavour*, *1*, 8. doi:10.1186/2044-7248-1-8

McGuire, R. G. (1992). Reporting of objective color measurements. *HortScience*, *27*(12), 1254-1255. doi:10.21273/HORTSCI.27.12.1254

Minea, R., Nemtanu, M. R., Brasoveanu, M., Oproiu, C., Mazilu, E., & Radulescu, N. (2004). *Accelerators use for irradiation of fresh medicinal herbs*. In: Proceedings of EPAC 2004, Switzerland, (pp. 2368-2370).

Minz, P. S., & Saini, C. S. (2021). Comparison of computer vision system and colour pectrophotometer for colour measurement of mozzarella cheese. *Applied Food Research*, *1*(2). doi:10.1016/j.afres.2021.100020

Olson, D. G. (1998). Irradiation of food. *Food Technology*, *52*, 56-62.

Polovka, M, & Suhaj, M. (2013). Classification and prediction of γ-irradiation of ten commercial herbs and spices by multivariate evaluation of properties of their extracts. *Journal of Food and Nutrition Research*, *52*(1), 45-60.

Reid, B. D. (1995). Gamma processing technology: an alternative technology for terminal sterilization of parenterals. *Journal of Pharmaceutical Science and Technology*, *49*(2), 83-89.

Sádecká, J. (2007). Irradiation of Spices- a Review. *Czech J. Food Sci.*, *25*(5), 231-242.

Schottroff, F., Lasarus, T., Stupak, M., Hajslova, J., Fauster, T., & Jäger, H. (2021). Decontamination of herbs and spices by gamma irradiation and low-energy electron beam treatments and influence on product characteristics upon storage. *Journal of Radiation Research and Applied Sciences*, *14*(1), 380-395.

Thayer, D. W., Josephson, E. S., Brynjolfsson A., & Giddings G.G. (1996). Radiation Pasteurization of Food. *Council for Agricultural Science and Technology*, *7*, 1-10.

Tjaberg, T. B., Underdal, B., & Lunde, G. (1972). The effect of ionizing radiation on the microbial content and volatile constituents of spices. *Journal of Applied Bacteriology*, *35*(3), 473-478. doi:10.1111/j.1365-2672.1972.tb03724.x

URL1, (2019, October 03). Food Irradiation Legislation *"Gıda Işınlama Yönetmeliği"*. Official Gazette of the Republic of Turkey, No:30907. www.resmigazete.gov.tr/eskiler/2019/10/20191003-1.htm

US FDA, US Food and Drug Administration (2022, March 14). Microbiological Surveillance Sampling: FY18-21 Fresh Herbs (Cilantro, Basil & Parsley) Assignment. www.fda.gov/food/sampling-protect-food-supply/microbiological-surveillance-sampling-fy18-21-fresh-herbs-cilantro-basil-parsley-assignment

WHO, World Health Organization (1994). Safety and nutritional adequacy of irradiated food. World Health Organization, Geneva. https://apps.who.int/iris/handle/10665/39463.

Wrolstad, R. E., & Smith, D. E. (2010) Colour Analysis. In: S. S. Nielsen (Eds.), *Food Analysis* (pp. 545-555). Springer Science+Media, New York, USA.