Research Paper

Future of Food: Journal on Food, Agriculture and Society
10 (2) April 2022

Comparative study of white LED light and dark condition in domestic refrigerator on reducing postharvest strawberries waste

TUANY GABRIELA HOFFMANN[1,*], SARAH FINARDI[1], JULIA TOMAZONI DE OLIVEIRA[1], EDUARDA MUELLER[1], SÁVIO LEANDRO BERTOLI[1], MURLIDHAR MEGHWAL[2] AND CAROLINA KREBS DE SOUZA[1]

[1] Department of Chemical Engineering, University of Blumenau, Blumenau, Brazil
[2] Department of Food Science and Technology, National Institute of Food Technology Entrepreneurship & Management Kundli, Haryana, India

* Corresponding author: tuanyhoffmann@gmail.com

Data of the article

First received : 02 November 2021 | Last revision received : 18 April 2022
Accepted : 14 May 2022| Published online :30 May 2022
DOI : 10.17170/kobra-202204136007

Keywords

LED, strawberry, refrigeration, food preservation

Strawberry is one of the most consumed fruits in the world, and due to its perishability, there is a need for new preservation technologies capable of extending its shelf life. An alternative for the preservation of short shelf life fruits is refrigeration associated with LED lights. In this context, the present study evaluated the effect of white LED light in strawberry preservation at the postharvest condition. Strawberry samples were stored in a perforated package under refrigeration (5 °C), in the presence and the absence of a white LED light. Samples were stored for seven days, and analysis was performed on days 0, 2, 4, and 7. Strawberry samples were analysed according to the physical, nutritional, and sensorial indexes. The results showed that white LED light incidence on strawberries results in higher transpiration rates (1030.3 ± 78.2 mg kg^{-1} h^{-1}), ascorbic acid degradation (85%), and instability in the total polyphenols content. The sensorial evaluation showed no influence from the presence or absence of white LED light in strawberry preservation of the visual quality. In brief, the results encourage the market to develop new refrigeration technologies, emphasizing that the use of white LED light, during the postharvest stage, can reduce strawberry preservation.

1. Introduction

Strawberry is a fruit with sensory characteristics that make it appealing to consumers, such as its bright red colour, distinct aroma, soft texture, and slightly acidic flavour. According to Musa et al. (2015), strawberry is a potential source of bioactive compounds, such as vitamin C and phenolic compounds. However, this non-climacteric fruit has a delicate skin that is prone to surface crushing (Zhang *et al.,* 2018), and has a short shelf life (Lan *et al.,* 2019; Finardi *et al.,* 2022).

As a result of its high susceptibility to mechanical injury, water loss, microbial and physiological deterioration, and high respiration rate (Nguyen *et al.,* 2020), postharvest handling and storage of this fruit is a complex matter. Hence, due to the high perishability and physiological activity of strawberries during the postharvest period, fast cooling at low temperatures is the most appropriate method for controlling strawberry senescence (Han *et al.,* 2004; Hoffmann *et al.,* 2021a).

Despite the high price, there is an increasing demand for fresh strawberries. For this reason, alternatives to

increasing the distribution ratio and extending strawberry shelf life are of interest (Almenar *et al.,* 2006). Besides storage at optimal temperature for preservation, the combination of low temperature with innovative technologies, such as ozonation (Soares *et al.,* 2018), food coating (Angioletti *et al.,* 2020), intelligent and active packaging (Hoffmann *et al.,* 2019, Hoffmann *et al.,* 2022), and UV and LED lights application has been discussed in the literature (Finardi *et al.,* 2021).

Light-emitting diodes (LEDs) are lighting devices with high photoelectric efficiency, low thermal output, compactness, and portability and are easily integrated into electronic systems (D'Souza *et al.,* 2015). This solid-state lighting can be applied to postharvest preservation, as it can affect the secondary metabolite of plants (Kasim & Kasim, 2017). The role of LED light is to delay the senescence of perishable fruits and vegetables, allowing them to be modified in terms of their nutritional content, fruit ripening rate, and prevention of fungal infections, which reduces food spoilage (D'Souza *et al.,* 2017).

Jiang et al. (2019) claimed that the use of light-emitting diodes has some advantages when applied to extend the shelf life of harvested fruits and vegetables. LED used in postharvest storage can delay senescence, provide nutritional enhancement, and reduce microbiological deterioration. Chong et al. (2022) also observed the contribution of LED light to the inactivation of microorganisms (*Rhizopus stolonifer* and *Botrytis cinerea*) and the physicochemical properties of strawberries. On the other hand, some negative effects were also observed. According to Hasperue et al. (2016), the use of LED light in broccoli preservation caused a higher weight loss, which resulted from the opening of the stomata when exposed to LED.

In strawberries preservation, it was observed that the long exposure to LED light caused an increase in the transpiration rate (Duarte-Molina *et al.,* 2016). In addition, Xu et al. (2014) evaluated the application of blue LED light in strawberries and the results evidenced the accelerated ripening by the increase in respiration and ethylene production. However, the use of blue, red, and green LED improved anthocyanin content in strawberries, when compared with the storage under dark conditions. The vitamin C content was preserved under blue and green LED lights and total phenolics production was stimulated under blue LED light (Kim *et al.,* 2011, D'Souza *et al.,* 2015).

In light of these considerations, this research objective is to investigate the effects of white LED incidence in strawberry preservation during postharvest storage. For this reason, the strawberries were submitted to different storage conditions (presence and absence of white LED), under refrigeration.

2. Materials and methods

2.1 Postharvest treatment and storage conditions

Strawberry samples were harvested from a hydroponic cultivation system in Indaial, Santa Catarina (Brazil). Fresh fruit sample selection was based on their uniform size (length/width of about 0.9-1.2), weight (15-20 g), colour (uniform colour all over the strawberry surface and between the samples), and maturity (30 days), as well as the absence of mechanical damage and diseases. Once harvested, samples were immediately transported, under refrigerated conditions (cooled box), within 1 hour, to the Laboratory of Food Preservation & Innovation (University of Blumenau).

Before storage, strawberry samples were washed under running water and the remaining surface water was removed with absorbent paper by applying gentle pressure. Then, the samples were packaged in polyethylene terephthalate material (15 cm x 13 cm x 5 cm), with 3 perforations of 1.5 cm of diameter at the cover. Each package included 4 samples of strawberries.

The samples were stored under dark and white LED light conditions, with 2 lx and 180 lx of luminosity, respectively. The white LED light was adjusted at 25 cm of distance from food samples and the white LED light power was 7.2W. In both conditions, the presence and the absence of light, were evaluated in strawberry preservation, for 7 days at 5 °C, in BOD (Biochemical Oxygen Demand) chamber, and samples were analysed on days 0, 2, 4, and 7. Physical, nutritional, and sensorial indexes were collected in order to validate the effects of white LED light in strawberry preservation. For this reason, mass variation, transpiration rate, total polyphenols, ascorbic acid (AA), and sensorial analyses were conducted.

ISSN-Internet 2197-411x OLCL 862804632

2.2 Physical index: mass variation and transpiration rate

Strawberry mass variation was determined based on each sample weight, over time. Mass variation (MV) was calculated from the initial (M_i, immediately after arrival at the laboratory) and final mass (M_f), as shown in Equation 1. The MV results were expressed as a percentage of mass loss/variation according to the fresh mass.

$$MV\ (\%) = \left(\frac{M_i - M_f}{M_i}\right) 100 \quad (1)$$

In addition, the strawberry transpiration rate (TR) was calculated per unit of initial mass and time (t), according to Equation 2 (Hoffmann *et al.,* 2021b).

$$TR\ \left(\frac{mg}{kg\ h}\right) = \left(\frac{M_i - M_f}{M_i \times \Delta t}\right) \quad (2)$$

2.3 Nutritional index: ascorbic acid and total polyphenols

Ascorbic acid (AA) content was measured using 2,6-dichloroindophenol, according to AOAC (2005). Strawberry samples (10 g) were grounded in a commercial processor (NPRO, Arno), for 3 min. The AA content was extracted from the ground material with oxalic acid 1%, for 15 min under dark conditions. Subsequently, the filtered extraction solution was obtained through a paper filter (C41, Unifil). Three aliquots of the filtrate were titrated with 2,6-dichloroindophenol and the results were expressed in mg of ascorbic acid 100 g^{-1} of fresh weight (FW).

Total polyphenols content was determined using the Folin Ciocalteau method (Nguyen *et al.,* 2020), where the results were expressed in mg of gallic acid 100 g^{-1} of fresh weight (FW). Briefly, strawberry samples (10g) were macerated and mixed with 20 mL of ethanol 96%. The solution was centrifuged (HERMLE, Z300K) at 4°C, for 10 min. The supernatant was collected and reacted with Folin Ciocalteu reagent and sodium carbonate 20% (w/v). The mixture was measured at the absorbance of 765 nm (UV-1800, SHIMADZU) and compared to the standard curve, which was developed using a standard solution of gallic acid.

2.4 Sensorial index: strawberry visual quality

The visual quality characteristic of strawberries was evaluated throughout the storage period by a sensory panel of five trained judges. Sensorial evaluations were carried out immediately after removing the strawberries from storage (5 °C), in an individual sensory booth, with control of the lighting, temperature, and the absence of noise (Meilgaard *et al.,* 2016). A nine-point hedonic scale, from excellent (9) to extremely poor (1), was used to evaluate the visual quality. This attribute was analysed considering food appearance, related to freshness, colour change, wilting, decay, and damage. A score of 6 was considered the shelf-life limit for strawberries. The execution of this project, which contemplates the participation of human beings, was approved by the Ethics Committee on Research with Human Beings at the University of Blumenau (CAAE: 48613415.1.0000.5370).

2.5 Statistical analysis

Data were subject to Tukey's test, at a 5% level ($p < 0.05$) of significance, in Statistica software 7.0 version (Box *et al.,* 2005). All analyses were performed in triplicate and the results are reported as the mean ± standard deviation.

3. Results

3.1. Mass variation

Figure 1 presents the mass variation results for strawberries stored under white LED light and in the dark. Strawberries lost weight at rates of 519.9 ± 76.4 mg kg^{-1} h^{-1} (under dark) and 1030.3 ± 78.2 mg kg^{-1} h^{-1} (in white LED light) in storage conditions, after 7 days. The results of mass variation showed that strawberries, submitted to white LED light, lost 19% of their weight, while strawberries in the dark, only 8% at the end of storage.

3.2. Ascorbic acid and total polyphenols

The lack of stability in ascorbic acid (AA) content resulted in a significant decrease ($p < 0.05$) in both storage conditions, with white LED light presenting

higher reductions (85%) than storage in the dark (69%). Figure 2(a) presents the ascorbic acid content in strawberries during refrigerated storage.

AA degradation was modelled by first-order kinetics since the natural logarithm of the ratio between AA and initial AA (AA0) against time is well described by a straight line, as presented in Figure 2(b). Lines for each ascorbic acid degradation, under dark and white LED light, were LN(AA/AA0)=-0.1484t, R2=0.8927, and LN(AA/AA0)=-0.2437t, R2=0.9314, respectively. Strawberry stored under white LED light degraded 1.64 times faster than strawberry stored in the dark.
The total polyphenols results are presented in Table 1. The results showed that both storage conditions did not negatively influence the total polyphenols content, where an increase was reported.

3.3 Sensorial analysis

Figure 3 presents images of strawberries under the white LED light (a) and in dark (b). Strawberry images reveal that, after the 4th day of storage, microbial (mould) proliferation became more intense and visible. In addition, drip loss is observed at the bottom of the package on the last day of storage.
Strawberry visual quality showed great results on the first day (after harvest), with a small reduction at the beginning of storage (2nd day), as presented in Figure 4. The main reason for this reduction, in visual quality, is the presence of small bruises on the strawberry surface and loss of luminosity in the samples due to mass loss. A more intense reduction, in visual quality, was registered after the 4th day, due to the presence of microbial proliferation. However, no significant difference ($p>0.05$) was observed in the preservation of the strawberry, when comparing the different conditions (white LED light and in the dark).

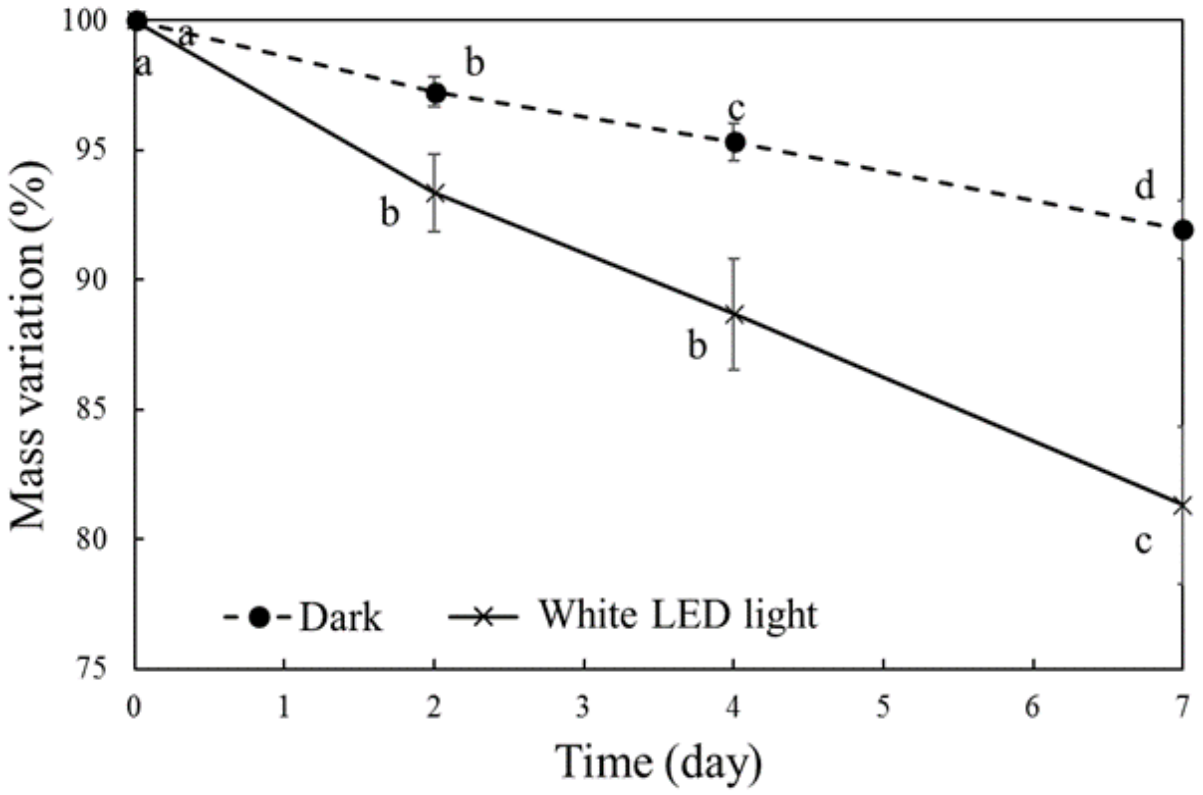

Figure 1. Strawberry mass variation under white LED light (×) and in the dark (•). Means ± SD (n = 3) with different letters are significantly different at 5% level, between white LED light and dark condition.

ISSN-Internet 2197-411x OLCL 862804632

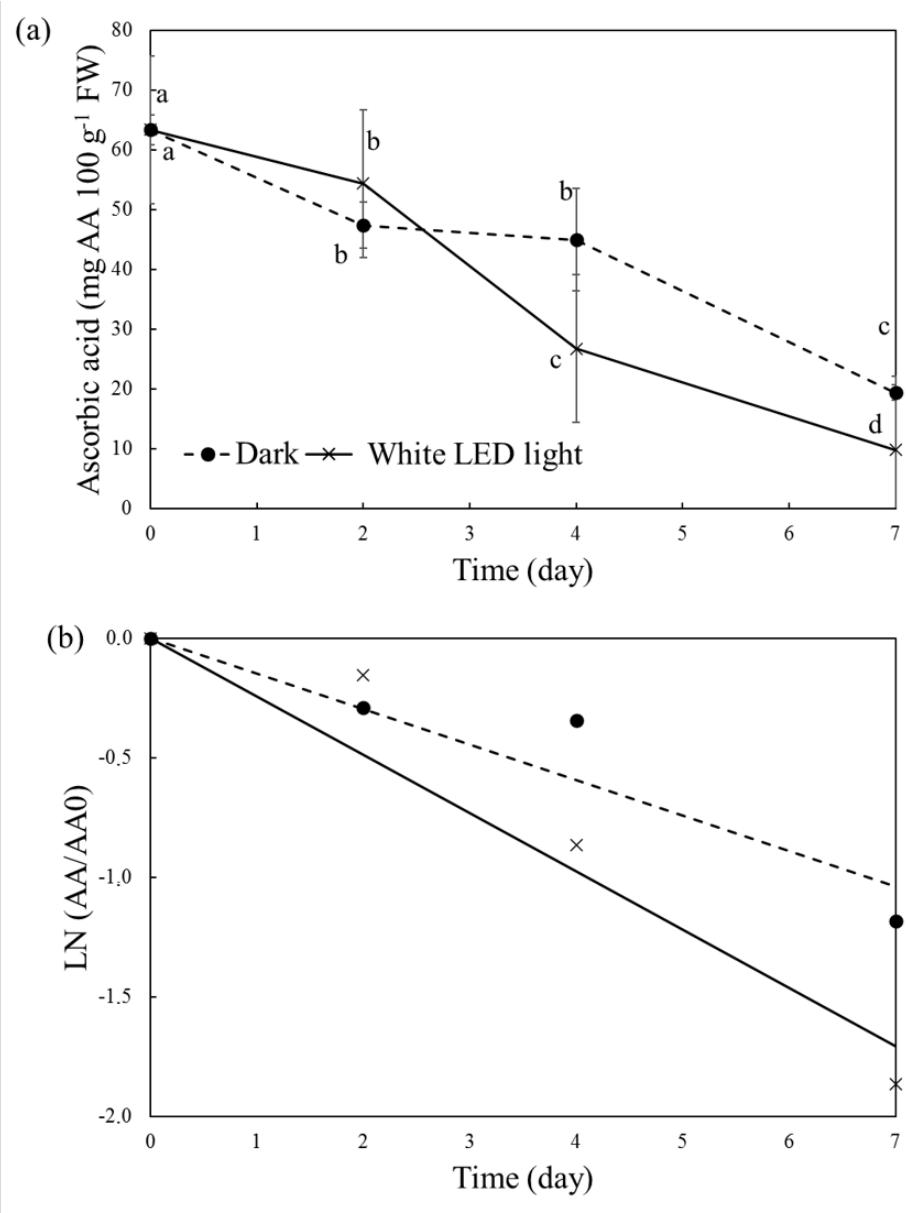

Figure 2. Strawberry ascorbic acid (AA) content in (•) dark and (×) white LED light (a), and AA degradation (b) during the storage time. Means ± SD (n = 3) with different letters are significantly different at 5% level, between white LED light and dark condition. AAO is the ascorbic acid at the initial of storage.

4. Discussion

Mass variation is mainly associated with respiration heat and evaporative cooling from the food surface, in response to transpiration. Both processes, transpiration, and respiration play an important role in water maintenance in the postharvest quality of strawberries (Hoffmann *et al.*, 2021b). The higher transpiration rate observed in strawberries stored under the white LED light was circa 2 times higher than the one observed in the absence of light, consequently resulting in the higher mass loss (mainly associated with the loss of water). Duarte-Molina et al. (2016), also observed higher mass loss in strawberries treated with a longer exposition of light and related this result to the tissue injury caused in strawberry samples due to light incidence. Photorespiration can additionally play an important role in strawberry transpiration under the white LED light once the achenes present in the strawberry, even after postharvest, have photosyn-

Table 1. Total polyphenols under the presence and absence of white LED light. (Means ± SD (n = 3), with different letters, are significantly different between white LED light and dark condition, at 5% level)

Total polyphenols (mg gallic acid 100g^{-1} FW)		
Day	Dark	White LED
0	1.8±0.1^{a}	1.8±0.1^{ab}
2	1.8±0.2^{a}	1.7±0.1^{a}
4	1.9±0.0^{a}	1.9±0.1^{ab}
7	2.0±0.0^{a}	1.9±0.1^{b}

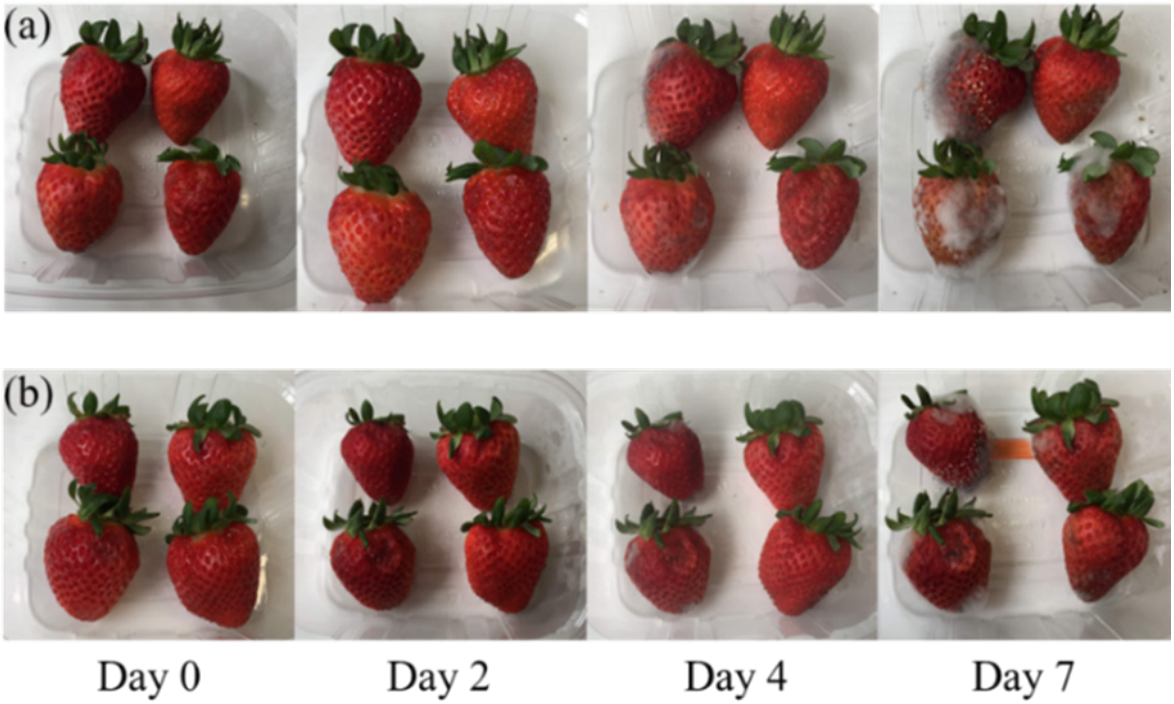

Figure 3. Visual quality of strawberry under white LED light (a) and in the dark (b), during the 7 days refrigerated storage.

thetic capacity due to chlorophyll incomplete decomposition, which leads to photorespiration (Meyerhoff and Pfündel, 2008). This physiological process has a direct effect on the metabolism and transpiration from fresh food produce, such as strawberries. According to Sastry and Buffington (1983), water removal from fresh food produce is assisted by evaporative heat due to the respiration mechanism, in which metabolism provides heat. For this reason, several studies recommend reducing the respiration rate to preserve fresh food produce (Chaomuang *et al.*, 2019, Hoffmann *et al.*, 2021a).

In accordance with mass loss, the ascorbic acid (AA) also presented a superior level of degradation under white LED light, when compared to dark condition, with approximately 16% higher AA degradation, after 7 days of storage. Xu et al. (2014), in a study with strawberries stored under blue LED light, obtained a higher level of ascorbic acid after 4 days, with ap-

ISSN-Internet 2197-411x OLCL 862804632

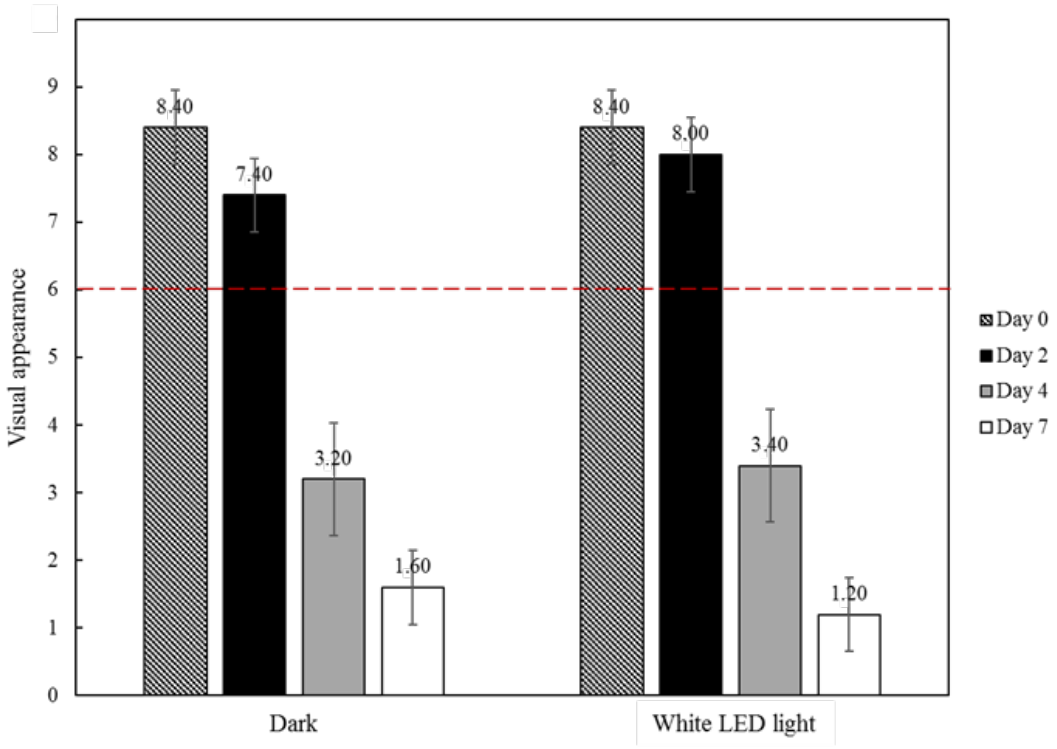

Figure 4. Visual quality white LED light and in the dark condition, in strawberry preservation under refrigeration, during the 7 days storage. (---) represents visual acceptance limit.

proximately 1.25 mg g^{-1} FW, at the end of 12 days of storage. On the other hand, the AA content in spinach, exposed to white LED light, showed 32% higher degradation than the samples stored in the dark, after 16 days of storage (Toledo *et al.,* 2003). The AA is an unstable vitamin present in strawberries. According to Klein (1987), some of the factors that have an important influence on AA content in food are temperature, pH, and light incidence. The reduction of ascorbic acid in strawberries can also be related to the mass loss (higher under white LED light) since the water movement, from the inside to the surroundings of the strawberries, carries other substances therein, such as vitamins, pigments (Ramallo and Albani, 2004, Agüero *et al.,* 2011).

The increase in total polyphenols content in strawberries can be associated with the mass loss since the water reduction from the samples resulted in an increase in polyphenols concentration. This correlation was presented by Agüero et al. (2011), who demonstrated that the quantification of the nutritional content in lettuce, when dealing with dried weight basis, reduces during food storage. In contrast to the fresh weight basis, which does not consider the water reduction from food and, for this reason, the results from substances are presented in higher levels. Despite the total polyphenolic compounds presenting similar results in both conditions evaluated in this study (white LED light and dark condition), the mass loss was significantly higher in the strawberries stored under white LED light, which may have provided a higher concentration in total polyphenols when results were presented in fresh weight basis. This observation led to the analysis that the total polyphenols under white LED light could be more degraded in this condition.

The visual quality presented no significant difference, in the strawberry preservation, under the presence and absence of white LED light, as shown by the sensorial analysis. The main factor that controlled the visual quality in this study was microbial proliferation because when moulds were visually present, after the 4th day, the sensorial scores dropped significantly. Both conditions, white LED light and dark condition, provided microbial proliferation, on a visual scale, at the same period, which can suggest that the different conditions did not influence this result. However, a

deeper study on microbial quantification is needed. In addition to microbial proliferation, the influence of tissue damage and bruising at the strawberry surface can also decrease sensorial scores.

5. Conclusion

The white LED light, when applied in the postharvest preservation of strawberries, had presented a negative effect, which can be mainly associated with photorespiration, caused by light incidence. This physiological process, stimulated by light, accelerated the mass loss by increasing the transpiration rate and, consequently, provided higher degradation of the ascorbic acid and total polyphenols content present in the strawberries. The sensorial scores, evaluated according to the visual quality, did not present influence from the presence or the absence of white LED light, while the microbial proliferation played an important role in the sensory evaluation, by reducing its visual quality value. In summary, the effects of the white LED light observed in strawberry indicates that, during the postharvest stage, this fruit storage should be conducted in the absence of light (white LED light) to preserve its organoleptic properties for longer.

Conflict of interest

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

Acknowledgements

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001. The authors also thank Fundação de Amparo à Pesquisa e Inovação do Estado de Santa Catarina (FAPESC) for the financial support.

References

Agüero, M. V., Ponce, A. G., Moreira, M. R., & Roura, S.I. (2011). Lettuce quality loss under conditions that favor the wilting phenomenon. Postharvest Biology and Technology, 59(2), 124–131. doi: 10.1016/j.postharvbio.2010.08.018

Almenar, E., Hernández-Munõz, P., Lagarón, J. M., Catalá, R., & Gavara, R. (2006). Controlled atmosphere storage of wild strawberry fruit (Fragaria vesca L.). Journal of Agricultural and Food Chemistry, 54(1), 86-91. doi: 10.1021/jf0517492

Angioletti, B. L., dos Santos, S. P., Hoffmann, T. G., Gonçalves, M. J., de Carvalho, L. F., Bertoli, S. L., de Souza, & C. K. (2020). Influence of whey protein edible film and refrigeration temperature on quality of acerola in natura during postharvest storage. AIChE Annual Meeting, Conference Proceedings. Retrieved from https://www.aiche.org/academy/conferences/aiche-annual-meeting/2020/proceeding/paper/160b-influence-whey-protein-edible-film-and-refrigeration-temperature-on-quality-acerola-natura

Box, G. E. P., Hunter, W. G., & Hunter, J. S. (2005). Statistics for Experimenters: An Introduction to Design, Data Analysis, and Model Building (2nd ed.). John Wiley & Sons.

Chaomuang, N., Flick, D., Denis, A., & Laguerre, O. (2019). Experimental analysis of heat transfer and airflow in a closed refrigerated display cabinet. Journal of Food Engineering, 244, 101–114. doi: 10.1016/j.jfoodeng.2018.09.009

Chong, L., Ghate, V., Zhou, W., Yuk, & H.-G. (2022). Developing an LED preservation technology to minimize strawberry quality deterioration during distribution. Food Chemistry, 366, 130566. doi: 10.1016/j.foodchem.2021.130566

D'Souza, C., Yuk, H. -G., Khoo, G. H., & Zhou, W. (2015). Application of light-emitting diodes in food production, postharvest preservation, and microbiological food safety. Comprehensive Reviews in Food Science and Food Safety, 14(6), 719-740. doi: 10.1111/1541-4337.12155

Dutta Gupta S. (2017). Light Emitting Diodes for Agriculture: Smart Lighting. In Application of light emitting diodes in controlled plant production system (pp. 191-235). Singapore: Springer. doi: 10.1007/978-981-10-5807-3_9

ISSN-Internet 2197-411x OLCL 862804632

Duarte-Molina, F., Gómez, P. L., Castro, M. A., & Alzamora, S. M. (2016). Storage quality of strawberry fruit treated by pulsed light: Fungal decay, water loss and mechanical properties. Innovative Food Science & Emerging Technologies, 34, 267-274. doi: 10.1016/j.ifset.2016.01.019

Finardi, S., Hoffmann, T. G., Schmitz, F. R. W., Bertoli, S. L., Khayrullin, M., Neverova, O., Ponomarev, E., Goncharov, A., Kulmakova, N., Dotsenko, E., Khryuchkina, E., Shariati, M. A., & De Souza, C. K. (2021). Comprehensive Study of Light-Emitting Diodes (LEDs) and Ultraviolet-LED Lights Application in Food Quality and Safety. Journal of Pure and Applied Microbiology, 15(3), 1125-1135. doi: 10.22207/JPAM.15.3.54

Finardi S., Hoffmann, T. G., Angioletti, B. L., Mueller, E., Lazzaris, R. S., Bertoli, S. L., Hlebova, M., Khayrullin, M., Nikolaeva, N., Shariati, M. A., & De Souza, C. K. (2022); Development and application of antioxidant coating on Fragaria spp. stored under isothermal conditions. Journal of Microbiology, Biotechnology and Food Sciences, 11(4), e5432. doi: 10.55251/jmbfs.5432

Gaithersburg, M. D. (2005). Official methods of analysis of AOAC International. Washington DC: Association of Official Analytical Chemists (AOAC).

Han, C., Zhao, Y., Leonard, S. W., & Traber, M. G. (2004). Edible coatings to improve storability and enhance nutritional value of fresh and frozen strawberries (Fragaria x ananassa) and raspberries (Rubus ideaus). Postharvest Biology and Technology, 33(1), 67-78. doi: 10.1016/j.postharvbio.2004.01.008

Hasperue, J. H., Guardianelli, L., Rodoni, L. M., Chaves, A. R., & Martínez, G. A. (2016). Continuous white-blue LED light exposition delays postharvest senescence of broccoli. LWT-Food Science and Technology, 65, 495-502. doi: 10.1016/j.lwt.2015.08.041

Hoffmann, T. G., Ronzoni A. F., da Silva D. L., Bertoli S. L., & de Souza C. K. (2021a). Impact of household refrigeration parameters on postharvest quality of fresh food produce. Journal of Food Engineering, 306, 110641. doi: 10.1016/j.jfoodeng.2021.110641

Hoffmann, T. G., Ronzoni, A. F., da Silva, D. L., Bertoli, S. L., & de Souza, C. K. (2021b). Cooling kinetics and mass transfer in postharvest preservation of fresh fruits and vegetables under refrigerated conditions. Chemical Engineering Transactions, 87, 115-120. doi: 10.3303/CET2187020

Hoffmann, T. G., Angioletti, B. L., Bertoli, S. L., & Souza, C. K. (2022). Intelligent pH-sensing film based on jaboticaba peels extract incorporated on a biopolymeric matrix. Journal of Food Science and Technology, 59(3), 1001-1010. doi: 10.1007/s13197-021-05104-6

Hoffmann, T. G., Peters, D. A., Angioletti, B. L., Bertoli, S. L., Péres, L. V., Reiter, M. G. R., & de Souza, C. K. (2019). Potentials nanocomposites in food packaging. Chemical Engineering Transactions, 75, 253-258. doi: 10.3303/CET1975043

Jiang, A., Zuo, J., Zheng, Q., Guo, L., Gao, L., Zhao, S., Wang, & Q., Hu, W. (2019). Red LED irradiation maintains the postharvest quality of broccoli by elevating antioxidant enzyme activity and reducing the expression of senescence-related genes. Scientia Horticulturae, 251, 73-79. doi: 10.1016/j.scienta.2019.03.016

Kasim, M. U., & Kasim, R. (2017). While continuous white LED lighting increases chlorophyll content (SPAD), green LED light reduces the infection rate of lettuce during storage and shelf-life conditions. Journal of Food Processing and Preservation, 41(6), e13266. doi: 10.1111/jfpp.13266

Kim, B. S, Lee, H. O, Kim, J. Y, Kwon, K. H, Cha, H. S, & Kim, J. H. (2011). An effect of light emitting diode (LED) irradiation treatment on the amplification of functional components of immature strawberry. Horticulture, Environment and Biotechnology, 52, 35-39. doi: 10.1007/s13580-011-0189-2

Klein, B. P. (1987). Nutritional consequences of minimal processing of fruits and vegetables. Journal of Food Quality, 10(3), 179-193. doi: 10.1111/j.1745-4557.1987.tb00857.x

Lan, W., Zhang, R., Ahmed, S., Qin, W., & Liu, Y. (2019). Effects of various antimicrobial polyvinyl alcohol/tea polyphenol composite films on the shelf life of packaged strawberries. LWT-Food Science and Technology, 113, 108297. doi: 10.1016/j.lwt.2019.108297

Meilgaard, M.C., Civille, G.V., & Carr, B.T. (2016). Sensory Evaluation Techniques (5th ed.).Boca Raton: CRC Press, Taylor & Francis Group.

Meyerhoff, O., & Pfündel, E. (2008). Photosynthesis in ripe strawberries (Fragaria × ananassa) recording by a MAXI IMAGING-PAM. PAM Application Notes, 1, 19-20.

Musa, C. I., Weber, B., Gonzatti, H. C., Biguelini, C. B., de Souza, C. F. V., & Oliveira, E. C. (2015). Vitamin C content of strawberries evaluation of different cultivars in different cropping systems in Bom Princípio /RS. Ciência e Natura, 37(2), 368-373. doi: 10.5902/2179460X16810

Nguyen, V. T. B., Nguyen, D. H. H., & Nhuyen, H. V. H. (2020). Combination effects of calcium chloride and nano-chitosan on the postharvest quality of strawberry (Fragaria x ananassa Duch.). Postharvest Biology and Technology, 162, 111103. doi: 10.1016/j.postharvbio.2019.111103

Ramallo, L. A., & Albani, O. A. (2004). Prediction and determination of water uptake in packaged yerba mate. Food Science and Technology International, 10(1), 35-40. doi: 10.1177/1082013204041877

Sastry, S. K., & Buffington, D. E. (1983). Transpiration rates of stored perishable commodities: a mathematical model and experiments on tomatoes. International Journal of Refrigeration, 6(2), 84–96. doi: 10.1016/0140-7007(83)90050-6

Soares, C. E., Weber, A., Moecke, E. H. S., de Souza, C. K., Reiter, M. G. R., & Scussel, V. M. (2018). Use of ozone gas as a green control alternative to beetles Alphitobius diaperinus (panzer)infestation in aviary bed utilized in the poultry industry. Chemical Engineering Transactions, 64, 589–594. doi: 10.3303/CET1864099

Toledo, M. E. A., Ueda, Y., Imahori, Y., & Ayaki, M. (2003). L-ascorbic acid metabolism in spinach (Spinacia oleracea L.) during postharvest storage in light and dark. Postharvest Biology and Technology, 28(1), 47-57. doi: 10.1016/S0925-5214(02)00121-7

Xu, F., Shi, L., Chen, W., Cao, S., Su, X., & Yang, Z. (2014). Effect of blue light treatment on fruit quality, antioxidant enzymes and radical-scavenging activity in strawberry fruit. Scientia Horticulturae, 175, 181-186. doi: 10.1016/j.scienta.2014.06.012

Zhang, C., Li, W., Zhu, B., Chen, H., Chi, H., Li, L., Qin, Y., & Xue, J. (2018). The quality evaluation of postharvest strawberries stored in nano-Ag packages at refrigeration temperature. Polymers, 10(8), 894. doi: 10.3390/polym10080894

ISSN-Internet 2197-411x OLCL 862804632