



Article

Long-Term Blueberry Storage by Ozonation or UV Irradiation Using Excimer Lamp

Yujiro Takano ¹, Daichi Hojo ¹, Kosuke Sato ¹, Noe Inubushi ¹, Chieto Miyashita ², Eiichi Inoue ¹ and Yuya Mochizuki ^{1,*}

- ¹ College of Agriculture, Ibaraki University, 3–21–1, Ami, Inashiki 300-0393, Ibaraki, Japan; yujiro.takano.qt18@vc.ibaraki.ac.jp (Y.T.); da.houjou@pref.ibaraki.lg.jp (D.H.); kou-satou@pref.ibaraki.lg.jp (K.S.); n.inbsh2@pref.chiba.lg.jp (N.I.); eiichi.inoue.a@vc.ibaraki.ac.jp (E.I.)
- ² Horticultural Science Division, Tokyo Metropolitan Agriculture and Forestry Research Center, 3–8–1, Tachikawa 190-0013, Tokyo, Japan; c-miyashita@tdfaff.com
- * Correspondence: yuya.mochizuki.fuji@vc.ibaraki.ac.jp; Tel.: +81-(29)-888-8554

Abstract

Blueberries are in high demand worldwide because of their taste and functional components. However, the shelf life of blueberries is short owing to their perishability and rapid quality deterioration. Therefore, a sterilization technology must be developed that can extend the shelf life of blueberries while maintaining their appearance and taste. As such, we verified the effectiveness of three pre-storage sterilization treatments (UV-C, ozone gas, and ozone water) using mercury-free excimer UV lamps that did not adversely affect the environment. We then created a device that continuously treated blueberries with approximately 2.57 ppm of ozone gas to ensure sterilization during the storage period, and we verified the effectiveness of the device. We found that the pre-storage ozone treatment reduced the number of fungi on the blueberry surface without adversely affecting fruit quality. The continuous ozone treatment suppressed the decrease in anthocyanin content, further reduced the number of fungi on the fruit surface and maintained fruit appearance for a longer period compared with the control. This suggests that continuous low-concentration ozone treatment suppresses the decay and extends the storage period of blueberries intended for raw consumption.



Academic Editor: Ayesha Sarker

Received: 3 June 2025

Revised: 25 July 2025

Accepted: 6 August 2025

Published: 21 August 2025

Citation: Takano, Y.; Hojo, D.; Sato, K.; Inubushi, N.; Miyashita, C.; Inoue, E.; Mochizuki, Y. Long-Term Blueberry Storage by Ozonation or UV Irradiation Using Excimer Lamp. *AgriEngineering* **2025**, *7*, 269. <https://doi.org/10.3390/agriengineering7080269>

Copyright: © 2025 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

Keywords: postharvest technology; *Vaccinium* spp.; excimer lamp; ozone; long-term storage; fruit quality

1. Introduction

Blueberries (*Vaccinium* spp.) are deciduous shrubs of the Ericaceae family native to North America. Interest in blueberries has recently increased because they are rich in polyphenols with high antioxidant activity and visual function-improving effects. Blueberries are considered superfood, leading to an increase in their consumption [1]. Domestically grown blueberries are widely cultivated in Japan as early-ripening highbush blueberries (*V. corymbosum*), which are harvested from June to July, and late-ripening rabbiteye blueberries (*V. virgatum*), which are harvested from July to August. However, the harvest period is short: only three months. Therefore, blueberries are cultivated in greenhouses [2] and plant factories [3] to extend the harvest period; however, the yield remains low. The period from October to January of the following year is the off-season for blueberries, during which few fruits are produced. Therefore, blueberries harvested in the summer must be stored for a long period, as well as imported, to meet the consumer demand for fresh fruit. Blueberries

have a short shelf life because of their perishability and rapid deterioration in quality even when stored under refrigerated conditions [4]. Therefore, effective pre- and post-storage sterilization methods must be established to extend the shelf life of blueberries.

Fungal diseases are the main cause of fruit-quality deterioration during storage. The main diseases are gray mold [5] and black spots [6] in strawberries, gray mold and rose mold in table grapes [7], and gray mold and anthracnose in blueberries [8]. The disease occurrence and decay caused by these microorganisms must be suppressed to maintain fruit quality. Washing with 50–200 ppm sodium hypochlorite is one of the most commonly used treatments for sterilizing fresh vegetables and fruits [9]. Various chemicals have been applied for sterilization treatments, including hydrogen peroxide, chlorine [10], lactic acid, and chlorine dioxide [11]. UV-C [12–15] is one of these treatments that is effective against all types of fungi and bacteria, being easy to use and causing almost no changes in the irradiated object after sterilization [16]. The ozone treatment method [17] is economical because its precursors are abundant in the air. Ozone generators are divided into three types: discharge, UV, and electrolysis generators [18]. The UV-type ozone generator using excimer lamps, which are mercury-free, is expected to be a method with less environmental impact. UV-C irradiation by excimer lamps ($\lambda_{\max} = 172$ nm) generates ozone using oxygen in the air, and is characterized by not generating nitrogen oxide (NO_x) as a by-product [18]. It has been reported that the UV-type ozone generator using the excimer lamp suppresses the corrosion of iron and copper more than the discharge type because of the difference in the amount of NO_x generated [18]. The effectiveness of ozone using a discharge-type ozone generator has been reported for strawberries [19,20], table grapes [21], peppers, watercress [22], and raspberries [23], although there has been no research. However, there are no or few reports on the effectiveness of using ozone generators of UV-type excimer lamps, or bactericidal tests aimed at the long-term storage of blueberries.

We applied UV-C irradiation using an excimer fluorescence lamp ($\lambda_{\max} = 228$ nm) to delay the onset of decay without adversely affecting the quality of strawberries in our previous study [15]. The use of low-pressure mercury lamps has increasingly faced environmental and regulatory challenges owing to the strict waste disposal and environmental regulations for mercury. We applied UV-C irradiation in this study to blueberries using a mercury-free germicidal discharge lamp, as well as ozone gas and water treatments. Our aim was to investigate the effects of these sterilization treatments using excimer lamps on the storability of blueberries. We conducted the pre-storage treatments and/or ozone treatment during storage, then investigated the effects of these treatments on the storability of blueberries, with the aim of further preserving blueberry quality.

2. Materials and Methods

2.1. Sterilization Using Excimer Fluorescent Lamps

2.1.1. Plant Materials

Rabbiteye blueberries ('Tifblue') were used as the plant materials. Approximately 10 kg of fruit was manually harvested from Agawa Farm (35.6559501, 139.3767729) in Hino City, Tokyo, Japan, on 12 August 2021. The maturation stage of fruits used in this experiment was determined to be when the color of the fruit skin was completely purple-blue. The harvested fruit was placed into packs of approximately 500 g each, which were put into a cooler box at 4 °C and immediately transported to the Laboratory of the Horticultural Science, Faculty of Agriculture, Ibaraki University. Only the fruits were sterilized and showed no scratches or withering.

2.1.2. Fruit Sterilization and Storage

Four treatments were established based on the different sterilization treatments (UV: UV-C irradiation; OG: ozone treatment; OW: ozone-water treatment; Control: no treatment). In UV treatment, the blueberries were spread out on a tray, ensuring no overlap, placed on a movable stage, and irradiated with an excimer UV lamp (OEL-160HSE, ORC Manufacturing Co., Ltd., Tokyo, Japan; Figure 1A). The distance between the lamp and stage was approximately 10 cm, the irradiation duration was approximately 66 min, and the stage movement speed was 1 mm s^{-1} . The UV dose was 93.0 mJ cm^{-2} , which was estimated to decrease the survival rate to $10^{-3}\%$ using *Penicillium digitatum* in a previous study [15].

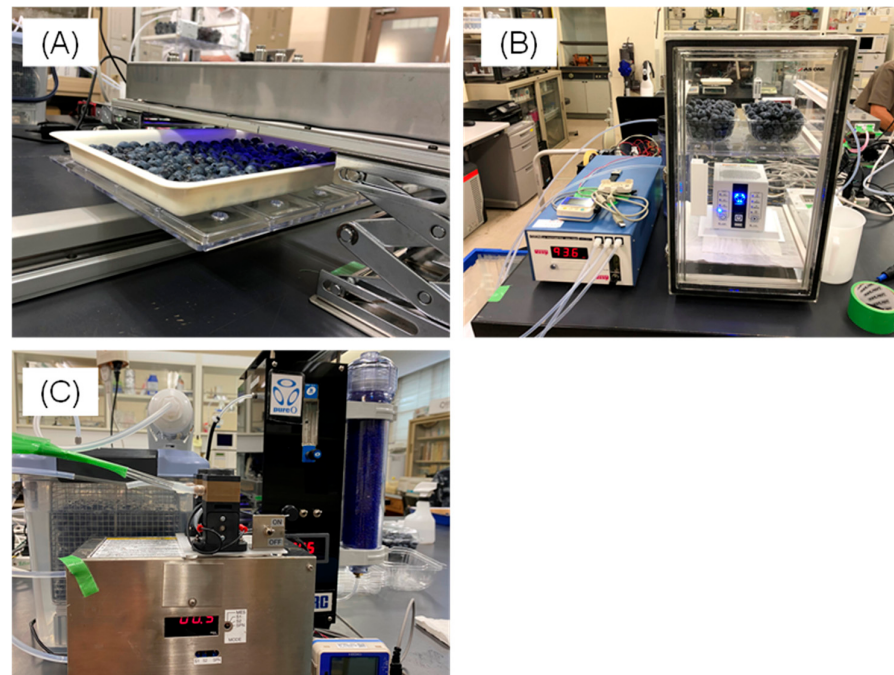


Figure 1. UV-C irradiation (A), ozone gas (B), and ozone-water treatment (C) before storage.

In OG treatment, two packs containing approximately 500 g of fruit were exposed to ozone generated using a mercury-free germicidal discharge lamp (ORC Manufacturing Co., Ltd., Tokyo, Japan) (Figure 1B). The ozone treatment concentration and duration were 200 ppm and approximately 2 h, respectively. The ct value was approximately 20,000 ct (ppm min), which had been estimated to decrease the survival rate to $10^{-3}\%$ using *Penicillium digitatum* in a previous study [24].

In OW treatment, approximately 1 kg of fruit was washed with ozone water generated using a mercury-free germicidal discharge lamp (ORC Manufacturing Co., Ltd., Tokyo, Japan; Figure 1C) for the ozone-water treatment. The ozone-water treatment's concentration and duration were 0.5 mg L^{-1} and approximately 1 h, respectively. The Ct value was approximately 30 ct (mg min L^{-1}), which had been estimated to decrease the survival rate to $10^{-3}\%$ using *Aspergillus brasiliensis* in a previous study [24].

The blueberries were spread on a tray after treatment and air-dried. Approximately 50 g of fruit was packed into plastic containers ($88 \times 88 \times 44 \text{ mm}$) after each sterilization treatment, which were wrapped in modified atmosphere packaging material of No. 8 standard (oxygen permeability $20,000 \text{ cc m}^{-2} \text{ d}^{-1} \text{ MPa}^{-1}$), and sealed with a sealer. Excess packaging material was removed using scissors. The blueberries were then stored in a low-temperature incubator (FMU-1331, Fukushima Industries Co., Ltd., Osaka, Japan; TPAV-120-20, Isuzu Manufacturing Co., Ltd., Niigata, Japan) at 4°C .

2.1.3. Weight Loss

The fresh weight (FW) of each fruit was measured before storage (day 0) and every two weeks after storage. The total weight loss was then calculated.

2.1.4. Soluble Solids Content (Brix) and Acidity

The Brix content and acidity of the fruits were measured using a pocket sugar acidity meter (PAL-BX | Acid F5, Atago Co. Ltd., Tokyo, Japan). The Brix content of the juice of fully colored crushed blueberries was measured. The acidity was determined using juice diluted with distilled water to 1:50.

2.1.5. Anthocyanin Content

Approximately 4 g of fruit was placed in a 50 mL tube, to which 20 mL of 5% acetic acid solution was added. The mixture was left to stand at 25 °C for 24 h and then filtered through a filter paper (No. 2, 90 mm standard). The filtrate was diluted 2-fold with 5% acetic acid and 200 µL aliquots were dispensed into the wells of a 96-well plate. The absorbance was measured at 530 nm using a multimode microplate reader (Flex Station 3, Molecular Devices, Sunnyvale, CA, USA). A calibration curve was prepared using cyanidin-3-glucoside (0–100 mg L⁻¹) and the anthocyanin content was expressed in mg per 100 g FW.

2.1.6. Mold Growth on Blueberry Surfaces

A weighed blueberry was placed in a zippered plastic bag, and sterilized water was added until the total weight reached 30 g. The blueberry was then washed using an ultrasonic cleaner for 12 min to obtain a fungal solution. The fungal solution was transferred to a test tube on a clean bench and diluted 10 times with sterile water. Then, 0.1 mL of the fungal solution was smeared on potato dextrose agar (PDA) medium and cultured in an incubator at 25 °C for 48 h. The medium was photographed after culturing to count the number of colonies and to determine the number of fungi per 1 g of fresh fruit. The number of fungi attached to the fruit surface was measured every two weeks.

2.1.7. Evaluation of Appearance Quality

Appearance quality was evaluated using the method described by Mochizuki et al. [25] with some modifications. The clamshell pack was photographed from above; the number of fruits that had rot, juice leakage, or were wilted, discolored, or moldy was counted, and the value was calculated by dividing the number of damaged fruits by the total number of fruits that could be seen from the top of the clamshell pack. Appearance quality was evaluated every two weeks.

2.2. Continuous Ozone Treatment

2.2.1. Plant Materials

The plant materials and harvesting methods were the same as those described in Section 2.1. Harvesting was performed on 6 August 2024.

2.2.2. Fruit Sterilization and Storage

Approximately 50 g of each blueberry was packed into perforated clamshell containers (88 × 88 × 44 mm), randomly divided into control and ozone treatment groups of 24 packs each, and stored in a low-temperature incubator (MIR-254, Panasonic Corp., Tokyo, Japan) at 5 °C. Continuous treatment was performed via pumping ozone gas into the storage chamber using an excimer UV lamp (OEL-050HSE, ORC Manufacturing Co., Ltd., Tokyo, Japan; Figure 2). The ozone concentration was measured at 2.57 ppm before the start of

the experiment. Air was pumped into the storage chamber at a constant flow rate in the control group. The relative humidity in the storage chamber ranged from 95% to 100%.

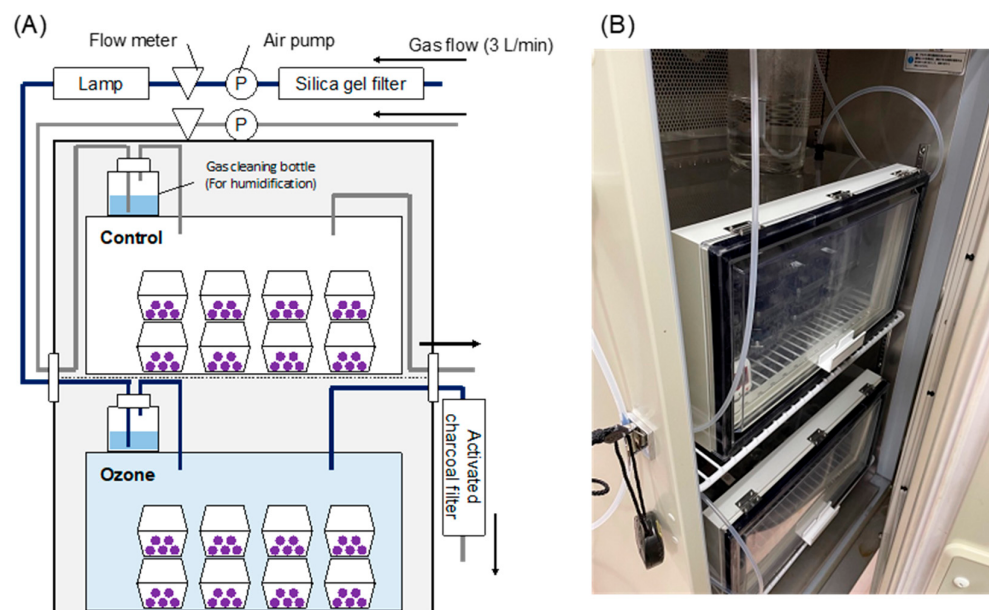


Figure 2. Schematic diagram of storage facility (A) and photograph of storage facility (B).

2.2.3. Weight Loss, Brix, Acidity, and Anthocyanin Content

The same method described in Section 2.1 was used.

2.2.4. Fruit Pericarp Hardness

The blueberry pericarp hardness was measured using a breaking strength analyzer (CA-3305, Yamaden Co. Ltd., Tokyo, Japan). The fruit was cut in half perpendicular to the equator, and a plunger was set to penetrate the equator of the fruit. The plunger had a diameter of 3 mm, and the test speed was 0.3 mm s^{-1} . Pericarp hardness was calculated as the maximum load (gf).

2.2.5. Mold Growth on Fruit Surfaces

The method used in Section 2.1 was slightly modified for this measurement. The measured fruit was placed in a plastic bag with a zipper, and sterilized water was added to a total of 30 g. The nutrient solution in the plastic bag was cleaned using an ultrasonic cleaner for 12 min and then collected to obtain the fungal solution. A dilution series of the fungal solution was prepared, and 1 mL of the fungal solution was mixed with PDA medium. The fungal solution was cultured for 7 days in an incubator at 25°C . The number of fungal colonies on the medium was counted after culturing, and the number of fungal colonies per 1 g of fresh fruit was calculated.

2.2.6. Evaluation of Appearance Quality

The same method as described in Section 2.1 was used.

2.3. Statistical Analysis

Analysis of variance (ANOVA) with random effects was conducted to investigate the effect of sterilization on the quality of the blueberries. The independent variable was the sterilization treatment, and the repeated measure was storage duration. Measurement values which are weight loss, anthocyanin content, pericarp firmness, and number of colonies were log-transformed for equal variance before analysis. The rate data, which are soluble

solids content and acidity data, were arcsine-transformed for equal variance before analysis. Multiple comparisons were conducted among the sterilization treatments for each storage duration when a significant interaction between the sterilization treatment and storage duration was found. ANOVAs were performed using the R function “anovakun” in R version 4.8.9. All statistical analyses were performed using R version 4.4.1 (R Development Core Team, 2024, Vienna, Austria).

3. Results

3.1. Effects of Sterilization Treatment Using Excimer Fluorescent Lamps on Blueberry Preservation and Storage

3.1.1. Weight Loss

Weight loss was significantly affected by the treatment and storage duration ($p < 0.05$, ANOVA, Table 1). We found no significant interaction between the treatment and storage duration ($p = 0.999$, ANOVA, Table 1). Weight loss in the UV and OG groups was significantly lower than that in the OW and control groups ($p < 0.05$, Holm’s test, Table 2).

Table 1. Analysis of variance (ANOVA) results of blueberry quality following sterilization treatment (Treat.) before storage.

		SS	DF	MS	F	p
Weight loss (g)	Treat.	0.412	3	0.138	8.53	0.001
	Storage	10.127	5	2.025	761.31	<0.001
	Treat. × Storage	0.008	15	0.001	0.21	0.999
	error	0.213	80	0.003		
Soluble solids content (Brix)	Treat.	0.001	3	0.000	1.49	0.255
	Storage	0.005	6	0.001	2.90	0.012
	Treat. × Storage	0.008	18	0.000	1.63	0.067
	error	0.025	96	0.000		
Acidity (%)	Treat.	0.010	3	0.003	0.81	0.509
	Storage	0.040	6	0.007	0.99	0.438
	Treat. × Storage	0.110	18	0.006	0.92	0.557
	error	0.559	84	0.007		
Anthocyanin content (mg gFW ^{−1})	Treat.	0.002	3	0.001	0.12	0.949
	Storage	0.057	6	0.010	2.70	0.024
	Treat. × Storage	0.039	18	0.002	0.62	0.866
	error	0.168	48	0.004		
No. colony-forming unit (CFU gFW ^{−1})	Treat.	18.620	3	6.207	17.24	<0.001
	Storage	19.576	6	3.263	9.05	<0.001
	Treat. × Storage	13.494	18	0.750	2.08	0.012
	error	34.605	96	0.361		

Table 2. Effects of pre-storage sterilization treatment on blueberry quality (average ± standard deviation (SD)). Different letters indicate significant difference for same storage duration for each fruit parameter ($p < 0.05$).

Treatment		Storage Duration (Weeks)						
		0	2	4	6	8	10	12
Weight loss (g) (n = 5)	UV ^A	(50.0 ± 0.78)	0.07 ± 0.03	0.13 ± 0.03	0.21 ± 0.03	0.31 ± 0.03	0.39 ± 0.04	0.47 ± 0.03
	OG ^{AB}	(50.4 ± 0.36)	0.07 ± 0.01	0.15 ± 0.04	0.23 ± 0.02	0.33 ± 0.02	0.41 ± 0.03	0.49 ± 0.03
	OW ^C	(49.5 ± 0.84)	0.09 ± 0.02	0.19 ± 0.01	0.30 ± 0.02	0.41 ± 0.03	0.53 ± 0.03	0.65 ± 0.05
	Control ^{BC}	(49.7 ± 0.44)	0.09 ± 0.02	0.17 ± 0.01	0.28 ± 0.02	0.39 ± 0.02	0.50 ± 0.03	0.61 ± 0.04
Soluble solids content (Brix) (n = 5)	UV	14.5 ± 1.96	14.0 ± 1.04	12.6 ± 1.62	13.9 ± 0.43	12.8 ± 0.85	11.8 ± 0.93	12.9 ± 2.12
	OG	13.8 ± 1.68	14.5 ± 1.34	13.9 ± 1.23	13.6 ± 1.91	13.3 ± 1.15	11.5 ± 1.89	13.1 ± 1.50
	OW	13.4 ± 1.36	13.4 ± 2.53	11.5 ± 0.71	12.3 ± 1.66	12.0 ± 2.85	13.1 ± 1.43	12.7 ± 0.68
	Control	14.3 ± 0.94	12.7 ± 2.32	13.8 ± 1.40	12.9 ± 1.45	13.5 ± 1.15	13.7 ± 2.12	10.4 ± 0.99

Table 2. Cont.

Treatment		Storage Duration (Weeks)						
		0	2	4	6	8	10	12
Acidity (%) (<i>n</i> = 5)	UV	0.38 ± 0.10	0.36 ± 0.03	0.34 ± 0.10	0.39 ± 0.06	0.39 ± 0.05	0.38 ± 0.05	0.45 ± 0.07
	OG	0.39 ± 0.09	0.37 ± 0.04	0.35 ± 0.01	0.40 ± 0.14	0.33 ± 0.03	0.43 ± 0.13	0.35 ± 0.04
	OW	0.39 ± 0.04	0.42 ± 0.09	0.41 ± 0.09	0.39 ± 0.13	0.38 ± 0.08	0.43 ± 0.08	0.40 ± 0.03
	Control	0.36 ± 0.02	0.40 ± 0.04	0.38 ± 0.06	0.43 ± 0.08	0.35 ± 0.04	0.39 ± 0.05	0.45 ± 0.07
Anthocyanin content (mg gFW ⁻¹) (<i>n</i> = 3)	UV	0.84 ± 0.06	0.82 ± 0.04	0.93 ± 0.10	0.84 ± 0.03	0.76 ± 0.08	0.74 ± 0.05	0.74 ± 0.16
	OG	0.84 ± 0.06	0.97 ± 0.08	0.86 ± 0.10	0.79 ± 0.05	0.78 ± 0.10	0.77 ± 0.10	0.76 ± 0.15
	OW	0.84 ± 0.04	0.90 ± 0.10	0.86 ± 0.10	0.79 ± 0.05	0.75 ± 0.20	0.83 ± 0.23	0.83 ± 0.06
	Control	0.79 ± 0.07	0.94 ± 0.02	0.82 ± 0.07	0.89 ± 0.14	0.82 ± 0.20	0.83 ± 0.05	0.70 ± 0.10

3.1.2. Soluble Solids Content (Brix) and Acidity

Brix was significantly affected by the storage duration ($p = 0.012$, ANOVA, Table 1). We found no interaction between treatment and storage duration ($p = 0.067$, ANOVA, Table 1).

Acidity was not significantly affected by the treatment or storage duration ($p > 0.05$, ANOVA, Table 1). Additionally, no interaction was found between the UV irradiation duration and storage duration ($p = 0.557$, ANOVA, Table 1). Changes in acidity were minimal throughout the storage period (Table 2).

3.1.3. Anthocyanin Content

The anthocyanin content was significantly affected by storage duration ($p = 0.024$, ANOVA, Table 1). Treatment before storage did not affect the anthocyanin content ($p = 0.949$, ANOVA, Table 1), and no interaction was found between treatment and storage duration ($p = 0.866$, ANOVA, Table 1).

3.1.4. Mold Growth on Fruit Surfaces

The fungal count on the fruit surface was significantly affected by treatment and storage duration ($p < 0.001$, ANOVA, Table 1). We found a significant interaction between treatment and storage duration ($p = 0.012$, ANOVA, Table 1). The fungal content in the OG blueberries was significantly lower than that in the UV and control blueberries from 4 to 10 weeks of storage (Figure 3).

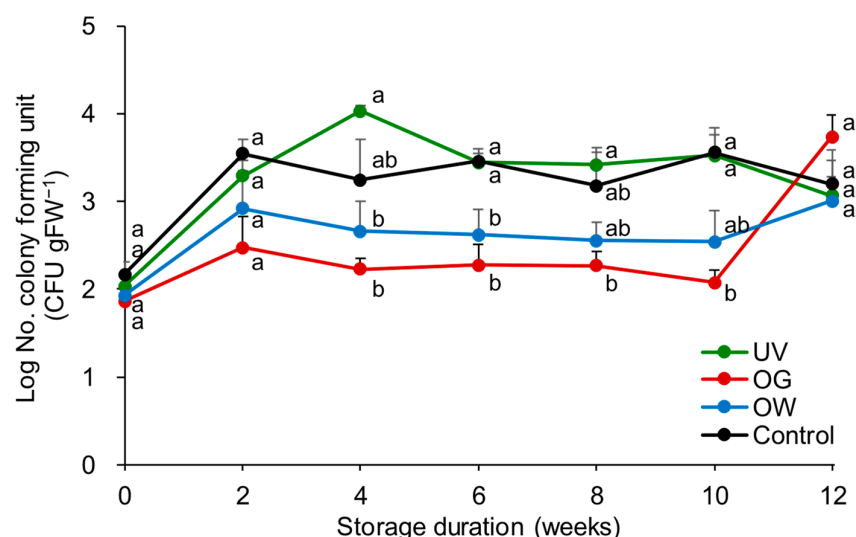


Figure 3. Effect of pre-storage sterilization treatment on fungal content during storage (CFU gFW⁻¹) (average + SD). Different letters indicate significant differences for same storage duration for each treatment ($p < 0.05$).

3.1.5. Evaluation of Appearance Quality

The fruit's appearance quality decreased in all treatments with increasing storage duration (Figure 4). The mold on the fruit appeared at different times in the different treatments: after 2, 4, 6, and 6 weeks of storage in the UV, control, OG, and OW treatments, respectively (Figure 4).

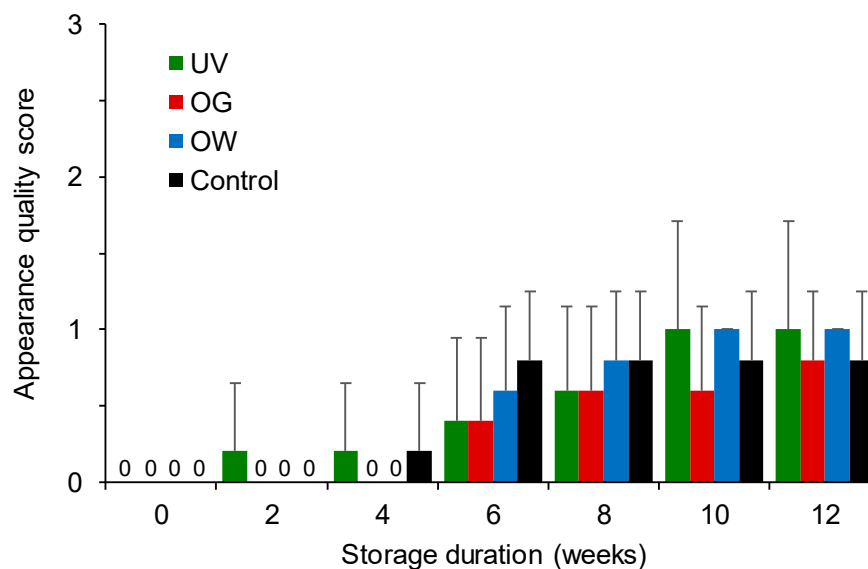


Figure 4. Appearance quality of blueberry fruit in different sterilization treatments before storage (average + SD). The value showed the appearance quality score was zero.

3.2. Effect of Continuous Ozone Treatment on Blueberry Fruit Storability

3.2.1. Weight Loss

Weight loss was significantly affected by the storage duration ($p < 0.001$, ANOVA, Table 3). No significant interaction was observed between ozonation and storage duration ($p = 0.65$, ANOVA, Table 3). The weight loss in the ozone treatment group tended to be higher than that in the control group for each storage duration between treatment intervals during the same storage period (Table 4).

Table 3. ANOVA results of blueberry fruit quality following continuous ozone treatment during storage.

		SS	Df	MS	F	p
Weight loss (g)	Ozone	0.291	1	0.291	4.882	0.078
	Storage	1.284	5	0.257	11.616	<0.001
	Ozone × Storage	0.074	5	0.015	0.670	0.650
	error	0.553	25	0.022		
Soluble solids content (Brix)	Ozone	0.000	1	<0.001	3.401	0.102
	Storage	0.011	6	0.002	13.171	<0.001
	Ozone × Storage	0.001	6	<0.001	1.475	0.207
	error	0.007	48	<0.001		
Acidity (%)	Ozone	0.000	1	0.000	0.090	0.772
	Storage	0.847	6	0.141	62.568	<0.001
	Ozone × Storage	0.011	6	0.002	0.803	0.573
	error	0.108	48	0.002		
Anthocyanin content (mg gFW ⁻¹)	Ozone	0.104	1	0.104	12.904	0.007
	Storage	0.528	6	0.088	16.850	<0.001
	Ozone × Storage	0.023	6	0.004	0.725	0.631
	error	0.251	48	0.005		
Pericarp firmness (gf)	Ozone	0.113	1	0.113	9.727	0.014
	Storage	0.128	6	0.021	0.893	0.508
	Ozone × Storage	0.129	6	0.022	0.906	0.499
	error	1.143	48	0.024		

Table 3. *Cont.*

		SS	Df	MS	F	p
No. colony forming unit (CFU gFW ⁻¹)	Ozone	14.167	1	14.167	59.524	<0.001
	Storage	10.828	6	1.805	5.106	<0.001
	Ozone × Storage	9.919	6	1.653	4.678	<0.001
	error	29.687	84	0.353		

Table 4. Effects of continuous ozone treatment during storage on blueberry fruit quality (average ± SD). Different letters indicate significant differences in fruit quality for same storage duration ($p < 0.05$).

	Treat.	Storage Duration (Weeks)						
		0	2	4	6	8	10	12
Weight loss (g) (n = 4)	Ozone	(51.9 ± 0.26)	0.29 ± 0.08	0.36 ± 0.18	0.39 ± 0.57	0.67 ± 0.33	0.82 ± 0.31	0.96 ± 0.26
	Control	(52.6 ± 0.27)	0.33 ± 0.05	0.33 ± 0.16	0.41 ± 0.12	0.60 ± 0.11	0.65 ± 0.06	0.75 ± 0.07
Soluble solids content (Brix) (n = 5)	Ozone		16.2 ± 1.05	13.0 ± 1.57	13.4 ± 1.51	13.6 ± 1.02	12.3 ± 0.70	11.3 ± 0.78
	Control	14.5 ± 1.24	14.8 ± 1.47	11.8 ± 1.16	13.4 ± 0.93	11.8 ± 1.35	12.4 ± 0.52	11.9 ± 1.36
Acidity (%) (n = 5)	Ozone		0.55 ± 0.05	0.35 ± 0.04	0.36 ± 0.06	0.30 ± 0.05	0.30 ± 0.02	0.28 ± 0.04
	Control	0.54 ± 0.05	0.50 ± 0.04	0.33 ± 0.04	0.37 ± 0.06	0.29 ± 0.04	0.31 ± 0.05	0.31 ± 0.04
Anthocyanin content (mg gFW ⁻¹) (n = 5)	Ozone ^A		1.12 ± 0.13	0.86 ± 0.06	0.93 ± 0.13	0.76 ± 0.14	0.69 ± 0.06	0.68 ± 0.17
	Control ^B	1.07 ± 0.23	0.85 ± 0.11	0.71 ± 0.11	0.79 ± 0.18	0.65 ± 0.05	0.59 ± 0.17	0.52 ± 0.06
Pericarp firmness (gf) (n = 5)	Ozone ^A		172.7 ± 54.9	181.1 ± 64.2	189.5 ± 44.7	172.5 ± 30.4	235.4 ± 73.8	171.5 ± 30.1
	Control ^B	184.2 ± 52.0	168.9 ± 17.0	185.0 ± 41.1	159.7 ± 56.7	142.4 ± 62.1	157.6 ± 75.7	125.4 ± 68.9

3.2.2. Soluble Solids Content (Brix) and Acidity

Brix was significantly affected by the storage duration ($p < 0.001$, ANOVA, Table 3). The ozone treatment during storage did not affect Brix ($p = 0.102$, ANOVA, Table 3). There was no significant interaction between the ozone treatment and storage duration ($p = 0.207$, ANOVA, Table 3).

Acidity was significantly affected by storage duration ($p < 0.001$, ANOVA, Table 3). The ozone treatment during storage did not affect the acidity ($p = 0.772$, ANOVA, Table 3). Additionally, there was no interaction between ozone treatment and storage duration ($p = 0.573$, ANOVA, Table 3), and the acidity showed little change throughout the storage period (Table 4).

3.2.3. Anthocyanin Content

Anthocyanin content was significantly affected by storage duration ($p < 0.001$, ANOVA, Table 3). The ozone treatment during storage suppressed this decrease in anthocyanin content ($p = 0.007$, ANOVA, Table 3). There was no significant interaction between the ozone treatment and storage duration ($p = 0.631$, ANOVA; Table 3).

3.2.4. Fruit Pericarp Hardness

The pericarp hardness was significantly affected by treatment ($p = 0.014$, ANOVA, Table 3) but not by storage duration ($p = 0.508$, ANOVA, Table 3). We found no interaction between the storage period and treatment ($p = 0.499$, ANOVA, Table 3).

3.2.5. Mold Growth on Fruit Surface

The fungal counts on the blueberry fruit surface were significantly affected by the treatment and storage duration ($p < 0.001$, ANOVA, Table 3). We found a significant

interaction between the treatment and storage duration ($p < 0.001$, ANOVA; Table 3). The fungal content in the ozone-treated group was significantly lower than that in the control group from 6 to 12 weeks of storage (Figure 5).

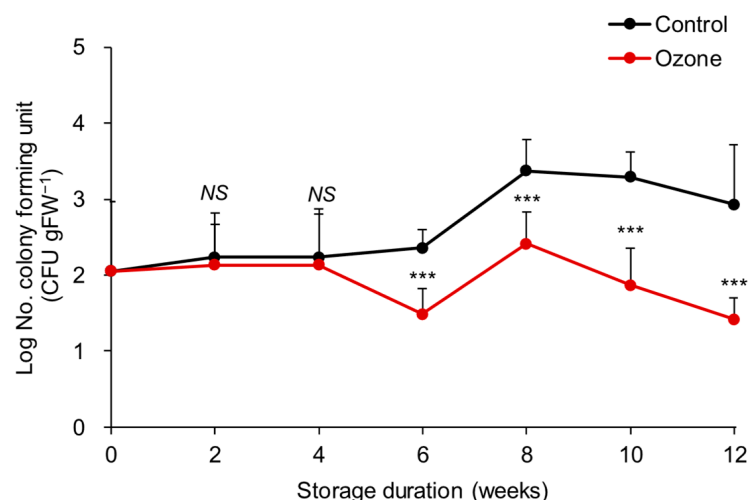


Figure 5. Effect of continuous ozone treatment during storage on progression of fungal content of blueberry fruit during storage (CFU gFW⁻¹) (average + SD). The number of colonies forming unit were compared between the continuous-ozone and control treatments for the same storage duration (NS: $p > 0.05$; ***: $p < 0.01$; Holm's test).

3.2.6. Evaluation of Fruit Appearance Quality

The appearance quality of the blueberries in the control treatment decreased with increasing storage duration, although no mold growth was observed in the continuous ozone treatment throughout the storage period (Figures 6 and 7). However, slight fruit cracks were observed after 8 weeks of continuous ozone treatment (Figure 6B).

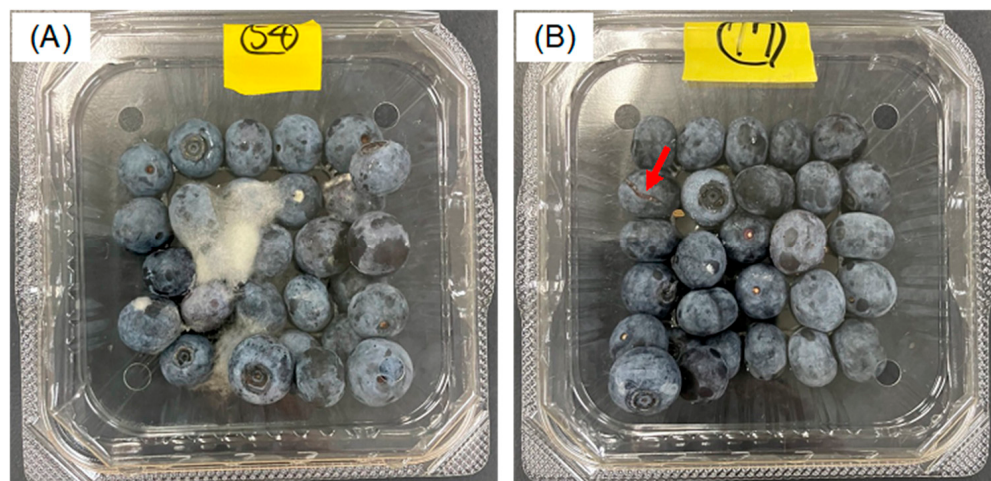


Figure 6. Appearance of blueberry fruit after 12 weeks of storage in (A) the control and (B) under continuous ozone treatment. The red arrow indicates a crack in the fruit.

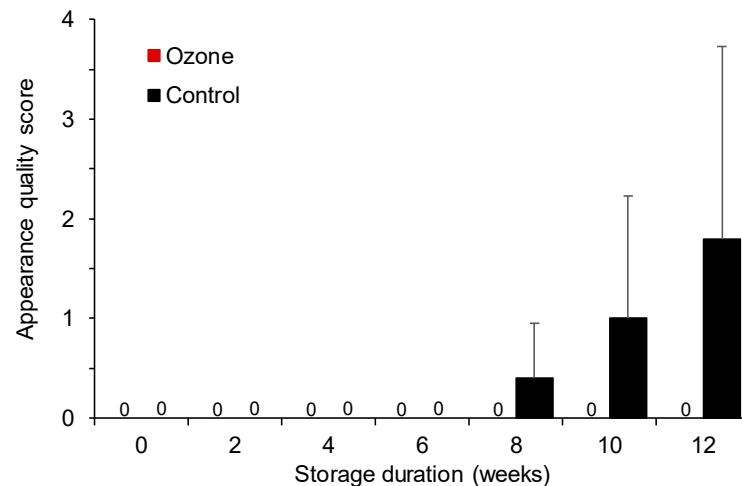


Figure 7. Appearance quality of blueberry fruit in continuous ozone treatment during storage (average + SD). The value showed appearance quality score was zero.

4. Discussion

The weight loss of blueberries treated with high-concentration ozone gas and UV irradiation before storage tended to be lower than that of the fruits in the ozone water and control treatments, although a significant difference was observed only between the UV and control treatments. (Table 2). However, continuous ozone treatment did not affect weight loss (Table 4). Concha-Meyer et al. [26] found no significant difference in weight loss when blueberry fruits were stored at 4 °C for 10 days under ozone treatment at 2.5 ± 1.5 ppm; however, the weight loss was significantly suppressed at 12 °C under identical conditions. The weight loss of strawberries was reduced by approximately 60% upon treatment with 18 mg L^{-1} ozone gas [19]. In addition, sulfur dioxide and ozone treatments suppressed the weight loss and decay of blueberries, increasing storage stability [27]. The results of this study also showed that the ozone treatment effectively suppressed fruit weight loss. Jaramillo-Sanchez et al. [28] reported that when blueberry fruits were washed with 18 mg L^{-1} ozone water for 10–30 min and stored at 4 ± 1 °C for 20 days, weight loss substantially increased when treated with ozone for 15 min or longer. Xu et al. [29] reported that fruit weight loss was suppressed when blueberries were irradiated with UV-C at an intensity of 4 kJ m^{-2} for 3 min. In addition, the maximum weight loss at which blueberry fruits lose their commercial value was reported as 5–8% [30]. The fruit weight loss rate in this study was less than 2%; therefore, we determined that the treatments did not adversely affect the fruit weight.

The soluble solids content decreased with increasing storage duration, irrespective of pre-storage sterilization treatment (Table 1). This decrease in Brix values may have been due to the consumption of soluble solids as respiratory substrates [31]. Perkins-Veazie et al. [32] reported that 254 nm UV-C irradiation of blueberry fruits did not affect their sugar content or acidity, which is consistent with our results. In addition, Contigiani et al. [20] found that treating strawberries with ozone water (maximum concentration of 3.5 mg L^{-1}) for 5 or 15 min did not affect their sugar content and acidity. Our results are consistent with these findings. Continuous ozone treatment at 0.3 or 0.9 ppm did not affect sugar content and acidity in raspberries [23,33]. In this study, continuous ozone treatment did not significantly affect the Brix or acidity (Table 3). Therefore, none of the sterilization treatments affected the Brix sugar content or acidity of blueberries.

None of the pre-storage sterilization treatments substantially affected the anthocyanin content of the fruits during storage (Table 1). Alexandre et al. [13] found that 254 nm UV-C irradiation and 0.3 ppm ozone water treatment maintained the anthocyanin content

of strawberries during refrigerated storage and did not markedly affect the anthocyanin content of raspberries [33], mulberries [34], or strawberries [4]. These findings are consistent with the results of this study: we thus determined that none of the sterilization treatments negatively affected the anthocyanin content of the blueberries. However, the anthocyanin content decreased with increasing storage duration, and continuous ozone treatment more strongly suppressed this decrease compared with the control treatment (Table 4). Anthocyanins are strong antioxidants that scavenge free radicals [35], and ozone treatment increases the levels of antioxidants in berries. Exposure of blueberries to 15 ppm ozone gas for 30 min every 12 h increased the levels of antioxidants, such as anthocyanins and chlorogenic acid, compared with those in untreated fruits [36]. Ozone treatment of strawberries at 1, 3, and 5 ppm for 10 h every 7 days increased the content of polyphenolic compounds, with the largest increase at 5 ppm [37]. Therefore, the high anthocyanin content in the continuous ozone treatment area may have been due to an increase in antioxidant levels in the fruits.

The continuous ozone treatment did not affect the firmness of the fruit pericarp (Table 3). Concha-Meyer et al. [26] found that ozone treatment did not significantly affect the firmness of blueberries stored at 4 °C for 10 days, and no significant difference was observed in firmness between strawberry fruits exposed to 5000 ppm ozone gas and control fruits [38]. These results suggest that the continuous ozone treatment in this study did not affect fruit firmness.

UV treatment did not substantially reduce the fungal content compared with that of the untreated fruits (Figure 3). Bank et al. [39] reported that the germicidal effect of UV light is limited to an area directly irradiated with a UV lamp. UV-C treatment suppressed fruit decay when both sides of the blueberry fruit were irradiated [29,32]. We applied UV-C irradiation to only one side of the blueberry fruit; therefore, a sufficient germicidal effect was not achieved. Alexandre et al. [13] reported that 0.3 ppm ozone water treatment for 2 min reduced the number of fungi attached to strawberries, and Crowe et al. [10] reported that treatment with 1 ppm ozone water for 60 or 120 s reduced the number of bacteria attached to blueberries. These results are consistent with ours. However, washing with water did not reduce the number of fungi and bacteria on the fruit surface compared with ozone-water treatment [10,13,17]. Therefore, the reduction in the fungal content on the fruit surface observed in this study could be attributed to the bactericidal effect of ozone. We observed a considerable reduction in the fungal content before and after continuous ozone treatment (Figures 3 and 5).

The bactericidal effects of ozone have been studied in various crops. Onopiuk et al. [23] showed that ozone treatment at 140 or 420 ppm reduced the number of fungi on raspberries. Bridges et al. (2018) [40] reported that ozone treatment at 200 and 400 ppm was not an effective bactericidal treatment for blueberries. The differences in these findings were caused by differences in the ozone treatments; that is, the ozone concentration was measured and maintained in our study and that of Onopiuk et al. [23], whereas ozone gas was simultaneously fed into the chambers (4 L of gas) in the study by Bridges et al. [40]. Ozone gas is sufficiently stable, allowing its concentration to be maintained during ozonation because ozone reacts with various organic substances and undergoes self-decomposition. In addition, the fungal content on the surface of the blueberries in the continuous ozone treatment was lower than that on the sterilized fruit before storage, demonstrating the effectiveness of the continuous ozone treatment.

In this study, the pre-storage sterilization treatments with ozone gas or ozonated water tended to suppress mold emergence on the blueberries (Figure 4). Xu et al. [29] reported that UV-C irradiation at 4 kJ m⁻² delayed the onset of rot in blueberries, and Perkins et al. [32] also found that UV-C irradiation at 1 to 4 kJ m⁻² suppressed rot in blueberries by 10%.

Contigiani et al. [20] observed that treatment with ozone water at a maximum concentration of 3.5 mg L⁻¹ suppressed strawberry rot caused by *Botrytis cinerea* approximately 17%, and Giuggioli et al. [33] found that 500 ppb and 200 to 50 ppb ozone treatment maintained the appearance of raspberries. These findings are consistent with our results, in which each sterilization treatment suppressed fruit rot. However, mold outbreaks caused by stem scarring are also frequently observed. The fungal invasion of stem scars must be prevented to prevent postharvest decay [41]. Therefore, continuous ozone treatment was applied, which could sterilize the fruit during storage. Consequently, fruit decay was considerably delayed compared with that of the control (Figure 7). However, cracks were observed in some fruits treated with ozone gas (Figure 6B), likely due to damage to the epidermal cells of the fruit. Ozone oxidizes the protein components of microorganisms and causes membrane damage; however, it also damages proteins and nucleic acids in the fruit epidermis, causing cell lysis [42]. In addition, the effects of ozone depend on the ozone concentration and exposure duration [43]. Therefore, further research is needed to develop more appropriate treatment techniques, such as continuous ozone gas at lower concentrations or intermittent ozone gas exposure, to maintain the appearance of fruits during long-term storage.

5. Conclusions

Pre-storage ozone treatment reduced the number of fungi on blueberry fruit surfaces without adversely affecting fruit quality. However, molds emerged over 6 weeks of storage. We then investigated the effects of continuous ozone treatment during storage, which suppressed the decrease in the anthocyanin content, reduced the number of fungi on the fruit surface, and maintained the quality of the appearance compared with the other treatments. This suggests that continuous treatment of blueberries during storage with low-concentration ozone gas can suppress decay and extend the storage duration of fresh blueberries.

Author Contributions: Conceptualization, Y.T. and Y.M.; formal analysis, Y.T.; investigation, Y.T., D.H., K.S., N.I. and Y.M.; resources, Y.M.; data curation, Y.T. and Y.M.; project administration, Y.T., C.M., E.I. and Y.M.; writing—original draft, Y.T., D.H., K.S. and Y.M.; writing—review and editing, Y.T., C.M., E.I. and Y.M.; funding acquisition, Y.M. All authors have read and agreed to the published version of the manuscript.

Funding: This study was supported by the Mishima Kaiun Memorial Foundation (FY2024 Academic Research Grant, Natural Sciences Division, Japan).

Data Availability Statement: The original contributions presented in this paper are included in this article; further inquiries can be directed to the corresponding author.

Acknowledgments: We thank Izumi Serizawa, who works at ORC Manufacturing Co. Ltd., for supporting the use of the excimer UV lamps in this experiment and the students at the Laboratory of Horticultural Science, Ibaraki University, for helping with this study.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Bell, L.; Williams, C.M. Blueberry benefits to cognitive function across the lifespan. *Int. J. Food Sci. Nutr.* **2020**, *72*, 650–652. [[CrossRef](#)] [[PubMed](#)]
2. Higashide, T.; Aoki, N.; Kinoshita, T.; Ibuki, T.; Kasahara, Y. Forcing culture of blueberry grown in a container using a hydroponics system suitable for use in hilly and mountainous areas. *Hortic. Res.* **2006**, *5*, 303–308. [[CrossRef](#)]
3. Aung, T.; Muramatsu, Y.; Horiuchi, N.; Che, J.; Mochizuki, Y.; Ogiwara, I. Plant growth and fruit quality of blueberry in a controlled room under artificial light. *J. Jpn. Soc. Hortic. Sci.* **2014**, *83*, 273–281. [[CrossRef](#)]

4. Pinto, L.; Palma, A.; Cefola, M.; Pace, B.; D'Aquino, S.; Carboni, C.; Baruzzi, F. Effect of modified atmosphere packaging (MAP) and gaseous ozone pre-packaging treatment on the physico-chemical, microbiological and sensory quality of small berry fruit. *Food Packag. Shelf Life* **2020**, *26*, 100573. [[CrossRef](#)]
5. Nadas, A.; Olmo, M.; García, J.M. Growth of *Botrytis cinerea* and strawberry quality in ozone-enriched atmospheres. *J. Food Sci.* **2003**, *68*, 1798–1802. [[CrossRef](#)]
6. Feliziani, E.; Romanazzi, G. Postharvest decay of strawberry fruit: Etiology, epidemiology, and disease management. *J. Berry Res.* **2016**, *6*, 47–63. [[CrossRef](#)]
7. Crisosto, H.C.; Smilanick, J.L.; Dokoozlian, N.K.; Luvisi, D.A. Maintaining table grape post-harvest quality for long distant markets. *Int. Symp. Table Grape Prod.* **1994**, 195–199.
8. Tournas, V.H.; Katsoudas, E. Mould and yeast flora in fresh berries, grapes and citrus fruits. *Int. J. Food Microbiol.* **2005**, *105*, 11–17. [[CrossRef](#)]
9. Hwang, C.; Huang, L.; Wu, V.C. In situ generation of chlorine dioxide for surface decontamination of produce. *J. Food Prot.* **2017**, *80*, 567–572. [[CrossRef](#)]
10. Crowe, K.M.; Bushway, A.A.; Bushway, R.J.; Davis-Dentici, K.; Hazen, R.A. A comparison of single oxidants versus advanced oxidation processes as chlorine-alternatives for wild blueberry processing (*Vaccinium angustifolium*). *Int. J. Food Microbiol.* **2007**, *116*, 25–31. [[CrossRef](#)]
11. Tadepalli, S.; Bridges, D.F.; Driver, R.; Wu, V.C.H. Effectiveness of different antimicrobial washes combined with freezing against *Escherichia coli* O157:H7, *Salmonella Typhimurium*, and *Listeria monocytogenes* inoculated on blueberries. *Food Microbiol.* **2018**, *74*, 34–39. [[CrossRef](#)]
12. Abdipour, M.; HosseiniFarahi, M.; Naseri, N. Combination method of UV-B and UV-C prevents post-harvest decay and improves organoleptic quality of peach fruit. *Sci. Hortic.* **2019**, *256*, 108564. [[CrossRef](#)]
13. Alexandre, E.M.C.; Brandão, T.R.S.; Silva, C.L.M. Efficacy of non-thermal technologies and sanitizer solutions on microbial load reduction and quality retention of strawberries. *J. Food Eng.* **2012**, *108*, 417–426. [[CrossRef](#)]
14. Lim, W.; Harrison, M.A. Effectiveness of UV light as a means to reduce *Salmonella* contamination on tomatoes and food contact surfaces. *Food Control* **2016**, *66*, 166–173. [[CrossRef](#)]
15. Takano, Y.; Ninohei, R.; Koike, A.; Serizawa, I.; Mochizuki, Y. Effects of excimer fluorescent UV lamps on mold and fruit quality in strawberries. *AgriEngineering* **2024**, *6*, 4889–4900. [[CrossRef](#)]
16. Kikuchi, C. Bactericidal lamp and its application. *J. IEL-J.* **1974**, *58*, 143–146.
17. Pangloli, P.; Hung, Y. Reducing microbiological safety risk on blueberries through innovative washing technologies. *Food Control* **2013**, *32*, 621–625. [[CrossRef](#)]
18. Hayakawa, T.; Okazaki, A.; Takano, Y.; Serizawa, I. Measurement and effects of nitrogen oxide in ozone gas emitted from air-fed ozone generators. *Bull. Med. Hyg. Ozone Res., Jpn.* **2022**, *29*, 48–56.
19. Alves, H.; Alencar, E.R.; Ferreira, W.F.S.; Silva, C.R.; Ribeiro, J.L. Microbiological and physical-chemical aspects of strawberry exposed to ozone gas at different concentrations during storage. *Braz. J. Food Technol.* **2019**, *22*, e2018002. [[CrossRef](#)]
20. Contigiani, E.V.; Kronberg, M.F.; Sanchez, G.J.; Gomez, P.L.; García-Loredo, A.B.; Munarriz, E.; Alzamora, S.M. Ozone washing decreases strawberry susceptibility to *Botrytis cinerea* while maintaining antioxidant, optical and sensory quality. *Heliyon* **2020**, *6*, e05416. [[CrossRef](#)]
21. Feliziani, E.; Romanazzi, G.; Smilanick, J.L. Application of low concentrations of ozone during the cold storage of table grapes. *Postharvest Biol. Technol.* **2014**, *93*, 38–48. [[CrossRef](#)]
22. Alexandre, E.M.C.; Santos-Pedro, D.M.; Brandão, T.R.S.; Silva, C.L.M. Influence of aqueous ozone, blanching and combined treatments on microbial load of red bell peppers, strawberries and watercress. *J. Food Eng.* **2011**, *105*, 277–282. [[CrossRef](#)]
23. Onopiuk, A.; Półtorak, A.; Moczowska, M.; Szpicer, A.; Wierzbicka, A. The impact of ozone on health-promoting, microbiological, and colour properties of *Rubus idaeus* raspberries. *CyTA J. Food* **2017**, *15*, 563–573. [[CrossRef](#)]
24. Takano, Y.; Kobayashi, G.; Koike, A.; Serizawa, I. Comparison of ozone generation methods using UV lamp and discharging in water processing. In Proceedings of the 32nd Japan Ozone Association Annual Conference, Kyoto, Japan, 23 June 2023; Volume 32, pp. 135–138.
25. Mochizuki, Y.; Meguro, I.; Fukuoka, A.; Miyashita, C.; Worarad, K.; Inoue, E. Storability of interspecific hybrid blueberry HoSp-S65G-13 suitable for cluster harvesting. *Hortic. Res.* **2021**, *20*, 463–468. [[CrossRef](#)]
26. Concha-Meyer, A.; Eifert, J.D.; Williams, R.C.; Marcy, J.E.; Welbaum, G.E. Shelf life determination of fresh blueberries (*Vaccinium corymbosum*) stored under controlled atmosphere and ozone. *Int. J. Food Sci.* **2015**, *2015*, 164143. [[CrossRef](#)] [[PubMed](#)]
27. Kim, T.J.; Silva, J.L.; Tokitkla, A.; Matta, F.B. Modified atmosphere storage influences quality parameters and shelf life of 'Tifblue' blueberries. *J. Miss. Acad. Sci.* **2010**, *55*, 143–148.
28. Jaramillo-Sánchez, G.; Contigiani, E.V.; Castro, M.; Hodara, K.; Alzamora, S.M.; Loredo, A.G.; Nieto, A.B. Freshness maintenance of blueberries (*Vaccinium corymbosum* L.) during postharvest using ozone in aqueous phase: Microbiological, structure, and mechanical issues. *Food Bioprocess Technol.* **2019**, *12*, 2136–2147. [[CrossRef](#)]

29. Xu, F.; Wang, S.; Xu, J.; Liu, S.; Li, G. Effects of combined aqueous chlorine dioxide and UV-C on shelf-life quality of blueberries. *Postharvest Biol. Technol.* **2016**, *117*, 125–131. [[CrossRef](#)]
30. Sanford, K.A.; Lidster, P.D.; McRae, K.B.; Jackson, E.D.; Lawrence, R.A.; Stark, R.; Prange, R.K. Lowbush blueberry quality changes in response to mechanical damage and storage temperature. *J. Am. Soc. Hortic. Sci.* **1991**, *116*, 47–51. [[CrossRef](#)]
31. Almenar, E.; Samsudin, H.; Auras, R.; Harte, B.; Rubino, M. 2008. Postharvest shelf life extension of blueberries using a biodegradable package. *Food Chem.* **2008**, *110*, 120–127. [[CrossRef](#)]
32. Perkins-Veazie, P.; Collins, J.K.; Howard, L. Blueberry fruit response to postharvest application of ultraviolet radiation. *Postharvest Biol. Technol.* **2008**, *47*, 280–285. [[CrossRef](#)]
33. Giuggioli, N.R.; Briano, R.; Girgenti, V.; Peano, C. Quality effect of ozone treatment for the red raspberries storage. *Chem. Eng. Trans.* **2015**, *44*, 25–30.
34. Tabakoglu, N.; Karaca, H. Effects of ozone-enriched storage atmosphere on postharvest quality of black mulberry fruits (*Morus nigra* L.). *LWT-Food Sci. Technol.* **2018**, *92*, 276–281. [[CrossRef](#)]
35. Wang, H.; Cao, G.; Prior, R.L. Oxygen radical absorbing capacity of anthocyanins. *J. Agric. Food Chem.* **1997**, *45*, 304–309. [[CrossRef](#)]
36. Piechowiak, T. Effect of ozone treatment on glutathione(GSH)status in selected berry fruit. *Phytochemistry* **2021**, *187*, 112767. [[CrossRef](#)] [[PubMed](#)]
37. Chen, C.; Zhang, H.; Dong, C.; Ji, H.; Zhang, X.; Ban, Z.; Zhang, N.; Xue, W. Effect of ozone treatment on the phenylpropanoid biosynthesis of postharvest strawberry. *RSC Adv.* **2019**, *9*, 25429–25438. [[CrossRef](#)]
38. Allende, A.; Marín, A.; Buendía, B.; Tomás-Barberán, F.; Gil, M.I. Impact of combined postharvest treatments (UV-C light, gaseous O₃, superatmospheric O₂ and high CO₂) on health promoting compounds and shelf-life of strawberries. *Postharvest Biol. Technol.* **2007**, *46*, 201–211. [[CrossRef](#)]
39. Bank, H.L.; John, J.; Schmehl, M.K.; Dratch, R.J. Bactericidal effectiveness of modulated UV light. *Appl. Environ. Microbiol.* **1990**, *56*, 3888–3889. [[CrossRef](#)]
40. Bridges, D.F.; Rane, B.; Wu, V.C.H. The effectiveness of closed-circulation gaseous chlorine dioxide or ozone treatment against bacterial pathogens on produce. *Food Control* **2018**, *91*, 261–267. [[CrossRef](#)]
41. Cappellini, R.A.; Ceponis, M.J. Vulnerability of stem-end scars of blueberry fruits to postharvest decays. *Phytopathology* **1977**, *67*, 118–119. [[CrossRef](#)]
42. Horvitz, S.; Cantalejo, M.J. Application of Ozone for the Postharvest Treatment of Fruits and Vegetables. *Crit. Rev. Food Sci. Nutr.* **2014**, *54*, 312–339. [[CrossRef](#)]
43. Sarron, E.; Widehem, P.G.; Aussenac, T. Ozone treatments for preserving fresh vegetables quality: A critical review. *Foods* **2021**, *10*, 605. [[CrossRef](#)]

Disclaimer/Publisher’s Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.