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Effects of Ionizing Energy and Ozone Treatments on the Microbial Decontamination and Physicochemical Properties of Aloe Powders and Bee Pollen

Hong-Sun Yook, Young-Jin Chung*, Jung-Ok Kim, Oh-Jin Kwon, Sung Kim and Myung-Woo Byun†**

Dept. of Food Irradiation, Korea Atomic Energy Research Institute, Taejon 305-600, Korea
**Dept. of Food and Nutrition, Chungnam National University, Taejon 305-764, Korea*
***Dept. Home Economics, King Sejong University, Seoul 133-747, Korea*

Abstract

The comparative effects of gamma irradiation and ozone treatment on the microbiological and physicochemical qualities were investigated for the improvement of hygienic quality of aloe powder and bee pollen. Gamma irradiation at 7.5~10kGy could reduce total aerobic bacteria, molds and coliforms below detection levels, but ozone treatment up to 18ppm for 8hr was not sufficient to eliminate the microorganisms from aloe powder and bee pollen. The physicochemical properties such as fatty acid and amino acid compositions, mineral content, TBA value, barbaloin and pigment contents were not significantly changed by gamma irradiation, whereas ozone treatment caused significant changes in fatty acid composition, lipid oxidation and destruction of barbaloin and natural pigments.

Key words: aloe, bee pollen, gamma irradiation, ozone treatment, hygienic quality

INTRODUCTION

Aloe leaves and bee pollen have been used for many purposes including cosmetics and health foods(1,2). Newly developed aloe and bee pollen products as natural health food attract many health-conscious consumers. In the manufacturing of aloe and bee pollen products, microbial contamination, particually pathogenic microorganisms are frequently found in these products.

The conventional method for decontamination of microorganisms was to treat aloe powders and bee pollen with gaseous ethylene oxide. But, such fumigation used for food and food products has been prohibited or is being increasingly restricted in most advanced countries for health, environmental, or occupational safety reasons(3,4). Above all, chemical preservatives added to the aloe powders and bee pollen are not considered to be an alternative because chemical addition dose not conform to the legislative trends for consumer protection. Gamma irradiation and ozone treatment do not have the problems associated with other processing methods. Gamma irradiation in food processing has been extensively studied over the last four decades in terms of the wholesomeness of irradiated food and the commercial feasibility aspects of the technology. Food irradiation is recently recognized as an important alternative method for reducing postharvest food losses, ensuring hygienic quality and trading in foodstuffs(5). As ozone is effective for the decontamination of microorganisms and viruses, it is of use not only for the sterilization and deodorization of the tap water, but also for the sterilization of hospital rooms. Technically, ozone is used for sterilization, deodorization, decolorization and decomposing of organic matters by its' inherent potential of oxidative reaction(6).

Gamma irradiation and ozone treatment are two major methods which have been tested and applied in many food institutions. However, the use of gamma irradiation and ozone treatment for the decontamination of aloe powders and bee pollen has not been tried and studied in terms of physicochemical property changes by these methods. Therefore, this study has explored the possibility of industrial application and investigated the microbiological and physicochemical property changes of nontreated, gamma-irradiated and ozone-treated aloe powders and bee pollen.

†Corresponding author

MATERIALS AND METHODS

Materials and sterilization treatments

Aloe powders(Aloe arborescence and Aloe vera) and bee pollen at the presterilization stage were purchased from a local company(Namyang aloe Co., Seoul, Korea). Moisture content of the samples was about 70~100g kg^{-1}. For the gamma irradiation, 50g lots of the samples were aerobically packed in PVC container(500mm diameter×800mm long).

Gamma irradiation was carried out in a cobalt-60 irradiator equipped with 100kCi activity at room temperature(20±0.5°C) and operated at a dose rate of 1kGy hr^{-1}. The applied dose levels were 0, 2.5, 5, 7.5 and 10kGy. Absorbed dose was monitored by a free radical dosimeter and ceric cerous dosimeter. In the ozone treatment, a flow rate of 5 liters min^{-1} was maintained. At this flow rate, the concentration of ozone in the air was 18mg $litre^{-1}$. Ozonized air was sparged into 100g samples contained in a round flask(modified from a rotary evaporator). The sparger in the middle of the rotating flask ensured the ozonized air was evently distributed throughout the samples. After the ozone treatment, the samples were packed in a PVC container as above.

Enumeration of microbial load

All the microbiological media were purchased from Difco Laboratories(Detroit, Mich., USA). Total aerobic bacteria were enumerated by the spread plate method using standard plate count agar with incubation at 37°C for 48hr(7). Coliforms were enumerated by the pour plate method using desoxycholate agar with incubation at 37°C for 48hr(8). Total molds and yeast were enumerated by the spread plate method using potato dextrose agar with chloramphenicol, after incubation at 30°C for 7 days (7). Counts were recorded as colony forming units(CFU) g^{-1} sample. Results were the average counts of three petri dishes for each test.

Physicochemical analysis

Analysis of total amino acids was carried out according to the method described by Kwon et al.(9), using an amino acid analyzer(Hitachi model 835-50)(10). Crude lipids were extracted from the sample with a solvent system of chloroform-methanol(2 : 1, v/v) and then purified. Fatty acid esters were determined by esterification of the purified lipids using BF_3-methanol following hydrolysis by 0.5N sodium hydroxide(11) and analyzed with a gas chromatography(Varian Aerograph Model 3700) equipped with a flame ionization detector. A fused silicagel capillary column(30m×0.32mm i.d., 0.2μm film thickness) coated with SP-2340 was used for methyl ester separation. The column oven temperature was programmed linearly from 150°C(5min) to 200°C(20min) at an increasing rate of 4°C per min. The temperature of injector and detector was maintained at 240°C. Flow rate of the nitrogen carrier gas was 1.0ml per min and split ratio was 1 : 30. The rancidity of the samples was determined by measuring the thiobarbituric acid(TBA) value(12). Eleven different elements of the samples, such as aluminium, boron, calcium, copper, iron, potassium, magnesium, manganese, nickel, phosphorus and zinc were analyzed, using an inductively-coupled plasma spectrometer(ICP, ARL Model 3510), following established wet digestion procedures(13). Barbaloin analysis was carried out after reflux-extraction. One gram of the sample in 100ml anhydrous methanol was extracted at 60°C for 4hr, and then filtered. The filtrate was finally made up to 100ml(14) and analyzed by Waters 510 HPLC with UV detector at 254nm using μ-Bondapac C_{18} 125Å 10μ column(3.9×300mm). The mobile phase was 50% aqueous methanol and the flow rate was 1.4ml per min, and Waters 746 Data Module was used as an integrator. Injection volume was 10μl, and retention time and peak area of each component were compared with those of the standard solution of barbaloin(Nacalai Chemical, Japan)(15-17). Analysis of chlorophyll and carotenoid pigments was carried out according to the method described by Pyeun et al.(18), using a spectrophotometer(Bausch & Lomb Spectronic 710) at 652nm and 450nm, respectively. The color change of the samples was determined using a Hunter's color and color difference meter(Model ND-1001 NP, Nippon Denshoku, Japan). The instrument was standardized using a white ceramic tile calibrated to exhibit tristimulus values of L=90.6, a=0.4 and b=3.3.

Statistical analysis

All experiments were replicated three times. Analysis of variance(SAS Institute, Inc., 1994) was used to analyze effects of gamma irradiation and ozone treatment in a one-way layout with means comparisons. When a significant change between nontreated and gamma-irradiated or ozone-treated samples resulted, various

interaction means are reported. Main effect means are reported when no significant interactions were found. Significance was established at $p<0.05$ unless otherwise indicated.

RESULTS AND DISCUSSION

Distribution and inactivation of microorganisms

As shown in Table 1, the viable cell counts for samples of different origins showed significant variations. In aloe powders, the populations of total aerobic bacteria, molds and yeast ranged from 10^4 to 10^5 colony forming units(CFU) g^{-1}, $10^2 \sim 10^3$ CFU g^{-1} and $10^3 \sim 10^4$ CFU g^{-1}, respectively. Especially, coliforms were detected in the samples, the numbers ranging from 10^2 to 10^3 CFU g^{-1}, indicating that most of the products had been prepared under unsanitary conditions. Major total aerobic bacteria were identified as *Bacillus subtilis* and *B. pumilus*, with lower frequencies of *B. megaterium* and *Micrococcus* sp. Those populations were higher than the legally permissive loads of microorganisms(total aerobic bacteria: below 10^3 CFU g^{-1}; coliforms: negative).

Also the populations of total aerobic bacteria, molds, and yeast of bee pollen were 10^4 CFU g^{-1}, 10^2 CFU g^{-1} and 10^4 CFU g^{-1}, respectively. The major bacteria species identified were *Bacillus* sp. and *Micrococcus* sp. The populations of these were higher than the legally permissive microbial loads(total aerobic bacteria: below 10^3 CFU g^{-1}). But, coliforms were not detected in the samples.

The comparative effects of gamma irradiation and ozone treatment in inactivating the microbial flora contaminating aloe powders and bee pollen are given in Table 1. With gamma irradiation, the minimum dose levels for the sterilization of total aerobic bacteria, molds, yeast and coliforms in samples were shown to be 7.5~10kGy, 5~7.5kGy, 5~7.5kGy and 2.5~5kGy, respectively. Generally molds and coliforms required lower doses for inactivation compared to total aerobic bacteria because of the high frequency of *Bacillus* sp. Therefore, 10kGy gamma irradiation reduced all microorganisms to below detection levels in both samples and these results are similar to the reports of Farkas et al.(19), Ahmed(5) and Ito et al.(20). On the other hand, ozone treatment with high concentration proved to be insufficient for reducing the microbial load of the all highly contaminated samples, possibly due to localized flow and poor contact. This study, therefore, has shown that gamma irradiation is more effective than ozone treatment in reducing the bacterial population of aloe powders and bee pollen.

Physicochemical properties

Table 2 shows the comparative effects of gamma irradiation and ozone treatment on the contents of total amino acids of aloe powders and bee pollen. No significant changes were observed in each amino acid content by gamma irradiation or ozone treatment.

Table 3 shows the comparative effects of gamma irradiation and ozone treatment on fatty acid compositions. No significant changes in the content of the fatty acids were observed between nontreated and gam-

Table 1. Comparative effects of gamma irradiation and ozone treatment on microbial inactivation of aloe powders and bee pollen (CFU/g sample)

Sample	Microorganisms	Treatment					
		Control	2.5kGy	5kGy	7.5kGy	10kGy	Ozone[1)]
Aloe arborescence	Total aerobic bacteria	1.6×10^5	1.3×10^4	8.8×10^3	1.2×10^3	-	1.1×10^3
	Molds	6.0×10^3	2.5×10^3	7.5×10^2	-	-	2.9×10^2
	Yeast	5.9×10^4	3.0×10^3	-	-	-	8.5×10^2
	Coliforms	7.0×10^3	2.6×10^2	-	-	-	1.3×10^2
Aloe vera	Total aerobic bacteria	2.7×10^4	1.5×10^3	3.7×10^2	8.0×10^1	-	6.5×10^2
	Molds	1.2×10^2	8.0×10^1	-	-	-	-
	Yeast	3.9×10^3	1.7×10^2	-	-	-	1.5×10^2
	Coliforms	1.0×10^2	-	-	-	-	-
Bee pollen	Total aerobic bacteria	7.2×10^4	5.9×10^2	6.5×10^2	-	-	1.0×10^3
	Molds	2.3×10^2	1.2×10^1	-	-	-	-
	Yeast	1.2×10^4	2.7×10^3	3.8×10^2	-	-	9.5×10^2
	Coliforms	-	-	-	-	-	-

[1)]Ozonized air with an ozone concentration of 18ppm was sparged into the sample for 8hr at an air flow rate of 5 liter min^{-1}

Table 2. Comparative effects of gamma irradiation and ozone treatment on total amino acids of aloe powders and bee pollen[1)]

Amino acid	Treatment								
	Aloe arborescence			Aloe vera			Bee pollen		
	Control	10kGy	Ozone[2)]	Control	10kGy	Ozone[2)]	Control	10kGy	Ozone[2)]
Aspartic acid	0.535	0.522	0.532	0.384	0.386	0.385	2.008	1.942	2.011
Glutamic acid	0.668	0.670	0.665	0.467	0.469	0.464	2.213	2.173	2.223
Asparagine	-	-	-	-	-	-	0.022	0.020	0.016
Histidine	0.145	0.150	0.145	0.071	0.065	0.066	0.498	0.494	0.478
Serine	0.301	0.304	0.297	0.181	0.183	0.184	1.097	1.091	1.094
Arginine	0.332	0.340	0.338	0.114	0.124	0.125	0.993	0.981	0.977
Glycine	0.347	0.367	0.358	0.192	0.196	0.193	1.059	1.061	1.061
Threonine	0.270	0.265	0.263	0.135	0.139	0.136	0.956	0.949	0.952
Alanine	0.368	0.372	0.358	0.184	0.191	0.186	1.179	1.156	1.160
Tyrosine	0.235	0.231	0.226	0.103	0.108	0.105	0.608	0.601	0.598
Methionine	0.028	0.028	0.025	-	-	-	0.351	0.339	0.364
Valine	0.346	0.337	0.339	0.175	0.177	0.178	1.090	1.075	1.084
Phenylalanine	0.311	0.305	0.296	0.128	0.124	0.207	0.908	0.902	0.889
Isoleucine	0.287	0.278	0.275	0.123	0.127	0.125	0.963	0.934	0.943
Leucine	0.515	0.515	0.514	0.240	0.244	0.250	1.472	1.462	1.470
Lysine	0.443	0.442	0.432	0.179	0.168	0.170	1.302	1.331	1.203
Total	5.131	5.126	5.063	2.676	2.701	2.695	16.719	16.511	16.523

[1)]Total amino acids were analysed immediately after gamma irradiation and ozone treatment and each value is the average of triplicate determinations and expressed as g $100g^{-1}$ dry basis
[2)]Ozonized air with an ozone concentration of 18ppm was sparged into the sample for 8hr at an air flow rate of 5 liter min^{-1}

Table 3. Comparative effects of gamma irradiation and ozone treatment on fatty acid compositions of aloe powders and bee pollen[1)]

Fatty acid		Treatment								
		Aloe arborescence			Aloe vera			Bee pollen		
		Control	10kGy	Ozone[2)]	Control	10kGy	Ozone[2)]	Control	10kGy	Ozone[2)]
Crude lipid	(%)	3.33	3.32	3.42	2.98	3.09	3.34	9.94	11.12	12.06
Lauric	$C_{12:0}$	3.15^a	3.16^a	5.25^b	1.43	2.02	0.83	0.56^a	0.66^a	1.63^b
Myristic	$C_{14:0}$	3.71^a	4.00^a	6.82^b	1.46^a	1.47^a	2.01^b	1.58^a	2.32^a	6.52^b
Palmitic	$C_{16:0}$	24.38^a	22.72^a	44.14^b	53.79^a	53.50^a	68.15^b	28.03^a	27.20^a	58.28^b
Palmitoleic	$C_{16:1}$	0.46	0.36	0.37	0.40	0.42	0.59	-	-	-
Stearic	$C_{18:0}$	2.20^a	2.31^a	3.50^b	16.65^a	16.73^a	21.71^b	2.40^a	3.43^a	9.04^b
Oleic	$C_{18:1}$	3.01^a	3.46^a	2.51^b	10.44^a	10.70^a	2.22^b	6.21^a	6.03^a	1.86^b
Linoleic	$C_{18:2}$	25.15^a	25.34^a	14.73^b	12.80^a	12.16^a	1.69^b	10.81^a	10.90^a	3.51^b
Linolenic	$C_{18:3}$	37.94^a	38.67^a	22.68^b	3.03	3.00	2.84	47.57^a	46.85^a	15.46^b
Arachidic	$C_{20:0}$	-	-	-	-	-	-	1.37	1.31	1.02
Gondoic	$C_{20:1}$	-	-	-	-	-	-	0.76	0.73	0.57
Behenic	$C_{22:0}$	-	-	-	-	-	-	0.71^a	0.58^a	2.11^b
SFA		33.44^a	32.19^a	59.71^b	73.33^a	73.72^a	92.70^b	34.65^a	35.49^a	78.60^b
MUSFA		3.47	3.82	3.22	10.84^a	11.12^a	2.77^b	6.97^a	6.76^a	2.43^b
PUSFA		63.09^a	63.99^a	37.07^b	15.83^a	15.16^a	4.53^b	58.38^a	57.75^a	18.97^b

[1)]Fatty acids were analyzed immediately after gamma irradiation and ozone treatment, and each value is the average of triplicate determinations and expressed as % fatty acid composition of total lipids
[2)]Ozonized air with an ozone concentration of 18ppm was sparged into the sample for 8hr at an air flow rate of 5 liter min^{-1}
SFA: Total saturated fatty acids(12:0+14:0+16:0+18:0+20:0+22:0)
MUSFA: Total monounsaturated fatty acids(16:1+18:1+20:1)
PUSFA: Total polyunsaturated fatty acids(18:2+18:3)
Values with the same alphabet within each row are not significantly different at $p<0.05$

ma-irradiated samples($p<0.05$). However, the composition of fatty acids in ozone-treated samples were significantly changed as compared with the nontreated control. Unsaturated fatty acids were significantly de-

Table 4. Comparative effects of gamma irradiation and ozone treatment on thiobarbituric acid value of aloe powders and bee pollen during storage at ambient temperature (unit: O.D. at 538nm)

Treatment	Storage period (month)								
	Aloe arborescence			Aloe vera			Bee pollen		
	0	3	6	0	3	6	0	3	6
Control	0.669[a]	0.681[a]	0.693[a]	0.271[a]	0.301[a]	0.693[a]	0.607[a]	0.632[a]	0.658[a]
2.5kGy	0.667[a]	0.686[a]	0.701[a]	0.290[a]	0.302[a]	0.701[a]	0.609[a]	0.628[a]	0.659[a]
5kGy	0 683[a]	0.694[a]	0.720[a]	0.321[a]	0.341[a]	0.720[a]	0.649[a]	0.676[a]	0.689[a]
7.5kGy	0.697[a]	0.702[a]	0.721[a]	0.330[a]	0.359[a]	0.721[a]	0.652[a]	0.688[a]	0.703[a]
10kGy	0.702[a]	0.727[a]	0.732[a]	0.337[a]	0.391[a]	0.732[a]	0.663[a]	0.709[a]	0.721[a]
Ozone[1)]	2.036[b]	2.463[b]	2.789[b]	1.349[b]	1.629[b]	2.789[b]	2.709[b]	2.918[b]	3.283[b]

[1)]Ozonized air with an ozone concentration of 18ppm was sparged into the sample for 8hr at an air flow rate of 5 liter min^{-1}
Values with the same alphabet within each column are not significantly different at $p<0.05$

Table 5. Comparative effects of gamma irradiation and ozone treatment on selected minerals of aloe powders and bee pollen[1)]

Mineral	Treatment								
	Aloe arborescence			Aloe vera			Bee pollen		
	Control	10kGy	Ozone[2)]	Control	10kGy	Ozone[2)]	Control	10kGy	Ozone[2)]
Aluminium	5.8	6.0	6 0	8.0	7.8	7.8	19.0	19.0	19.0
Boron	18.0	19.0	18.5	20.0	20.5	19.8	27.5	28.0	27.0
Calcium	4240.0	4280.0	4250.0	2420.0	2470.0	2460.0	210.0	210.0	210.0
Copper	0.2	0.3	0.2	0.2	0.2	0.2	0.8	0.7	0.8
Iron	10.0	9.8	10.2	17.5	18.0	17.8	26.0	26.0	26.0
Potassium	2870.0	2760.0	2810.0	5930.0	5890.0	5910.0	515.0	510.0	515.0
Magnesium	1040.0	1100.0	1080.0	1010.0	1020.0	1015.0	160.0	165.0	160.0
Manganese	18.5	19.0	18.7	43.0	42.5	43.2	2.0	2.0	2.0
Nickel	0.2	0.3	0.2	0.4	0.4	0.4	0.4	0.4	0.4
Phosphorus	155.0	150.0	159.0	110.0	108.0	111.0	480.0	480.0	480.0
Zinc	6.5	7.0	6.5	11.5	11.1	11.3	6.0	6.0	6.0

[1)]Minerals were analysed using a ICP immediately after gamma irradiation and ozone treatment and each value is the average of triplicate experiments and expressed as mg $100g^{-1}$ dry basis
[2)]Ozonized air with an ozone concentration of 18ppm was sparged into the sample for 8hr at an air flow rate of 5 liter min^{-1}

creased but saturated fatty acids were significantly increased by ozone treatment($p<0.05$). Especially, in the case of ozone-treated aloe vera powder, oleic and linoleic acids decreased about 80~87%, as compared with the nontreated control. Hafez et al.(21) did not find changes in the fatty acids of soybeans at different radiation doses(1, 5, 10, 20, 40, 60, 80 and 100kGy), whereas ozone treatment caused significant changes to fatty acid compositions($p<0.05$). The destruction of double bond compounds in fatty acids might be responsible for the changes in fatty acid compositions of the ozone-treated samples.

The TBA test is often used to assess lipid oxidation in foods, products of which are believed to be responsible for the oxidized flavor(also called rancid or warmed-over flavor) that develops in food during storage or treatment. Table 4 shows the changes in TBA value of gamma-irradiated and ozone-treated samples during storage. TBA value slightly increased depending on the increment of irradiation dose level and the elapse of storage period in all samples but these changes were not significantly changed. Change in TBA value depending on the irradiation dose level treatment and subsequent storage of the sample has also been reported for some dried foods(22). However, the increase in TBA value of the ozone-treated samples was more evident than that of irradiated samples and these phenomena were significantly changed($p<0.05$).

The comparative effects of gamma irradiation and ozone treatment on minerals in samples were assessed (Table 5). As a whole, no significant changes were observed in the elemental contents of the samples up to 10kGy irradiation and ozone treatment($p<0.05$).

Barbaloin, an anthraquinone glycoside, is the main laxative component in aloe species. Table 6 shows the changes of barbaloin contents by gamma irradiation

Table 6. Comparative effects of gamma irradiation and ozone treatment on barbaloin of aloe powders

Sample	Treatment					
	Control	2.5kGy	5kGy	7.5kGy	10kGy	Ozone[1]
Aloe arborescence	8.08[a]	8.09[a]	8.12[a]	8.09[a]	8.15[a]	6.03[b]
Aloe vera	3.60[a]	3.56[a]	3.65[a]	3.80[a]	3.75[a]	2.11[b]

[1]Ozonized air with an ozone concentration of 18ppm was sparged into the sample for 8hrs at an air flow rate of 5 liter min^{-1} and each value is the average of triplicate experiments and expressed as mg $1g^{-1}$ dry basis
Values with same alphabet within each row are not significantly different at $p<0.05$

or ozone treatment. The content of barbaloin was much higher in aloe arborescence than in aloe vera. No significant changes in the content of barbaloin were observed between irradiated and nonirradiated samples ($p<0.05$). However, the content of barbaloin after ozone treatment significantly decreased about 30~40%, as compared with nontreated control($p<0.05$).

Table 7 shows the changes of pigments by gamma irradiation or ozone treatment of aloe arborescence during storage at room temperature. The contents of chlorophyll and carotenoid pigments slightly decreased depending on the increment of irradation doses level and the elapse of storage period in all samples. However, decrements in chlorophyll and carotenoid pigments in the ozone-treated samples were more evident than those in irradiated samples($p<0.05$). Chlorophyll and carotenoid pigments decreased with the increment of lipid oxidation which was mainly due to destroying of double bond compounds by ozone treatment.

Table 8 shows the changes of color parameters of samples by gamma irradiation or ozone treatment. Hunter's color parameters of lightness(L), redness(a), yellowness(b) and color difference(ΔE) were determined. In the case of aloe arborescence, gamma irradiation caused minor changes to the color specifications of the samples: lightness and yellowness values of the sample decreased at the high dosage(10kGy). However, the changes in overall color difference were more evident

Table 7. Comparative effects of gamma irradiation and ozone treatment on chlorophyll and carotenoid pigments of aloe arborescence during storage at ambient temperature

(Retention of pigments[1], %)

Treatment	Storage period (month)					
	0		3		6	
	Chlo.	Caro.	Chlo.	Caro.	Chlo.	Caro.
Control	100[a]	100[a]	94.5[a]	92.1[a]	87.6[a]	84.9[a]
2.5kGy	100[a]	99.5[a]	95.0[a]	91.5[a]	92.2[a]	85.2[a]
5kGy	95.0[a]	97.6[a]	94.0[a]	91.5[a]	87.2[a]	82.7[a]
7.5kGy	95.9[a]	98.6[a]	93.1[a]	90.3[a]	86.2[a]	81.8[a]
10kGy	94.5[a]	96.2[a]	93.1[a]	89.1[c]	83.5[a]	79.1[a]
Ozone[2]	80.3[b]	64.0[b]	76.6[b]	76.7[b]	61.0[b]	69.7[b]

[1]The relative content(%) to the control sample
[2]Ozonized air with an ozone concentration of 18ppm was sparged into the sample for 8hr at an air flow rate of 5 liter min^{-1}
Chlo.: Chlorophyll, Caro.: Carotenoid
Values with same alphabet within each column are not significantly different at $p<0.05$

Table 8. Comparative effects of gamma irradiation and ozone treatment on color parameters of aloe powders and bee pollen[1]

Sample	Treatment	Hunter's color value			
		L	a	b	ΔE
Aloe arborescence	Control	60.7	-6.2	19.2[a]	0.0[a]
	2.5kGy	61.0	-6.2	19.0[a]	0.4[a]
	5kGy	60.4	-5.8	19.0[a]	0.5[a]
	7.5kGy	59.9	-5.3	19.1[a]	1.1[a]
	10kGy	59.5	-5.4	19.0[a]	1.4[a]
	Ozone[2]	64.9	-5.1	15.7[b]	5.6[b]
Aloe vera	Control	76.8	2.9	15.2	0.0
	2.5kGy	76.0	3.3	15.3	0.9
	5kGy	75.8	3.7	15.3	1.3
	7.5kGy	75.9	3.3	15.4	1.0
	10kGy	75.3	3.7	15.6	1.7
	Ozone[2]	76.6	3.2	15.3	0.4
Bee pollen	Control	74.5[a]	4.2	30.8	0.0[a]
	2.5kGy	74.3[a]	4.5	30.9	0.4[a]
	5kGy	74.7[a]	4.5	30.5	0.5[a]
	7.5kGy	74.6[a]	4.5	30.6	0.4[a]
	10kGy	73.7[a]	5.0	30.5	1.2[a]
	Ozone[2]	77.1[b]	2.8	29.2	3.3[b]

[1]Color parameters were determined immediately after gamma irradiation and ozone treatment, and each value is the average of triplicate determinations
[2]Ozonized air with an ozone concentration of 18ppm was sparged into the sample for 8hr at an air flow rate of 5 liter min^{-1}
L: Degree of lightness(white+100↔0black)
a: Degree of redness(red+100↔-80green)
b: Degree of yellowness(yellow+70↔-80blue)
ΔE: Overall color difference($\sqrt{(\Delta L)^2+(\Delta a)^2+(\Delta b)^2}$)
Values with same alphabet within each column are not significantly different at $p<0.05$

in the ozone-treated samples than in the 10kGy-irradiated samples. Significantly higher lightness and redness values but lower yellowness value were due to loss of chlorophyll and carotenoid in the visually dull and light green ozone-treated samples. Color parameters of aloe vera were not significantly changed by gamma irradiation or ozone treatment($p<0.05$). In the bee pollen, no significant changes were observed in the color specifications of the samples up to 7.5kGy irradiation ($p<0.05$). But, gamma irradiation at 10kGy caused minor changes to the color specifications of the samples; the redness value slightly increased at the high dosage. However, the redness value was significantly decreased, but the lightness value was increased in ozone-terated sample because of decoloration by ozone treatment as compared to the nontreated and irradiated samples up to 7.5kGy($p<0.05$). Ozone-treated bee pollen was visually dull and light brown in color.

CONCLUSION

This study has shown that gamma irradiation was more effective than ozone treatment in reducing the microbial load of aloe powders and bee pollen. Ozone-treated aloe powders and bee pollen showed changes in the fatty acid compositions, whereas physicochemical properties were not significantly changed by gamma irradiation up to 10kGy. Therefore, gamma irradiation is considered to be a viable alternative method to chemical fumigant(ethylene oxide etc.) which is suspected of causing unsafe and undesirable effects on food quality.

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