

Effects of Package Materials on Quality Change of Pine Bud Beverage Under Ultraviolet Light

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Abstract

The effects of packaging materials on preserving the functional component of pine bud beverage stored under UV (ultraviolet) light exposure conditions were studied. The order of UV light blocking properties of the selected packages was: opaque can > opaque PET (polyethylene terephthalate) with green lamination = transparent PET with 10% PEN (polyethylene naphthalate) blending > transparent PET, and did not depend on film thickness in specified range. At 20°C, the order of preserving degree of original color and endobornyl acetate, which is quality index of pine bud beverage, was the same as above. Exposure to UV light can cause of deterioration of functional food components, but green color lamination and blending of PEN materials with transparent PET help to preserve the UV sensitive pine bud beverage components. However, the treated PET bottles have poorer preservation capabilities than the opaque cans. Transparent PET with PEN blending, in particular, will be very useful packaging material for colorful functional beverage preservation by helping to protect the ingredients while attracting consumer attention.

Key words: pine bud beverage, PEN (polyethylene naphthalate), UV (ultraviolet) light, PET (polyethylene terephthalate), green lamination

INTRODUCTION

From commercial standpoint, functional food can be a very attractive item in societies in which consumers are health- and beauty-oriented. However, many functional components and colorants that have several double bonds in their structure are subject to loss of their original functionality, including color change, due to exposure to light. This is especially true for ultraviolet light, which can cause disruption or dislocation of double bonds by photo degradation (1,2). Chan (2) mentioned that even though the double bonds in functional components are not normally subjected to direct ultraviolet irradiation, they can undergo photo-sensitized oxidation owing to light absorption. This can eventually cause quality changes in the product, including flavor and color losses. Additionally, Kim and Park (3) reported toxic photo products were generated by the light (290 nm~700 nm) exposure to some medicines, which resulted in toxic or carcinogenic materials. Therefore, foods and pharmaceutical solutions that are sensitive to light should be protected from ultraviolet light by adoption and designing of suitable packaging materials (4,5).

Metal or aluminum has been used as packaging material in the form of can, which is designed to protect the contained functional component from UV light and me-

chanical damage. In recent years, plastic bottles with coloring laminated or blended materials have been used for better preservation of functional beverage and for diversification of the packaging unit; however, the colored bottle, whose effect on preservation of functional component is not as well known, is not friendly to environment. Therefore, several ultraviolet absorbing or blocking agents were developed for protection of functional beverages bottled in transparent plastic. However, data are still sparse on the relations of various packaging materials to the degradation of functional components and properties under ultraviolet light, so more thorough and detailed research are needed. For example, endobornyl acetate from pine bud gives the smell and color of pine needles, so it is a very attractive functional component for beverages (6). However, it is very difficult to preserve during its storage time due to its sensitivity to ultraviolet light.

While the metal can is very effective for protecting endobornyl acetate, it is not possible for consumer to enjoy the color of pine bud beverage. Our objectives were to determine the effect of various packaging materials on degradation of functional components in pine bud beverage under ultraviolet light and also to find transparent packaging material with ultraviolet absorbing

capacity.

MATERIALS AND METHODS

We tested four materials (metal, transparent PET, opaque PET with green lamination, transparent PET with PEN) representing different thicknesses and activation spectra maximums. Color change was monitored by chromameter and volatile functional component was entrapped by nitrogen purge and trap method at 70°C, and gas chromatography (G.C.)–Mass spectrometer (M.S.) was used to observe change of functional component compositions and identify the chemical structures of them.

Pine bud beverage

Pine bud beverage containing 500 mg pine bud extract, which is packed in metal can (240 mL), was obtained from a local food company and were stored at room temperature.

Packages

Packages for storing the pine bud beverage were metal cans (52.5 mm × 133.1 mm), and bottles of PET (polyethylene terephthalate), PET with green lamination, and PET with 10% (w/w) polyethylene naphthalate (PEN). (65.4 mm × 206.5 mm) The resin is capable of withstanding high temperature conditions and is also known to be a better ultraviolet light barrier with high transparency than PET (7). Unused, clean, blow-molded PET, PET with green lamination, and PET with PEN were obtained from a local company.

Storage for UV light exposure

Ultraviolet light TLD 18 W/0 8 (Philips Co.) for UV light was purchased from local company and Sanyo pharmaceutical chamber was used in closed condition for storage of each packaged beverage at 20°C.

Measurement of physical properties of packaging materials

Thickness: A coating thickness meter, UNO-CHECK 'FE' from List-Magnetik Co., was used to measure thickness of each test specimen at room temperature three times.

Light Absorption Spectrum and % Transmission: UV/Visible spectrophotometer (Perkin-Elmer Lambda 4B, USA) was used to measure light absorption/transmission spectrum (190 nm ~ 380 nm) of each plastic film, which was cut into 3 cm × 5 cm. To measure % transmission of each plastic film, UVI ultraviolet transilluminators were used at 3 ultraviolet wavelengths: 254, 312, 363 nm.

Sampling of pine bud beverage

Pine bud beverage in steel cans were transferred to the PET, PET with lamination and PET with PEN up to highest level of each bottle in clean bench. After capping each bottle, they were sterilized in hot water (85°C) for 30 sec in a cooker-mixer and stored in pharmaceutical stability chamber with UV light at 20°C. Each bottle was about 45 cm from the Ultraviolet light TLD.

Color change of pine bud beverage by UV irradiation

Chroma meter JS555 with accessories was used to measure color change during UV light exposed condition in every three days. The Hunter system was employed to show the color change as L (brightness), a (hue, degree of redness), and b (chroma, degree of yellowness) value.

UV irradiation of flavor profile pine bud extract

Pine bud extract was obtained from a local food company and tightly wrapped in aluminum foil and stored in a refrigerator at 4°C. The pine bud extract (0.1 g) was diluted in 5 mL of water, by shaking vigorously for 3 min, and stored in 10 separate clear glass bottles. Half of these bottles were irradiated with UV light while the other five bottles were wrapped with aluminum foil to avoid the light illumination and were allowed to stand at 20°C for the same period of time. Changes in the flavor profile were determined by G.C. (8-10) by comparing calibration chart vs distilled pine bud extract of GC areas.

Isolation and determination of change of volatile flavor

Flavor change was determined in a Dynamic Thermal Stripper (Dynamic Co., USA) system by the NPT (nitrogen purge and trap) method. After storing each bottle for one day at room temperature, 20 mL strip vials with individual pine bud beverage samples weighed (± 1 mg) were prepared and heated at 70°C for 3 min in DTS system. The volatile flavors were driven into Tenax-TA (15 cm × 4 mm ID, Supelco Co.) by nitrogen gas (220 mL/min). The entrapped flavors were released by Thermal Desorption Unit (Dynamic Co.) and injected into gas chromatography through a stainless steel pipe. A Hewlett Packard 5890 Gas chromatography with flame ionization detector and SE-54 fused silica capillary column (0.32 mm × 60 m) from Supelco Co. were used. Additional operation conditions included He gas at 1 mL/min. and injection port 220°C and detector 265°C. Column temperature was programmed from 35°C to 250°C at 8°C/min. A Hewlett Packard 3365 ChemStation program was used to analyse and integrate the obtained peak.

Table 1. Effects of film thickness of packages on % transmission of UV light at 363 nm

Packaging materials	Thickness (μm)	% transmission of UV (%)
PET	359	78
	469	76
	554	79
PET with green lamination	492	3
	578	3
	740	4
PET with PEN	388	3
	477	3
	593	2

Identification of pine bud flavor component

Analysis was carried out using a Hewlett Packard 5890 Gas chromatography with same condition as that of analysis of flavor change and a mass selective detector VG Platform II with a potential of 70 eV for ionization by electron impact. The identification was done by comparing both the sample compound's retention index and mass spectrum data with the retention index data bank in International Flavors and Fragrances and the mass spectra library, obtained using the authentic compounds (11-13).

RESULTS AND DISCUSSIONS

Physical properties of various packaging materials

Thickness: The effect of thickness and density of each packaging materials on UV blocking property were studied. As seen in Table 1, UV light blocking property did not depend on thickness of each plastic film in the specified range (359 μm ~740 μm).

Light absorption spectrum and % transmission: The spectrum of each film in ultraviolet range (190 nm~380 nm) was investigated. The activation spectra maxims for both PET with PEN and green lamination were 380 nm, but transparent PET has 325 nm of spectra maxims.

Table 2. % transmission of selected package materials in three UV light range (%)

Wavelength	PET	PET with green lamination	PET with PEN blending	Can
254 nm	2	3	5	0
312 nm	5	4	5	0
363 nm	77	3	2	0

This means PET with PEN green lamination block transmission of UV light below wavelengths of 380 nm, while transparent PET does allow the transmission of UV light up to 325 nm. Therefore, PET with PEN and green lamination are better UV light barriers than clear PET. A % transmission of each film was shown in Table 2. From these data, we assume that NDC (Naphthalene Dicarboxylate monomer) and green lamination act as a UV blocking agents and can protect UV light sensitive food ingredients.

Monitoring of color change

According to the data of color change in pine bud beverage stored in the various packaging materials, PET with green lamination resulted in the least color difference as compared to the aluminum steel stored pine beverage (Table 3). In redness (a), the order of preserving degree of original color under ultraviolet condition was: Can > PET with green lamination > PET with PEN > PET, which was the order of decreasing % transmission rate of ultraviolet. Degree of color change based on yellowness was same order as that of redness. Results indicate that % transmission rate of package materials under UV exposed condition affect color change of light sensitive component in the contained food.

Identification of pine bud extract flavor

The identified pine bud flavor compounds with GC-MS were listed in Table 4. Among them, alpha-pinene (RT. 12.58 min), beta-pinene (RT. 13.63 min), alpha-fenchene (RT. 14.82 min) and endobornyl acetate (RT. 20.49 min) were considered as major flavor com-

Table 3. Color change of each packaged pine bud beverages in UV light exposed condition

Packaging materials	1 week			2 weeks			3 weeks					
	a	b	L	a	b	L	a	b	L			
PET	-1.23	4.23	97.49	-1.15	4.20	98.06	-1.10	3.55	98.42			
PET with green	-1.57	4.58	96.87	-1.54	4.40	96.82	-1.53	4.23	97.03			
PET with PEN	-1.61	4.53	96.90	-1.59	4.46	96.88	-1.60	4.31	97.28			
Can	-1.56	4.57	96.23	-1.60	4.55	96.56	-1.57	4.56	96.22			
Packaging materials	4 weeks			5 weeks			6 weeks			7 weeks		
	a	b	L	a	b	L	a	b	L	a	b	L
PET	-1.00	3.13	99.12	-0.89	3.07	99.13	-0.92	2.97	99.28	-0.91	2.96	99.21
PET with green	-1.52	4.06	97.34	-1.49	3.83	98.03	-1.52	3.74	97.99	-1.50	3.81	98.84
PET with PEN	-1.55	4.33	97.13	-1.57	4.01	97.29	-1.53	4.11	97.76	-1.52	3.98	98.17
Can	-1.54	4.52	96.39	-1.58	4.20	96.35	-1.56	4.33	96.60	-1.56	4.23	96.23

pounds by % order of individual peak area in total peak and their properties. According to previous research (14-18), endobornyl acetate smells of pine needles and is considered to be the main flavor quality index of pine bud extract due to its high sensitivity against external condition. Endobornyl acetate imparts a refreshing, fresh taste and piney odor. Alpha and beta pinenes have characteristic odor of pine and turpentine-like odor, but they seem to be lost during production of pine bud beverage. In addition, alpha-fenchene (camphene) used for reduction of the cholesterol saturation index in the treatment of gallstones and also has burning odor and taste, and gives yellowish color.

UV irradiation of pine bud beverage

To verify UV irradiation of pine bud beverage and determine main peak of pine bud beverage, flavor profile of the beverage with clear glass was compared with that of the beverage with aluminum foiled glass under UV light exposure. Because clear glass provides a perfect barrier against outer gases and moisture except transmission of light, it was selected to investigate the effect of UV light only on the stability of functional components in pine bud beverage. Alpha-fenchene and endobornyl acetate were present in the beverage as major flavor components. Table 5 showed UV light deteriorated the flavor profile of pine bud beverage with clear glass,

Table 4. Peak of pine bud extract and its identification

Peak #	Retention time (RT)	Identified compound
1	12.58 min	Alpha-pinene
2	13.63 min	Beta-pinene
3	14.82 min	Alpha-fenchene
4	16.14 min	Gamma-terpinene
5	17.19 min	Camphor
6	20.49 min	Endobornyl acetate

Table 5. Effect of UV light on fractional composition of major flavor components of pine bud beverage (%)

Peak	At initial	After 7 weeks under UV light	
		Aluminum wrapped glass	Transparent glass
Alpha-fenchene	54.6	55.3	77.1
Camphor	3.9	4.8	12.1
Endobornyl acetate	28.1	25.4	3.1

Table 6. Change of flavor profile in the various packaged pine bud beverage under UV light exposed condition at 20°C

Packaging materials	1 week ¹⁾	2 weeks	3 weeks	4 weeks	5 weeks	6 weeks	7 weeks
PET	61.5:4.1:25.0	60.3:3.7:23.1	66.7:4.0:22.9	68.9:3.8:19.5	72.4:3.6:15.8	75.4:3.9:14.6	76.1:3.4:13.8
PET with green	55.8:4.3:27.8	60.4:4.1:26.0	59.9:5.1:26.1	62.1:4.9:25.3	65.0:5.3:24.9	64.9:5.7:23.2	65.6:5.7:23.4
PET with PEN	56.2:4.0:27.9	57.1:3.8:25.8	61.8:4.3:27.4	60.6:4.7:24.7	59.7:5.8:23.9	62.5:5.2:23.1	63.9:6.2:22.1
Can	54.6:3.9:28.1	54.9:4.1:26.8	55.6:3.9:27.4	57.0:4.4:27.1	57.2:4.6:27.2	56.6:4.9:27.8	58.3:4.7:27.0

¹⁾ peak area ratio of alpha-fenchene, camphor, and endobornyl acetate peak.

while aluminum wrapped glass prevents quality change of pine bud beverage from UV light exposure. From these data, it was concluded that endobornyl acetate was very sensitive to UV light and % decreased and increased proportion of endobornyl acetate and alpha-fenchene respectively could be a main quality index of pine bud beverage under the UV light exposed condition. Increased yellowness of pine bud beverage with UV light exposure may be the results of increased proportion of alpha-fenchene.

Flavor change with various packaging materials

Change of flavor profile in the various packaged pine bud extract beverages under UV light exposure conditions at 20°C was examined. The % decrease of endobornyl acetate, and increase of alpha-fenchene and camphor in the beverage were shown in Table 6. Order of % proportion of endobornyl acetate in each packaged beverage was opaque can > opaque green PET = transparent PET with PEN > transparent PET, which was in accord with the order of decreasing % transmission of ultraviolet light at 363 nm. These results indicate that stability of endobornyl acetate, which is a quality index of pine bud beverage, was strongly affected by UV light. Green color lamination and blending of PEN material to clear PET bottles also preserve the UV light sensitive components and their combination has additional preservation effects on the light sensitive functional components.

UV light blocking properties can be improved with green lamination and blending of PEN materials to PET. Retention of endobornyl acetate, which is the major quality index flavor in pine bud beverage, was remarkably increased with the use of appropriate packaging materials under UV light exposed condition. These results imply that selection and evaluation of packaging materials for extending shelf life are very important processes in developing of new functional food items.

Moreover, transparent plastic packaging material is more reusable compared to laminated, opaque plastic packaging. Thus, knowledge of the transparent packaging materials with UV light barrier properties for extending shelf life can also provide guidance regarding which such recycle packaging materials to use.

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