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Research article

Changes in chemical properties and bioactivities of turmeric pigments by photo-degradation

Yu Na Jung[1] and Jungil Hong[1,]*

Division of Applied Food System, College of Natural Science, Seoul Women's University, Seoul 01797, Korea

* **Correspondence:** hjil@swu.ac.kr; Tel: +8229705639; Fax: +8229705977.

Abstract: Turmeric pigments have attracted a great attention for their variety of physiological functions. The pigments are, however, chemically unstable under various conditions including light irradiation. In this study, changes in chemical characteristics and bioactivities of turmeric pigments under light were investigated. Chemical changes of turmeric oleoresin (20 μg/mL) and curcumin (20 μM) significantly proceeded under irradiation by a regular household fluorescent light (27 W, 30 cm distance). After 24 h irradiation, color intensity of turmeric and curcumin decreased by 65.4 and 63.0%, respectively. Among three curcuminoids in turmeric, bisdemethoxycurcumin was the most resistant to decomposition by light. Scavenging activities of the irradiated turmeric pigments against 2,2-diphenyl-2-picrylhydrazyl radical and intracellular reactive oxygen species were significantly less pronounced. The activity against 2'-azino-bis-(3-ethylbenzothiazoline-6-sulfonic acid radical was, however, significantly enhanced after photo-degradation. Cytotoxic effects of turmeric oleoresin after 24 h irradiation on HCT 116 colon cancer cells decreased, while those of curcumin was enhanced after photo-degradation. Our results indicates that chemical properties and bioactivities of turmeric pigments can be modulated under light, and the phenomena should be considered in various processing and storage conditions for the pigment-containing foods.

Keywords: turmeric; curcumin; photo-degradation; antioxidant; cytotoxicity

1. Introduction

Color of foods is one of the most important factors for attracting consumer preference. The color compounds in foods are commonly associated with flavor, taste, and quality and safety of food [1].

Many pigment compounds in foods such as riboflavin, protoporphyrin, chlorophyll, myoglobin etc. show a light sensitive and photosensitizing properties. These compounds can generate reactive oxygen species (ROS) including singlet oxygen, superoxide anion, and hydroxyl radical under light, resulting in lipid oxidation, off-flavor, and reduction of food quality [2,3]. Accordingly, maintaining the stability of pigments is an important strategy for controlling quality of various foods.

Turmeric (*Curcuma longa*) is a medicinal plant which have also been used widely as a spice or a coloring agent. Curcuminoids are major and biologically active color ingredients in turmeric rhizomes [4]. Turmeric contains three yellow curcuminoids including demethoxycurcumin (DMC), bisdemethoxycurcumin (BMC), and curcumin which is a main coloring compound [5,6]. Curcumin has shown various physiological activities including antioxidant, anti-bacterial, anti-inflammatory and anti-cancer effects as well as protective effect on the neurodegenerative diseases including the Alzheimer disease [6–10]. For these reasons, turmeric pigments have been widely applied to many processed foods including meat, cheese, and bakery products not only for coloring purpose, but also for various uses to enhance health benefit [6]. The curcuminoid pigments have two aromatic phenolic ring structures connected by α, β-unsaturated diketone carbonyl group, which exists in equilibrium state with its enol tautomer. According to the environment exposed, each curcuminoid forms enol or keto form, which could act as a powerful hydrogen or electron doner [6]. Accordingly, turmeric pigments are chemically unstable, and undergo significant decomposition in many environmental conditions. Various factors such as pH, temperature, and light have been reported to affect the stability of turmeric pigments [6,11,12].

Several previous studies have also reported the photo-degradation of turmeric pigments indicating that curcumin undergoes photo-degradation in solution and even in solid form [12,13]. Despite the increasing demand for the pigments, their light-sensitive property might be a major obstacle that could restrict their general application in the food industry. Although the bioactivities of turmeric including cytotoxic and antioxidant properties have also been widely investigated, there has been little research on chemical changes under light irradiation and in particular, changes in the properties caused by the irradiation process. Accordingly, in the present study, a photo-degradation pattern of an organic extract of turmeric, turmeric oleoresin (a mixture of curcumin, DMC, and BMC) and curcumin (curcumin ~80%) were investigated. The consequent effects on bioactivities including antioxidant and cytotoxic properties of turmeric pigments were also evaluated.

2. Materials and methods

2.1. Chemicals

Turmeric oleoresin (a food additive, 40% curcuminoids) was purchased from ES ingredients (Gunpo, Korea). Curcumin reagent (curcumin, DMC, and BMC; 79.4, 16.8, and 3.8% (w/w), respectively, referred to as curcumin in this study) was purchased from Acros Organics (Morris Plains, NJ, USA). Dimethyl sulfoxide (DMSO) was from Daejung chemical (Seoul, Korea). High-performance liquid chromatography (HPLC) grade solvents were obtained from J.T. Baker Co. (Phillipsburg, NJ, USA). All other chemicals were purchased from Sigma-Aldrich (St. Louis, MO, USA).

2.2. Cell lines

INT 407 human embryonic intestinal cells (CCL-6) and HCT 116 human colon adenocarcinoma cells (CCL-247) were obtained from American Type Culture Collection (Manassas, VA, USA). INT 407 cells were maintained in Eagle's minimum essential medium (MEM) and HCT 116 cells were in Roswell Park Memorial Institute (RPMI) 1640 medium containing 10% fetal bovine serum (FBS), 1% antibiotics (100 unit/mL penicillin, 0.1 mg/mL streptomycin). Non-essential amino acids (1%) were added to MEM for INT 407 cells additionally. The cells were kept at 37 ℃ in 95% humidity and 5% CO_2.

2.3. Measurement of color stability of turmeric pigments under light

Turmeric (20–1000 μg/mL) and curcumin (20–1000 μM) dissolved in DMSO were divided into 100 μL in each well of a 96 well plate. The plate was incubated for 24 h under irradiation by a regular fluorescent light with 30 cm distance (27 W, model FPL27EX-D, Cosmoselectric Co., Seoul, Korea) or in a dark place at room temperature (RT). After the incubation, each sample was diluted in DMSO to 20 μM, and the color intensity was analyzed by measuring absorbance at 435 nm (Spectra Max M3, Molecular Device, Sunnyvale, CA, USA).

2.4. Analysis of individual curcuminoid level by HPLC

For measuring individual curcuminoid level, HPLC analysis was performed with a LC equipped with a L-6200 intelligent pump (Hitachi, Tokyo, Japan), an UV-975 UV/Vis detector (Jasco Co., Tokyo, Japan), and a Shiseido C18 packed column (150 × 4.6 mm, 5 μm particle size). The mobile phase consisted of 60% water containing 1% citric acid and 40% (v/v) tetrahydrofuran, and pH was adjusted to pH 3 using concentrated KOH solution. The solvent was run isocratically at a flow rate of 1.0 mL/min, and injection volume was 20 μL. Individual curcuminoid peak was detected at 420 nm according to the previous method [14].

2.5. Analysis of H_2O_2 levels produced by turmeric pigments

H_2O_2 level produced by the pigments was analyzed using ferrous oxidation-xylenol orange (FOX) assay. The FOX assay working solution (160 μL) containing 400 μM xylenol orange in distilled water (DW), 800 mM D-sorbitol in 200 mM H_2SO_4, and 1 mM ammonium ferrous sulfate (1:1:2, v/v/v) was added to each sample (40 μL). The mixture was then incubated for 45 min in a dark place, and the absorbance was measured at 550 nm (Spectra Max M3) [15].

2.6. Measurement of antioxidant properties

For analyzing 2,2-diphenyl-2-picrylhydrazyl (DPPH) radical scavenging activity, 100 μL of each pigment dissolved in DMSO were mixed with 100 μL of DPPH radical MeOH solution (600 μM). The absorbance was measured at 517 nm after 30 min incubation in a dark at RT [16]. For analyzing 2,2'-azino-bis-(3-ethylbenzothiazoline-6-sulfonic acid) (ABTS) radical scavenging, the mixture of ABTS radical (7.4 mM) with potassium persulfate (2.6 mM) was diluted by 5 times with DW. The

diluted ABTS solution (150 μL) was mixed with each pigment (50 μL) dissolved in DW, and the mixture was then incubated for 30 min in a dark place [17]. For investigating antioxidant activities of turmeric pigments in cells, intracellular reactive oxygen species (ROS) were analyzed using 2',7'-dichlorodihydrofluorescein diacetate (DCFH-DA), a fluorescence probe. INT 407 and HCT 116 cells were seeded with 1.5 × 104 cells per well of a 96-well plate and then treated the next day with each sample diluted in media. After 1 h, 100 μL of fresh serum-free medium containing DCFH-DA (10 μM) was added to each well. The cells were further incubated at 37 °C. After 30 min, the medium was removed, and 100 μL of DMSO were added to each well. The fluorescence was analyzed at an emission 535 nm, excitation 485 nm (cut off 530 nm) using a multi-plate reader (Spectra Max M3) [18].

2.7. Determination of cytotoxic effects

Effect of turmeric pigments on viabilities of INT 407 and HCT 116 cells were determined using the 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide (MTT) assay. INT 407 and HCT 116 cells were seeded with 1.5 × 104 cells per well of a 96-well plate and then treated the next day with each sample diluted in media. After 24 h incubation, the treated medium was removed, and 100 μL of fresh serum-free medium containing MTT (0.5 mg/mL) was added to each well. The cells were further incubated at 37 °C. After 45 min, the medium was removed, and 100 μL of DMSO was added to each well for solubilization of MTT formazan formed. The absorbance was measured at 550 nm (Spectra Max M3).

2.8. Data analysis

Statistical significance was evaluated by the Student's t-test. One-way ANOVA with the Tukey's HSD (honestly significant difference) test was used for comparing multiple results using the SAS system (SAS Institute; Cary, NC, USA).

3. Results and discussion

3.1. Changes in color stability of turmeric pigments by photo-degradation

The light-sensitive property of many pigments might be a major disadvantage for their application to food products. In the present study, changes in color intensity of turmeric pigments by photo-degradation were analyzed. In this study, both turmeric oleoresin used as a food additive and curcumin reagent (~80% curcumin) were used, and their photo-degradation pattern and bioactivity changes under light were analyzed. First, turmeric oleoresin and curcumin were incubated for 24 h under irradiation by a regular household fluorescent light or in a dark, and residual color intensity was analyzed as compared to initial control. Turmeric oleoresin dissolved in DMSO was stable in a dark; there was no significant change in color intensity observed after 24 h (Figure 1A). Under a regular fluorescent light (27 W, 30 cm distance, EX-D daylight type), color intensity of turmeric oleoresin and curcumin decreased to a similar extent. The pigment degradation was accelerated at lower concentrations. Color loss of turmeric oleoresin (200 and 20 μg/mL) occurred by 38.9 and 65.4%, respectively during 24 h, whereas its color intensity at 1000 μg/mL decreased only by 28.6%.

The irradiation with the fluorescent light also induced degradation of curcumin. After 24 h irradiation, 1000 μM of curcumin color was destroyed by 27.0%, whereas color intensity of curcumin (200 and 20 μM) decreased by 46.2 and 63.0%, respectively (Figure 1B). These results suggest that turmeric pigments are not stable under light, and their photo-degradation could be delayed at higher concentration. The reason why degradation rate of the pigments was accelerated in the low concentration might be due to stronger intra- or inter-molecular bonding at higher concentration and to inner-filer effect [11,19]. Decomposition of turmeric pigments in solution was affected by various factors such as solvent polarity and pH. In our experimental condition, DMSO, a universal solvent, was used for analyzing changes in color stability of turmeric pigments under light. Since the pigments dissolved in DMSO were stable during 24 h in a dark as indicated in Figure 1A, it is believed that the solvent conditions were able to more reliably analyze the decomposition effect induced by light, excluding the influence of other factors.

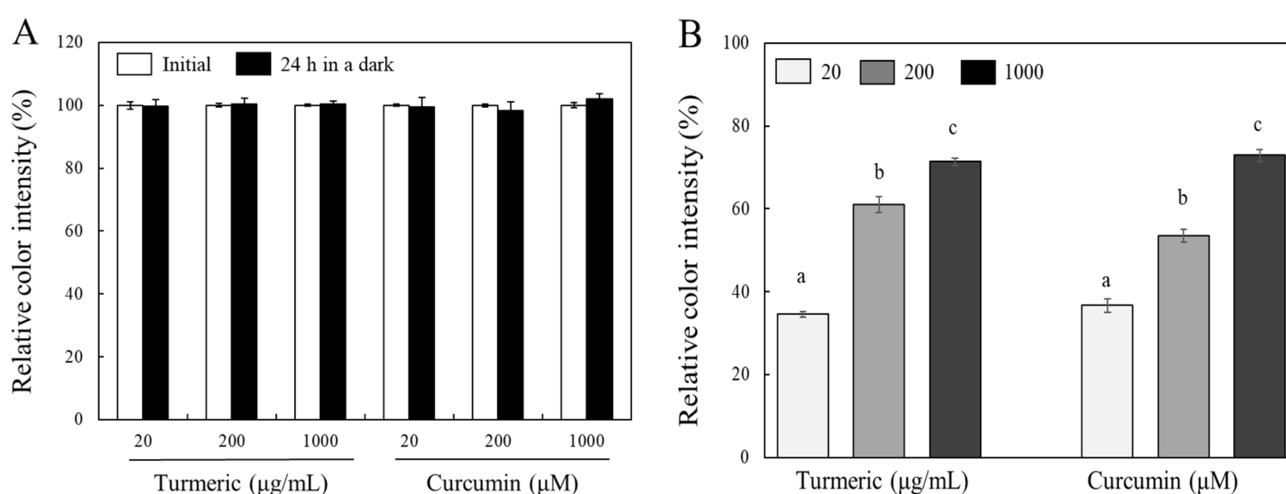

Figure 1. Changes in color intensity of turmeric pigments by photo-degradation. Changes in color intensity of turmeric oleoresin and curcumin were measured at 435 nm after 24 h incubation in a dark (A) or under fluorescent light (B). Each value (mean ± D) represents relative color intensity based on initial control (n = 4). Different letters indicate a significant difference ($p < 0.05$) based on one way ANOVA and the Tukey's HSD test.

Turmeric pigments consist of three major curcuminoids including curcumin, DMC, and BMC [5,6]. Accordingly, changes in degradation patterns of each individual curcuminoid by fluorescent light irradiation were also analyzed using HPLC. In the current HPLC system, three peaks of curcumin, DMC, and BMC were detected. The compositions of curcumin, DMC, and BMC in the turmeric oleoresin and curcumin reagent were 61.0, 21.2 17.8% and 80.8, 16.1, 3.1%, respectively based on their peak responses (Figure 2A and B). After irradiation for 24 h, levels of curcumin, DMC, and BMC in turmeric oleoresin decreased by 45.4, 38.1, and 27.7%, respectively. Their decomposition did not occur in a dark condition (Figure 2C). The incubation under our irradiation condition also decreased the response of all curcuminoid peaks of curcumin reagent. The relative residual levels of curcumin, DMC, and BMC were 51.5, 56.0, and 78.6%, respectively; the

decreased levels of curcumin and DMC by ~10% were also observed even in a dark (Figure 2B and D). Degradation ratio of each curcuminoid was similar in both turmeric oleoresin and curcumin, especially curcumin was most sensitive to light, but BMC was the most stable under the fluorescence light irradiation (Figure 2). The presence of methoxy group on phenolic ring of curcumin structure appears to accelerate the degradation process under light. During curcumin auto-oxidation process, the methoxy group on a phenol ring performs as an electron-donor which can accelerate formation of bicyclopentadione, a major oxidative product from curcumin. Accordingly, oxidation rate of DMC with one methoxy group was markedly delayed compared to curcumin, and BMC without methoxy group was not oxidized spontaneously [20,21]. It is believed that the similar degradation pattern occurred in the light-induced oxidation of curcuminoids and was consistent with the results of this study.

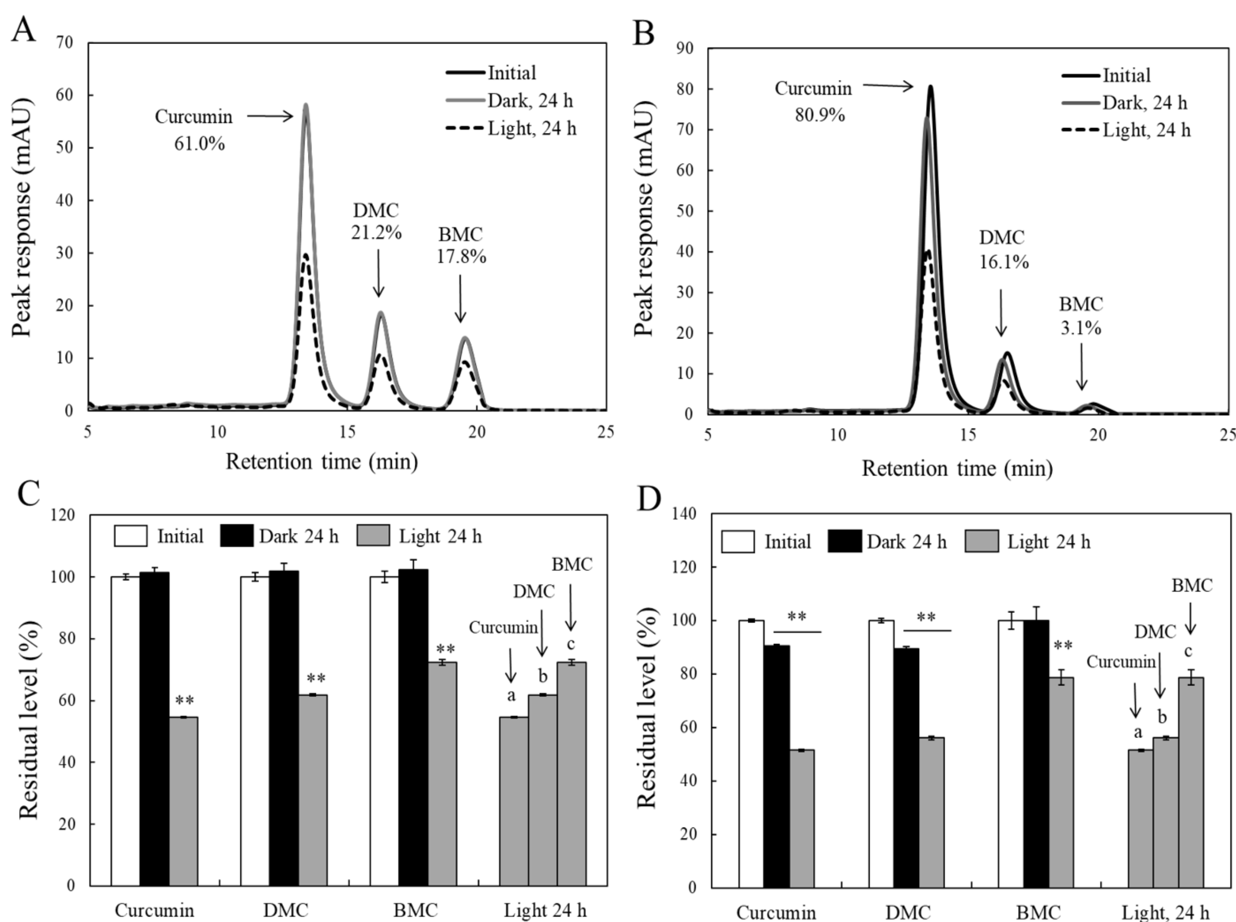

Figure 2. Degradation of individual curcuminoid under light exposure. Changes in chromatograms of each curcuminoid in turmeric oleoresin (40 μg/mL) (A) or curcumin reagent (40 μM) (B) by irradiation of fluorescence light for 24 h were shown. Residual levels of each curcuminoid in turmeric (C) or curcumin (D) were also analyzed. Each value represents the mean ± SD (n = 3). *,** Significantly different from control according to Student's t-test (*p < 0.05, **p < 0.01). Different letters indicate a significant difference ($p < 0.05$) based on one way ANOVA and the Tukey's HSD test.

3.2. Production of H_2O_2 by turmeric pigments

Turmeric pigments have been reported to exhibit photosensitizing property [22]. During photo-degradation of the pigments, the generation of reactive oxygen species (ROS) was expected due to their photosensitizing activity. Previous reports also indicate that curcumin could generate ROS during its oxidative degradation process [12]. Accordingly, H_2O_2 level produced from the turmeric pigments under light exposure or in a dark were analyzed using the FOX assay. In this assay, ferrous ion in FOX working solution is oxidized to ferric ion by peroxide in samples and is then conjugated with xylenol orange. This conjugated complex, as a chromogen, can be measured by absorbance at 550 nm [15].

Turmeric oleoresin and curcumin were incubated in the same irradiation condition as described above or in a dark for 24 h. Turmeric oleoresin produced H_2O_2 in a concentration-dependent manner (10–40 μg/mL) (Figure 3A). The H_2O_2 levels produced by turmeric oleoresin incubated in a dark was comparable to those by fresh turmeric, whereas the level from turmeric incubated under light for 24 h significantly increased (Figure 3A). A similar pattern of changes in H_2O_2 production by curcumin after incubation under light or in a dark was also observed. The H_2O_2 level generated by curcumin also increased concentration-dependently and was not changed by incubation for 24 h in a dark. Irradiation of curcumin for 24 h, however, induced a significant increase of H_2O_2 level (Figure 3B). The present results suggest that exposure of turmeric pigments to light accelerates their oxidative decomposition and decolorization as well as promotes the production of ROS.

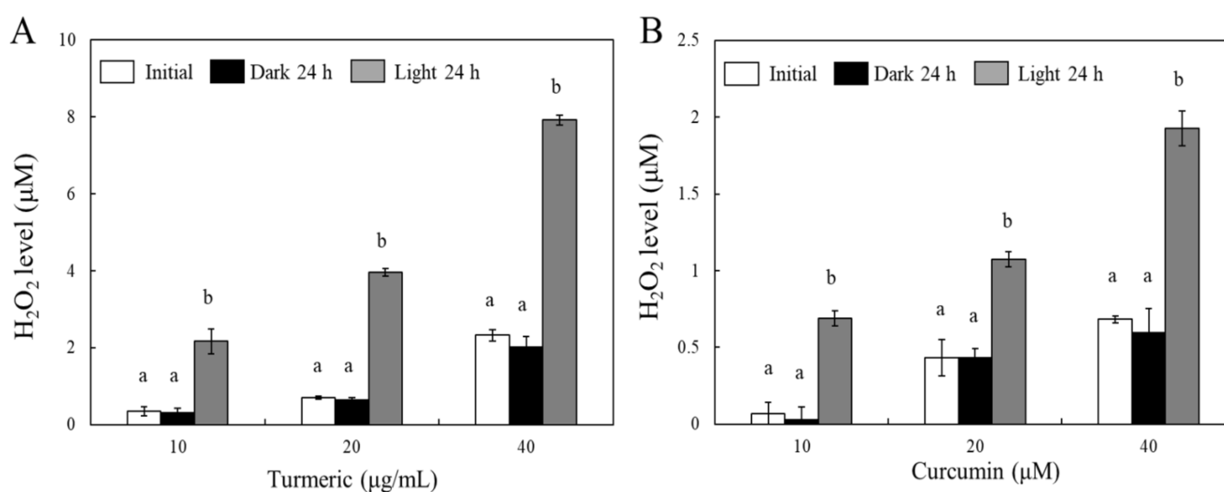

Figure 3. Changes in H_2O_2 generation capacity from turmeric pigments after light exposure. H_2O_2 levels generated from turmeric oleoresin (A) and curcumin (B) were analyzed after incubation for 24 h under fluorescent light or in a dark. Each value represents the mean ± SD (n = 3). Different letters indicate a significant difference ($p < 0.05$) based on one way ANOVA and the Tukey's HSD test.

3.3. Changes in antioxidant properties by photo-degradation

Curcuminoids, as phenolic compounds, have shown an antioxidant property in different in vitro assays. The free hydroxyl group commonly occurred in the phenolic structure of curcuminoids are known to be mainly responsible for their antioxidant property [23]. To investigate whether the photo-degradation of turmeric pigments causes changes of their antioxidant activity, scavenging activities of fresh and irradiated turmeric pigments against DPPH and ABTS radicals were investigated (Figure 4).

Scavenging activity of turmeric oleoresin against DPPH radical decreased significantly by 31.4% after 24 h irradiation. That of ABTS radical was, however, significantly enhanced by 18.8% as compared to initial control (Figure 4A). A similar pattern of antioxidant activity changes was also observed occurred by irradiated curcumin. DPPH radical scavenging activity of curcumin decreased by 21.4%, whereas that of ABTS radical scavenging activity was enhanced by 15.5% after 24 h incubation in a dark. After 24 h irradiation, scavenging activity of DPPH radical decreased by 29.7%, and that of ABTS radical was increased by 23.5% (Figure 4B). Whereas peak color response and HPLC analysis of curcumin and turmeric after 24 h irradiation indicated that degradation of curcuminoids occurred by 50–60%, their DPPH radical scavenging activity decreased by 20–30%, and ABTS radical scavenging activity was rather enhanced by 15–19%. The results suggests that the degradation products derived from curcuminoids through the irradiation process also possess considerable antioxidant activities.

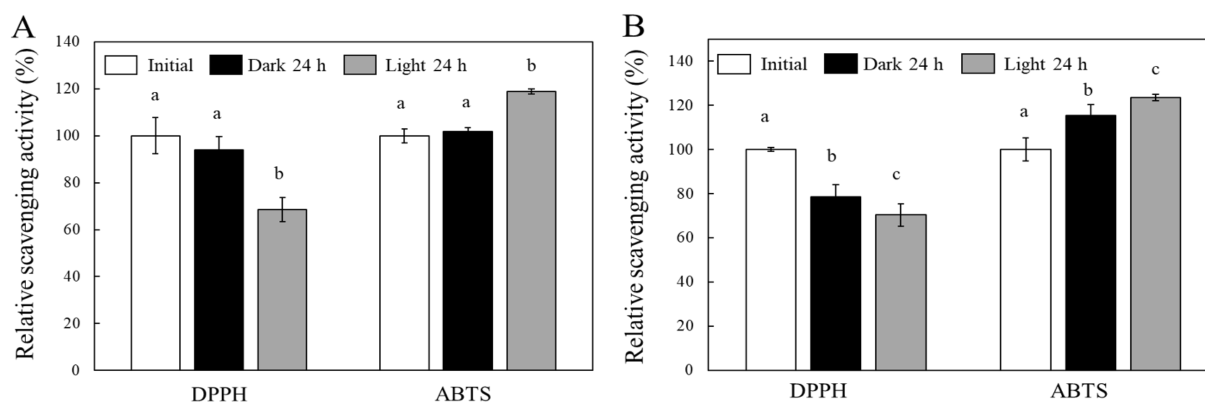

Figure 4. Changes in radicals scavenging activities of turmeric pigments by photo-degradation. Scavenging activities of turmeric oleoresin (20 μg/mL) (A) and curcumin (20 μM) (B) against of DPPH and ABTS radicals were analyzed after incubation for 24 h under fluorescent light or in a dark. Each value represents the mean ± SD (n = 3). Different letters indicate a significant difference ($p < 0.05$) based on one way ANOVA and the Tukey's HSD test.

Oxidative degradation of turmeric pigments proceeds through the cleavage of β-diketone link in their structure, resulting in formation of smaller phenolic compounds [12,24]. The previous studies reported that major degradation products of curcumin include ferulic acid, feruloyl methane, vanillic acid, vanillin, p-hydroxybenzoic acid, p-hydroxybenzaldehyde etc., which are more hydrophilic compounds with lower molecular weight then curcumin [24,25]. Curcumin is

easily soluble in various organic solvents such as DMSO, ethanol, acetone, and methanol due to its hydrophobic nature. Its degradation products, however, show greater solubility in water than organic solvents [24,25]. Therefore, antioxidant activities of curcumin photo-degradation products could be more pronounced in an aqueous analytical system such as ABTS radical scavenging assay, whereas they might be less effective in the DPPH radical scavenging assay system using methanol solvent comparted to their hydrophobic parent compound. Our previous study also showed that ABTS radical scavenging activity of turmeric pigments was enhanced by the microwave irradiation and the conventional heating process [26,27], which is consistent to the current observation.

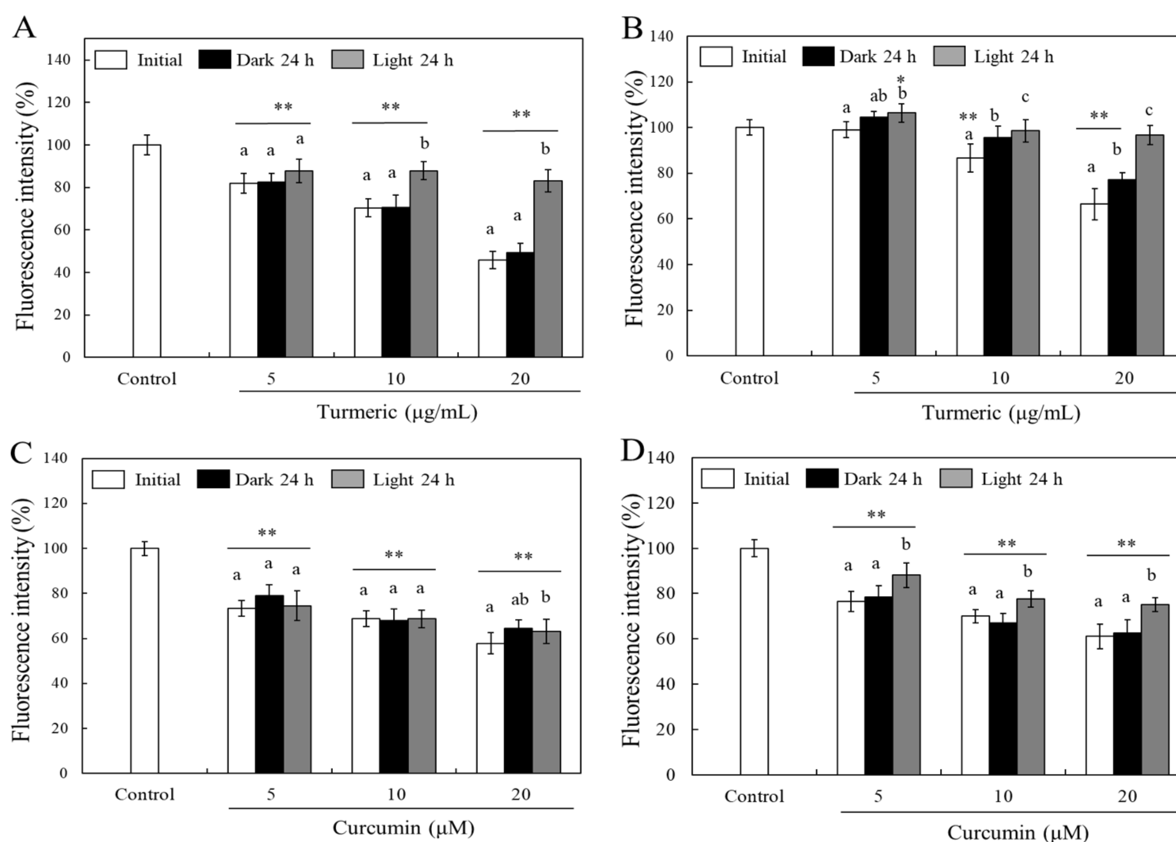

Figure 5. Changes in intracellular ROS scavenging activities of turmeric pigments after light exposure. ROS scavenging activity of turmeric oleoresin in cells of INT 407 (A) or HCT 116 (B) were analyzed after incubation for 24 h under fluorescent light or in a dark using the DCFH-DA probe. Effects of curcumin on INT 407 (C) and HCT 116 cells (D) were also analyzed. Each value represents the mean ± SD (n = 7–8). *,** Significantly different from control according to Student's t-test (*p < 0.05, **p < 0.01). Different letters indicate a significant difference (p < 0.05) based on one way ANOVA and the Tukey's HSD test.

3.4. Changes in intracellular ROS level by turmeric pigments

ROS are continuously produced in cells during physiological processes such as respiration and immune functions [28]. They cause lipid peroxidation and impair biomolecules including DNA and

proteins, which could result in malignant transformation of cells [29,30]. Turmeric pigments have shown an inhibitory activity on lipid peroxidation in cells through scavenging intracellular ROS [31]. Curcumin was also reported to act as a powerful intracellular antioxidant through intercepting ROS after penetration into cells [32]. In the present study, effects of turmeric pigments and their photo-degradation products on ROS levels in INT 407 normal intestinal and HCT 116 colon cancer cells were evaluated using DCFH-DA, a cell permeable ROS probe.

The DCF fluorescence intensity indicating the intracellular ROS levels was significantly less pronounced in the cells treated with fresh turmeric pigments as compared to control, and the effects were proportional to the concentration of the pigments in both cells (Figure 5A and B). Turmeric oleoresin incubated in a dark also showed a similar effect to fresh pigment, except showing relatively lower ROS scavenging activity in cancer cells (at 5 and 10 μg/mL) (Figure 5B). The turmeric oleoresin incubated under light for 24 h showed significantly less potent intracellular ROS scavenging activity in normal INT 407 cells; it rather enhanced the DCF fluorescence in HCT 116 cells at 5 μg/mL (Figure 5B). Curcumin also significantly decreased intracellular ROS levels in both cells regardless of the irradiation process. The curcumin irradiated by 24 h was less effective for scavenging ROS in HCT 116 cells; the activity changes by irradiation were less pronounced as compared to turmeric (Figure 5C and D).

These results indicate that scavenging activities of turmeric pigments against intracellular ROS decreased by photo-degradation. The results appear to conflict somewhat with the observation that ABTS radical scavenging activity of the pigments increased by photo-degradation as shown in Figure 4. It is considered that increased polarity of the photo-degradation products might be an obstacle to cell membrane penetration. In addition, the increased ability of the photo-degradation products for ROS generation as shown in Figure 3 seems to cause a negative effect on reducing the intracellular ROS level.

3.5. Changes in cytotoxic effect of turmeric pigments by photo-degradation

Curcumin has been reported to suppress the proliferation of several types of cancer cells in vitro and in vivo by inducing apoptosis and interfering the cell cycle progress [6,10]. The pigment could also regulate transcription factors, growth factors, and their receptors associated with all stages of cancer cells [6,10.33]. Accordingly, changes in cytotoxic property of turmeric pigments by photo-degradation were explored using INT 407 normal human intestinal and HCT 116 human colon adenocarcinoma cells.

The cell viability decreased in a concentration-dependent manner in the cells treated with turmeric oleoresin showing stronger potency on cancer cells (Figure 6A and B). The cytotoxic effect of turmeric oleoresin on normal INT 407 cells was not significantly changed by the irradiation, whereas 24 h incubated turmeric pigments under light showed a significantly lower cytotoxic activity against HCT 116 cancer cells (Figure 6B). Interestingly, addition of superoxide dismutase (SOD)/catalase (15/30 unit/mL, respectively) in culture media significantly enhanced cytotoxic effect of turmeric oleoresin on the HCT 116 cells; the phenomenon might be due to the improved stability of turmeric pigments by SOD/catalase (Figure 6C). It is reported that certain antioxidants such as ascorbic acid and SOD/catalase improved curcumin stability, resulting in more efficient cellular uptake and more potent cytotoxicity of curcumin [34]. Enhancing effects of SOD/catalase on turmeric cytotoxicity were, however, was less pronounced on the 24 h irradiated turmeric. It might

be because SOD/catalase did not work for stabilizing the irradiated turmeric pigments which were already considerably destroyed under light.

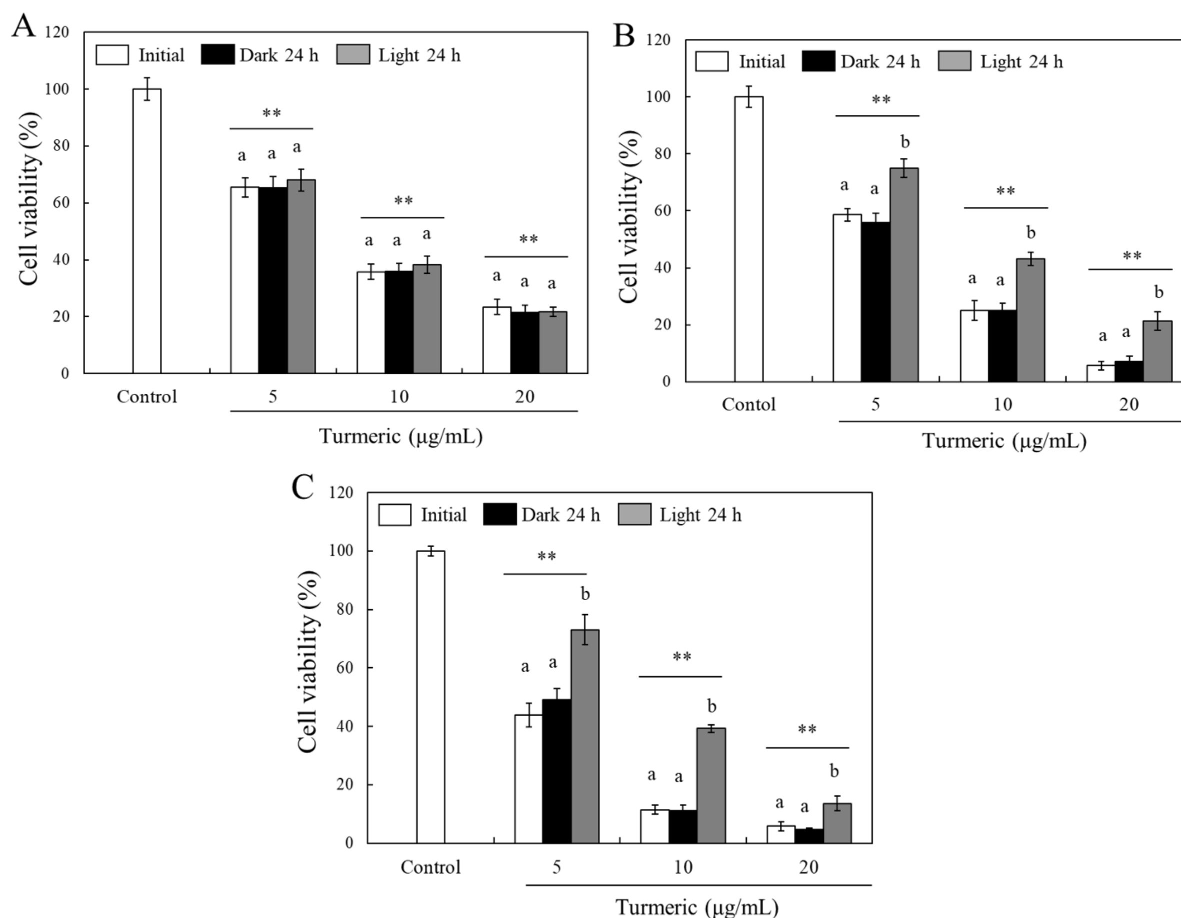

Figure 6. Modulation of cytotoxic property of turmeric oleoresin by photo-degradation. Cytotoxic activity of turmeric oleoresin on INT 407 (A) and HCT 116 cells (B) were analyzed after incubation for 24 h under fluorescent light or in a dark using the MTT assay. Changes in its cytotoxic activity in the presence of SOD/catalase were also analyzed (C). Each value represents the mean ± SD (n = 7–8). *,** Significantly different from control according to Student's t-test (*$p < 0.05$, **$p < 0.01$). Different letters indicate a significant difference ($p < 0.05$) based on one way ANOVA and the Tukey's HSD test.

However, curcumin showed a tendency to increase cytotoxicity after photo-degradation in both cells, and the increase in activity of curcumin by photo-degradation was more prominent in HCT 116 cells (Figure 7A and B). Recently, we observed that the treatment of sinapinic acid under irradiation or by a heating process resulted in enhanced cytotoxicity against HCT 116 cells indicating that degradation products from phenolic compounds could show more potent cytotoxicity [35]. Accordingly, certain photo-degradation products mainly from curcumin might be involved in the enhanced cytotoxicity, which needs to be further explored.

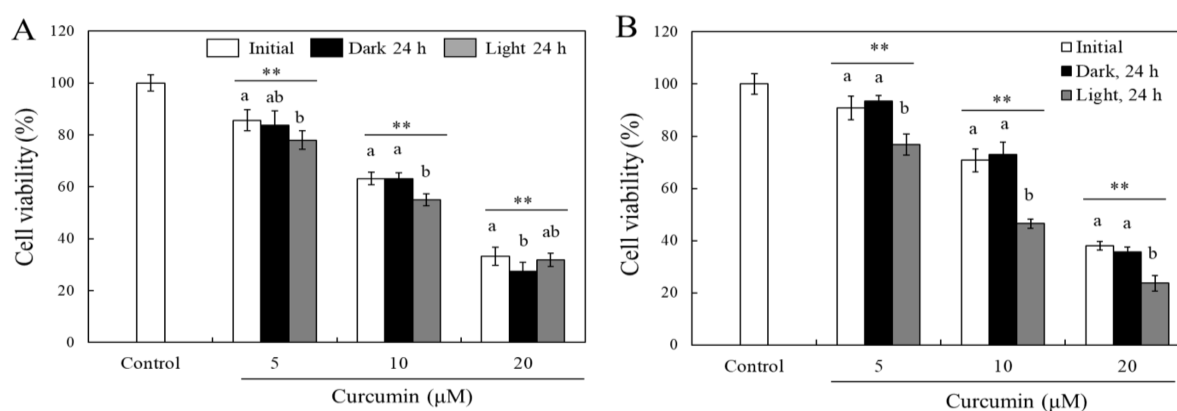

Figure 7. Modulation of cytotoxic property of curcumin by photo-degradation. Cytotoxic activity of curcumin on INT 407 (A) and HCT 116 cells (B) were analyzed after incubation for 24 h under fluorescent light or in a dark. Each value represents the mean ± SD (n = 7–8). *,** Significantly different from control according to Student's t-test (*$p <$ 0.05, **$p < 0.01$). Different letters indicate a significant difference ($p < 0.05$) based on one way ANOVA and the Tukey's HSD test.

4. Conclusions

Turmeric pigments including curcumin, DMC, and BMC have shown many beneficial health effects. They are, however, unstable and decomposed easily under many processing conditions. In this study, changes in chemical stability and bioactivities of turmeric oleoresin and curcumin under light were investigated. Considerable levels of turmeric oleoresin and curcumin were reduced under irradiation of a household fluorescent light (27 W, 30 cm distance). Among three curcuminoids, BMC was the most stable under light. The photo-degradation products of turmeric pigments showed the decrease in scavenging activities against DPPH radical and intracellular ROS, whereas their scavenging activity on ABTS radical was significantly enhanced. Cytotoxic effect of turmeric oleoresin after 24 h irradiation on HCT 116 colon cancer cells was significantly less pronounced, but curcumin cytotoxicity after 24 h irradiation was significantly enhanced. This study indicates that stability and color intensity of turmeric pigments decreased under light, and their bioactivities including antioxidant and cytotoxic properties were also modulated. This study provides fundamental information of light stability of turmeric pigments and their consequent activity changes and suggests that the phenomena should be considered in the processing and storage of turmeric-related food products.

Acknowledgments

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Conflict of interest

The authors declare that there is no conflict of interest.

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