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ARTICLE

Effects of Ultraviolet Irradiation on the Physicochemical and Functional Properties of Gum Arabic

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The impact of ultraviolet (UV) irradiation on the physicochemical and functional properties of gum arabic was investigated. Gum arabic samples were exposed to UV irradiation for 30, 60, 90, and 120 min; gum arabic was also treated with formaldehyde for comparison. Molecular weight analysis using gel permeation chromatography indicated that no significant changes occurred on the molecular structure on the samples exposed to UV irradiation. Free amino group analysis indicated that mild UV irradiation (30 min) could induce cross-linking on gum arabic; this result was comparable with that of samples treated with formaldehyde. However, viscosity break down was observed for samples exposed to UV irradiation for longer times (90 and 120 min). All irradiated and formaldehyde-treated samples exhibited better emulsification properties than unirradiated samples. These results indicate that UV-irradiated gum arabic could be a better emulsifier than the native (unmodified) gum arabic and could be exploited commercially.

KEYWORDS: Gum arabic; ultraviolet irradiation; physical modification; rheological properties; emulsification properties

INTRODUCTION

Gum arabic (E-number 414) is the oldest and best-known tree gum exudate obtained from the stems and branches of acacia trees [*Acacia senegal* (L.) Wild. and *Acacia seyal* Del.], and it is rich in nonviscous soluble fiber (*1*). The gum is harvested commercially throughout the Sahelian belt of Africa, principally from Sudan to Somalia, although historically it has been cultivated in Arabia and West Asia. Approximately 70% of the world production of gum arabic occurs in Sudan, and the remainder comes from countries in West Africa (*2*). Ancient Egyptians used gum arabic as an adhesive to wrap mummies and to make hieroglyphs by incorporating the substance into mineral paints (*3*). In modern times, the most important applications of gum arabic are as emulsifiers in the food and pharmaceutical industries. The functional properties of gum arabic are closely related to their structure, which determines the way it interacts with water and oil in an emulsion. The chemical and physicochemical properties can vary depending on the source, tree age, time of exudation, type of storage, and climatic conditions (*1*).

Gum arabic is predominantly a branched chain, complex polysaccharide that is either neutral or slightly acidic (*1*). It is a highly heterogeneous material that possesses both hydrophilic and hydrophobic affinities. Gum arabic consists of a group of macromolecules characterized by a high proportion of carbohydrate, of which D-galactose and L-arabinose are the predominant monosaccharides responsible for the hydrophilic affinity, and a low proportion of protein, mostly composed of hydroxyproline (*4*). The carbohydrate structure consists of a backbone of 1,3-linked β-D-galactopyranosyl units with extensive branching at the C6 position. The branches consist of galactose and arabinose, which terminate with rhamnose and glucuronic acid (*1*, *4*). The structure can be subdivided into three broad molecular fractions (*4*), termed arabinogalactan (AG), arabinogalactan protein (AGP), and glycoprotein (GP), which differ principally in their size and protein fractions. Randall et al. (*5*) reported that the AGP is the major component of gum arabic that is responsible for the gum's ability to stabilize emulsions. They proposed that the amphiphilic protein component of the AGP anchored the molecules to the surface of the oil droplets, while the hydrophilic carbohydrate component protruded out into the aqueous phase, preventing droplet aggregation through electrosteric repulsions. Mahendran et al. (*6*) recently offered a new insight into the structure of the AGP fraction that would further explain its functionality in an emulsion based on its peptide sequences and carbohydrate blocks.

Cross-linking can be useful for modifying the physical and functional properties of proteins. Numerous methods have been reported to induce cross-linking in protein, including chemical treatment, enzymatic treatment, and ionizing radiation (*7*–*9*). Glutaraldehyde, formaldehyde, and gloxal are examples of chemical cross-linking agents (*10*, *11*). However, these chemical cross-linkers are toxic, which limits their use in food systems (*12*). The use of enzyme treatments to induce cross-linking is costly and time-consuming. Therefore, a physical method—ultraviolet (UV) irradiation to induce cross-linking—was selected in this study.

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The primary advantage of using UV irradiation is that it does not employ radioactive sources, like γ-radiation, thus avoiding environmental issues (*13*). In addition, UV irradiation is cost-effective, nonthermal, and environmentally friendly.

UV irradiation is receiving increasing attention and has been used to improve soy protein films, to cross-link collagen and gelatin films in medical and pharmaceutical research, and to preserve and decontaminate food products (*14*). In addition, the impact of γ-radiation on the properties of gum arabic (*4*) and the impact of UV irradiation on reducing the microbial load of aqueous gum arabic solutions (*15*) have been reported. However, to the best of our knowledge, no studies have explored the impact of UV irradiation on the properties of gum arabic in solid (powder) form. We hypothesized that UV irradiation would cross-link the protein component in gum arabic and improve its emulsifying properties. Therefore, the main objectives of the present study were to investigate the effects of UV treatment on gum arabic and envisage the possible changes in its physicochemical and functional properties to provide a basis for further research into the potential application in the food industry. Being a good chemical cross-linking agent for protein (*10*, *11*), formaldehyde was also used as a comparison to verify whether the proteinaceous components in gum arabic could be cross-linked.

MATERIALS AND METHODS

Materials. The gum arabic from the acacia tree (Fluka 51200) used in this study was a spray-dried commercial product procured from Sigma-Aldrich Co. (Kuala Lumpur, Malaysia). Other chemicals were all reagent grade and were used without further purification.

Modification of Gum Arabic. Gum arabic samples were treated in duplicate with UV irradiation as previously described by Bhat and Karim (*16*) with modification. Samples (~15 g) were spread in a thin layer on sterile oven dishes (15 cm × 15 cm) and then exposed to a UV light source (253.7 nm; 30 W, Sankyo Denki, Kanagawa, Japan) positioned 30 cm away in a laminar flow cabinet (Pro-Lab, Neston, United Kingdom). The exposure times were 0, 30, 60, 90, and 120 min. The samples were then transferred aseptically into sterile polyethylene bags and stored for further analysis.

Gum arabic samples also were treated with formaldehyde in duplicate. A desiccator was used to create an environment full of formaldehyde vapor by placing ~500 mL of formaldehyde in the space below the platform. Gum arabic was then treated for 2 h.

Molecular Mass Determination. The molecular mass distribution of all of the gum arabic samples was determined by gel permeation chromatography (GPC) using a Waters (Division of Millipore, United States) Solvent Delivery System model 6000A or P-500 dual piston syringe pump (Pharmacia Biotech, Sweden), a Rheodyne series 7125 injector with a 200 μL loop, and a series of 3 Suprema columns (Suprema 100, Suprema 3000 and Suprema 30000; with a bead diameter of 10 μm). The Dawn DSP laser scattering photometer equipped with a 632.8 nm He−Ne laser (Wyatt Technology, United States) with 15 detectors was used in conjunction with a Wyatt Optilab DSP interferometric refractometer operated at 632.8 nm equipped with a 10 mm P100 cell (Wyatt Technology) and a UV−visible spectrophotometer (Agilent) at 280 nm. Data accumulation for detectors used was Astra software (Astra 4.90.08 for Windows, Wyatt Technology). Approximately 10 mg/mL solutions of the gum arabic samples was prepared in the eluent (0.1 M sodium nitrate containing sodium azide) by dispersing the gums in the eluent using a vortex mixer at room temperature, allowing the samples to fully dissolve. Accurately weighed 2.0 mg/mL samples were filtered through 0.45 μm nylon filters and injected and analyzed. Full details of the system and solution preparation are given elsewhere (*17*). In the following text and tables, the expressions M_w and M_n are used for the weight and number average molecular weights, respectively, and M_w/M_n is used for the polydispersity index (M_w/M_n).

Color Measurement. Samples in triplicate were transferred to a glass Petri dish and measured with a colorimeter (Minolta CM-3500D; Minolta Co. Ltd., Osaka, Japan). The instrument was calibrated to standard black and white prior to use. A large size aperture was used, and CIE color L^*, a^*, b^* values were reported via the computerized system using Spectra Magic software version 2.11 (Minolta Cyberchrom Inc., Osaka, Japan). The L^* value is the psychometric lightness (dark-light) and corresponds to black ($L^* = 0$) and white ($L^* = 100$), and the a^* and b^* values correspond to psychometric chromaticity. A positive a^* value represents red, and a negative value denotes green. A positive b^* value corresponds to yellow, whereas a negative value indicates blue.

Free Amino Group Measurement (Formol Titration). The content of free amino groups in the samples was determined by following Denis et al. (*18*). Briefly, 0.5 g of sample (P) was placed in a 100 mL beaker, and 20 mL of deionized water was added. The suspension was stirred for 5 min until complete dissolution occurred, and the pH was then adjusted to 7.4 ± 0.1 with 0.05 N NaOH by means of a pH meter (Delta 320, Mettler Toledo, Greifensee, Switzerland). The formol reagent was prepared by diluting 500 mL of the commercial solution with 200 mL of deionized water and thoroughly stirring the solution. The pH was adjusted to 7.4 ± 0.1 with 0.05 N NaOH just before use. Thirty-five milliliters of the formol reagent was added to the suspension to be tested, the mixture was stirred for 5 min, and it was titrated to pH 9.2 ± 0.1 with 0.05 N NaOH using a 25 mL buret. The volume V (mL) of NaOH required was recorded. The quantity of total free amino groups N_t (mmol/g) present was then determined as

$$N_t = 0.05 \times \frac{V}{P}$$

Rheological Properties. Rheological measurements were performed using a rheometer (AR 1000-N, TA Instruments, Newcastle, DE) with a cone geometry (steel 2° cone angle, 6.0 cm diameter, and 0.6 μm truncation gap). Approximately 2% of gum arabic solutions were prepared for this analysis. To decrease the initial acceleration and the effects of instrument inertia, the torque was imposed following a logarithmic ramp. The temperature was maintained at 25.0 ± 0.1 °C in all experiments. The torque vs angular velocity data were converted to apparent viscosity vs shear rate using the TA software. The Sisko model parameters were then determined using the Rheology Advantage Data Analysis Version 5.4.0 software (TA Instruments).

Emulsification Properties. The emulsification properties of the irradiated and unirradiated samples were determined by the method previously described by Pearce and Kinsella (*19*), which entailed the formation of an emulsion and then determination of the turbidity of a dilution series at 500 nm. The emulsion was formed by transferring 1.0 mL of palm oil (Felda Iffco Sdn. Bhd., Selangor, Malaysia) into 3.0 mL of 0.1% w/v sample solution in 100 mM sodium phosphate buffer at pH 7.4. The mixture was then homogenized in an Ultra-Turax T25 basic (Ika-Works) at 12000 rpm for 1 min at 25 °C. A 100 μL aliquot of the emulsion sample was taken from the bottom of the test tube at 0, 1, 2, 3, 5, 10, and 20 min and immediately diluted with 5 mL of 0.1% sodium dodecyl sulfate solution. The absorbance of the diluted emulsion was then determined at 500 nm. The emulsifying activity was determined from the absorbance measured immediately after the emulsion formed. The stability of the emulsion was measured by determining the half-life of the decrease in the emulsion turbidity.

Droplet Size Distribution. Emulsions were prepared in the same manner described above, the oil droplet distributions were measured with a Malvern MSS laser diffraction system (Malvern Instruments Ltd., Worcestershire, England), and data were analyzed using Mastersizer-S (V 2.19, Malvern Instruments Ltd.) software. The emulsion was transferred into the instrument's dispersion circulator tank, which contained deionized water, after 20 min of standing at room temperature. The emulsion then was fed into the diffraction cells. Sufficient sample was added to yield an obscuration factor within 10−15% before measurement. The particle size was then expressed as the volume mean diameter D[4,3]:

$$D_{4,3} = \sum n_i d_i^4 / \sum n_i d_i^3$$

where n_i is the number of particles with diameter d_i. All particle size distributions were measured in triplicate.

Statistical Analysis. All experiments were conducted in triplicate. All data analyses were performed using SPSS for Windows Version 12.0 (SPSS, Chicago, IL). Differences between means were assessed using

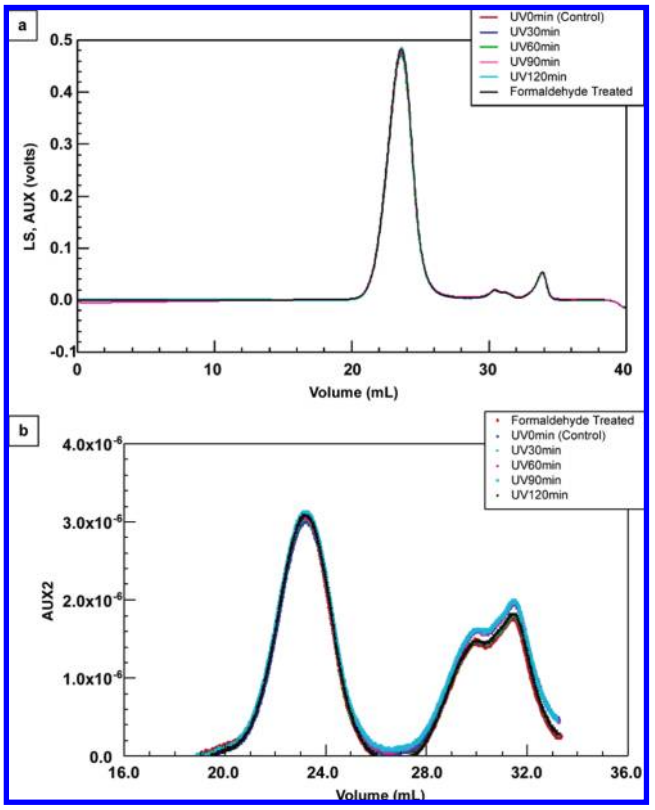

Figure 1. GPC elution profiles of gum arabic underwent UV irradiation obtained using (**a**) RI and (**b**) UV detectors.

a one-way analysis of variance with a posthoc determination by Tukey's test. The α level was set at 0.05.

RESULTS AND DISCUSSION

Molecular Mass Determination. The aim of this analysis was to compare the molecular weight distribution of UV-irradiated and formaldehyde-treated gum arabic with unirradiated gum arabic. The presence of the three main fractions, namely, the AGP complex, AG, and GP, can be clearly identified in all of the samples from the GPC elution profiles. Interpretation of the elution profile has been described previously (*4*). The molecular weight of the samples was measured for the whole gum and for the two components (i.e., AGP and AG) as identified by the refractive index profile. **Figure 1a** gives typical refractive index and molecular weight distribution for all of the gum arabic samples, and they are similar and superimposible. The small peak that occurred at around 33 mL elution for all of the samples was the salt peak due to the presence of electrolyte. All of the samples were found to have a single large and fairly sharp elution peak at 23.5 mL (corresponding to the AGP). There was also a very small, broader peak (corresponding to the AG and GP) eluting at around 30.5 mL in all of the samples, but the intensity of this peak was significantly smaller than the larger peak. The elution behavior in UV response shows remarkably similar profiles in terms of peak sizes, peak shapes, elution volumes/times, and intensities (**Figure 1b**), indicating that the molecular structure of gum arabic was not affected by UV irradiation which was then further confirmed by data interpretation in **Table 1**. It is evident that the difference in molecular mass (M_w) and average molecular mass (M_n) for UV-irradiated and formaldehyde-treated samples was insignificant as compared to the control sample. This result is in contrast to the effect of γ-irradiation, which has been reported to exhibit significant molecular weight changes on gum arabic due to depolymerization (*4*, *20*). Thus, we postulate that the gum arabic was not susceptible to destruction and depolymerization under different UV irradiation exposure under the conditions used in this experiment. However, it is interesting to note that although UV irradiation did not cause any significant changes on molecular weight of gum arabic, the analysis on emulsification property showed a significant improvement (see the discussion on emulsification properties).

Table 1. Molecular Weight Parameters for UV-Irradiated and Formaldehyde-Treated Gum Arabic Determined by GPC-MALLS

UV exposure time (min)	moleular weight (M_w)
0 (control)	1.10×10^6
30	1.12×10^6
60	1.16×10^6
90	1.17×10^6
120	1.14×10^6
formaldehyde treated	1.13×10^6

Table 2. CIE *L**, *a**, *b** Values for UV-Irradiated and Formaldehyde-Treated Gum Arabic

	color values[a]		
exposure time (min)	*L**	*a**	*b**
0 (control)	87.12 ± 0.01 a	0.64 ± 0.02 bc	17.93 ± 0.03 e
30	86.79 ± 0.02 b	0.68 ± 0.04 abc	18.26 ± 0.01 c
60	86.74 ± 0.00 bc	0.71 ± 0.01 bc	18.43 ± 0.02 b
90	86.67 ± 0.03 c	0.62 ± 0.02 c	18.13 ± 0.02 d
120	86.58 ± 0.01 d	0.73 ± 0.03 a	18.74 ± 0.01 a
formaldehyde treated	87.06 ± 0.06 a	0.70 ± 0.03 bc	18.14 ± 0.08 d

[a] Results are expressed as means ± standard deviations; $n = 3$. Different letters in the same column are statistically different ($P < 0.05$).

Color Measurement. Table 2 lists the colors of irradiated and formaldehyde-treated gum arabic samples. UV irradiation caused color changes in the samples. Decreasing *L** values indicate the gradual darkening of samples that occurred with increasing treatment time. γ- and electron beam irradiation had also been reported to cause darkening of gum arabic via the degradation process (*20*). It is possible that the darkening of gum arabic samples upon UV exposure was a consequence of a Mailard browning reaction. Polysaccharides are susceptible to degradation upon irradiation due to the scission of glycosidic bonds, which causes decomposition of pyranose rings and formation of compounds with carbonyl and carboxyl groups (*21*). Oxygen also plays an important role in the degradation of polysaccharides (*22*). Zegota (*22*) reported that the peroxyl radicals formed by the existence of oxygen on primary carbohydrate radicals initiated the oxidative degradation and resulted in chain scission of gum arabic. Therefore, we postulate that the browning of gum arabic occurred via oxidative degradation upon UV irradiation. In contrast, gum arabic treated with formaldehyde showed no significant color change as compared with the control, which indicated that degradation did not occur in formaldehyde-treated samples.

Free Amino Group Measurement (Formol Titration). Gum arabic contains a low proportion of proteinaceous component relative to carbohydrate. The variations in proteinaceous component for gum arabic range from 0.13 to 10.4% (*4*). Approximately 50% of the proteinaceous component in gum arabic consists of serine, proline, and typically high levels of hydroxyproline. With regard to protein molecule AGP, Urbain (*23*) reported that irradiation of protein in the solid state could cause either cross-linking or molecular degradation, depending on the protein nature and irradiation dosage. On the basis of this

premise, we hypothesized that UV irradiation would cross-link the proteinaceous component in gum arabic, thus reducing the content of free amino groups. Formol titration was conducted to determine the content of free amino groups in irradiated gum arabic that was not cross-linked upon irradiation. The initial and final pH selected to carry out the formol titration must be adapted to the dissociation constant (p*K*) of the different entities of protein. According to Denis et al. (*18*), to avoid titration of acid functions (glutamic acid) and the imidazole group of histine, the initial pH should be slightly greater than 7.0. On the other hand, to avoid titration of the phenol group of tyrosine, the final pH should not be much higher than 9.0. Proline and hydroxyproline would require a final pH of 9.7. The actual pH used in our analyses was between 7.0 and 7.5.

Total free amino group for UV-irradiated and formaldehyde-treated gum arabic is shown in **Table 3**. Samples with values higher than that of the control indicated that breakdown of amino groups occurred to yield an increase in free amino groups. In contrast, samples with lower values indicate the occurrence of cross-linking, which decreased the content of free amino groups. On the basis of this principle, the results suggest that UV irradiation induced cross-linking of gum arabic at 30 min of exposure time and depolymerization from 60 to 120 min of exposure time. Rhim et al. (*24*) reported that UV radiation-induced depolymerization might occur simultaneously with cross-linking. A similar finding (*4*) was reported for the effect of γ-irradiation on the molecular weight of AGP; the molecular weight increased (due to cross-linking) to a maximum with increasing radiation dose, but it decreased (depolymerization) as the radiation dose was further increased. However, UV-treated gum arabic samples in our experiment did not exhibit a significant degree of depolymerization as shown by the GPC analysis. Therefore, we suggest that any changes brought about by UV irradiation might be attributed to predominantly cross-linking. As shown in **Table 3**, reduction in the total free amino group content occurred in the formaldehyde-treated samples. Irradiated gum arabic sample for 30 min was observed to have slightly lower (insignificant) total free amino group as compared with the formaldehyde-treated sample, indicating that the degree of cross-linking was higher in the sample treated for 30 min of UV irradiation than the sample treated with formaldehyde for 2 h. Various studies (*25*−*27*) have reported on the role that formaldehyde plays in protein cross-linking, but its toxicity has yet to be established. Our results clearly show that with minimal UV irradiation (30 min) can cause AGP cross-linking, similar to that caused by formaldehyde or γ-radiation (*4*). Hence, UV irradiation could be effectively used as an alternative to formaldehyde to induce protein cross-linking in gum arabic.

Table 3. Total Free Amino Group for UV-Irradiated and Formaldehyde-Treated Gum Arabic

exposure time (min)	total free amino group (mmol/g)[a]
0 (control)	0.12 ± 0.00 cd
30	0.11 ± 0.00 e
60	0.13 ± 0.00 bc
90	0.13 ± 0.00 ab
120	0.14 ± 0.00 a
formaldehyde treated	0.11 ± 0.01 de

[a] Results are expressed as means ± standard deviations; $n = 3$. Different letters in the same column are statistically different ($P < 0.05$).

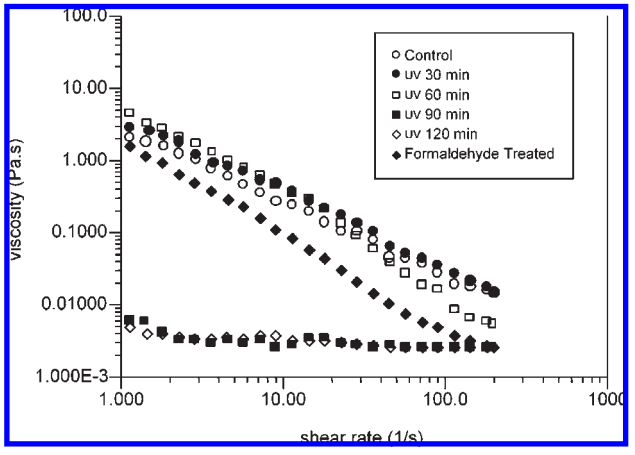

Figure 2. Apparent viscosity (η_a) vs shear rate ($\dot{\gamma}$) of UV-irradiated and formaldehyde-treated gum arabic dispersions.

Permanent changes in irradiated proteins include deamination, decarboxylation, reduction of disulfide linkages, oxidation of sulphydryl groups, cross-linking, valence change of coordinated metal ions, and peptide chain cleavage or aggregation (*28*). The increase of total free amino group content in the irradiated samples (60−120 min) (**Table 3**) indicated that deamination might have taken place.

Rheological Properties. Figure 2 shows the log η_a vs log $\dot{\gamma}$ data of UV-irradiated and formaldehyde-treated gum arabic dispersions. Except for samples treated with UV at 90 and 120 min, all gum arabic dispersions exhibited typical shear thinning and non-Newtonian flow behaviors, as reported by Mothé and Rao (*29*). According to Mothé and Rao (*29*), the Sisko model is the most suitable model to describe the gum dispersion; thus, we used it to describe the dispersions in this study. **Table 4** shows the values of the Sisko model parameters. The flow behavior index was < 1, reflecting the shear-thinning nature of the dispersions. The smaller flow behavior index for samples exposed to UV for 60 min and samples treated with formaldehyde indicate that the shear thinning behavior was more pronounced in these samples.

The changes in molecular dimensions are reflected in the dramatic changes in rheology associated with the treated gum arabic. According to Al-Assaf et al. (*4*), the gum is a compact globular system initially, with no significant effect of shear. At this stage, the polysaccharide acts as a set of small compact balls, with no shear thinning. As the irradiation time is increased, an entangled network is produced, typical of longer molecules when shear thinning can be observed. **Table 4** and **Figure 2** show that the formaldehyde-treated and UV-irradiated gum arabics for 30 and 60 min are typical of an entangled shear-dependent network

Table 4. Sisko Model Parameters of UV-Irradiated and Formaldehyde-Treated Gum Arabic Dispersions

exposure time (min)	consistency index (Pa s^n)	flow behavior index (dimensionless)	η_∞ (Pa s)	standard error
0 (control)	2.12	0.041	1.40×10^{-8}	16.89
30	3.04	0.027	1.11×10^{-9}	17.13
60	3.06	4.73×10^{-8}	1.09×10^{-11}	56.31
90	9.55×10^{-4}	3.56×10^{-4}	2.80×10^{-3}	109.2
120	1.72×10^{-3}	4.02×10^{-5}	2.70×10^{-3}	120.4
formaldehyde treated	1.03	4.75×10^{-6}	5.79×10^{-4}	59.11

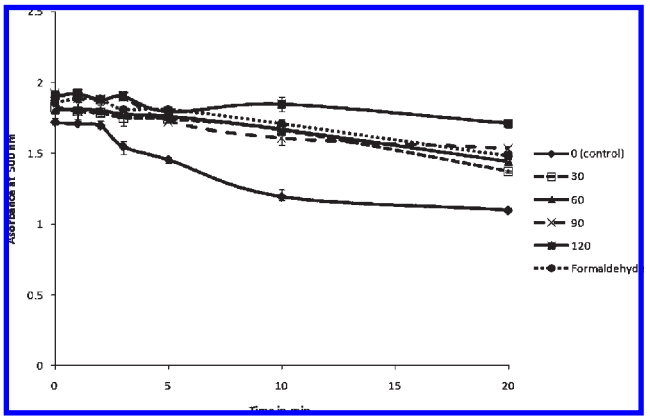

Figure 3. Effect of UV irradiation and formaldehyde on emulsification properties of gum arabic. Key: 0, control; 30, 60, 90, and 120, exposure time in min; and formaldehyde, sample treated with formaldehyde for 2 h. Each plotted point is the mean ± standard deviation; $n = 3$.

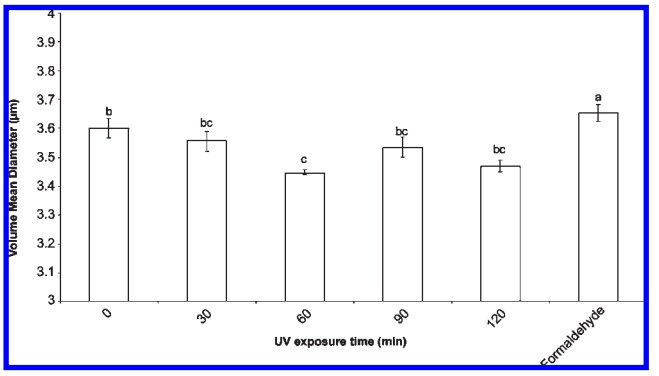

Figure 4. Effect of UV irradiation and formaldehyde on droplet size of the O/W arabic gum emulsion. Each plotted point is the mean ± standard deviation; $n = 3$. Different letters denote statistical difference ($P < 0.05$).

as compared to control sample; therefore, the shear thinning behavior was pronounced.

The apparent viscosity (η_a) of samples exposed to UV irradiation for 30 and 60 min was similar than that of the control sample at 1−50 s^{-1} of shear rate (**Figure 2**). This finding agrees with results of the GPC-MALLS that no significant changes were observed on the molecular structure; therefore, similar flow behavior was observed. However, a drastic drop of apparent viscosity (η_a) occurred for samples exposed to UV irradiation for 90 and 120 min as compared to the control sample. Additionally, these samples also exhibit more Newtonian behavioral dispersion. This is an intriguing finding because it could not be attributed to the depolymerization of the molecules as GPC results showed no significant changes in molecular weight.

The fact that the samples treated with formaldehyde and with UV irradiation for 90 and 120 min show a dramatic reduction in viscosity without a corresponding change in molecular weight is unexpected. It is known that gum arabic molecules self-associate in solution as evidenced by Sanchez et al. (*30*) who monitored the rheological properties of the gum as a function of time. They found that gum arabic solutions at concentrations as low as 3%, which is well below the critical overlap concentration, exhibited shear thinning at shear rates below 10 s^{-1} and that the elastic modulus increased with time. It is possible that the treatments prevent the self-association of the gum arabic molecules. Therefore, further work is warranted to explain the reduction in viscosity for these samples.

Emulsification Properties. Emulsions are not thermodynamically stable, and an unstable emulsion is very susceptible to separation of the oil and water phases. Gum arabic is considered to be a good gum for stabilizing oil-in-water emulsion systems (*31*) due to the hydrophilic affinity contributed by its polysaccharide fractions and the hydrophobic affinity contributed by its protein fractions. Because stabilization can occur in a system comprised of protein and polysaccharide components (*32*), the emulsification properties of gum arabic were determined to assess the degree of stabilization that occurred under different UV irradiation exposure conditions.

Figure 3 shows markedly improved emulsion stability upon UV irradiation. During the short standing time (the first 3 min), the emulsion stability of the control and irradiated samples was similar, but upon extended UV exposure time, the emulsion stability of samples containing UV-irradiated gum arabic was better than that of the control samples. **Figure 4** shows the droplets size distribution of UV-irradiated and formaldehyde-treated gum arabic emulsions measured after 20 min of standing at room temperature. Oil droplets from samples exposed to UV radiation (30, 60, 90, and 120 min) were quantitatively smaller but statistically insignificant than those of the control sample (0 min) except the sample treated with UV for 60 min. This finding implies that oil droplets in unirradiated gum arabic increase in size after 20 min due to flocculation and coalescence, thereby causing destabilization of the emulsion. In contrast, the droplet size for UV-irradiated samples and formaldehyde-treated samples was markedly different, indicating the high emulsion stability induced by UV irradiation. This enhancement of emulsification could be attributed to the change in AGP content of the irradiated gum, wherein cross-linking could occur. One possibility could be attributed to denaturation of AGP fraction, which led to an effective unfolding of the protein moiety at the oil−water interface and thus an improvement in the emulsifying stability. This model of emulsion stabilization has been proposed by Buffo et al. (*33*) to explain the observation that pasteurization of gum arabic enhances emulsion stability. However, we could not provide any evidence on the AGP denaturation based on our experimental design. Al-Assaf et al. (*4*) reported that γ-irradiation-induced cross-linking on protein could increase the molecular proportion of AGP and give rise to the improved emulsification properties. However, our GPC results did not provide any evidence on cross-linking of proteinaceous components (**Figure 1**). Further research of this phenomenon is needed to elucidate the mechanism.

In conclusion, our results indicate the possibility of using mild UV irradiation to induce cross-linking of gum arabic. However, further work is necessary to understand the molecular weight changes of AGP that occur upon UV irradiation-induced cross-linking. The reduction in viscosity and improved emulsification properties found in this study imply that UV-irradiated gum arabic could serve as a novel emulsifier that could be used in food products that require better emulsifying properties with reduced viscosity, such as dressings, spreads, and beverages, as well as in other nonfood products such as lithographic formulations, textiles, and paper manufacturing.

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