DEVELOPMENT OF *BULGOGI* SAUCE HAVING STABLE QUALITY TO HIGH DOSE IRRADIATION

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***Abstract*—At this study, the viscosity of the gum solutions (1%, w/w) prepared with xanthan gum, guar gum, and locust bean gum were examined to select gum (thickening agent) maintaining viscosity after irradiation. The viscosity and sensory perperty of *Bulgogi* sauce containing xanthan gum (1%, w/w) were also evaluated after high dose irradiation up to 40 kGy. The viscosity of xanthan gum solution was the most stable (p < 0.05) after irradiation up to 9 kGy. Thus, xanthan gum (1%, w/w) was added to *Bulgogi* sauce to improve its viscosity. The viscosity and sensory property of sauce were not changed by irradiation and storage at 35°C for 90 days. This result indicates that addition of xanthan gum increase viscosity of *Bulgogi* sauce irradiated without compromising of sensory properties.**

Index Terms—***Bulgogi* sauce, xanthan gum, viscosity, sensory property, irradiation.**

I. INTRODUCTION

Because a commercial *Bulgogi* sauce by small meat benders is gradually increased, the safety of the products is concerned due to possible contamination of spoilage bacteria from soy sauce and fresh vegetables. Song et al. (2001) reported that the level of *Bacillus* spp. of soy sauce, which is a major component of *Bulgogi* sauce, was 10^5 CFU/mL. This result suggested that the method to decrease bacterial populations in soy sauce is necessary.

Jo, Kim, Shin, Kang and Byun (2003) and Lee, Kim and Oh (2001) compared the effect of gamma irradiation and heat-pasteurization on shelf-life and quality of *Bulgogi* sauce as well as their cost efficiency, and the results showed that the gamma irradiation (2.5 – 10.0 kGy) was more effective to ensure safety of *Bulgogi* sauce compared to heat treatment (100°C for 30min), but *Bulgogi* sauce was not sterilized by irradiation up to 10 kGy. Thus, higher dose irradiation was needed to ensure shelf-stability of *Bulgogi* sauce especially for the extreme environments.

Meanwhile, the viscosity is critically important for colloidal foods (sauce, syrup and ice cream). However, exposure to irradiation may produce certain changes in the chemical properties (viscosity and color) and sensory properties of colloidal foods (Aliste, Vieira & Del Mastro, 2000). Hence, the use of food additives (thickening agent/stabilizer) is needed to maintain rheological property of irradiated products. Hydrocolloids are polymers or polysaccharides interacting strongly with water. Xanthan gum, guar gum and locust bean gum are most frequently used hydrocolloids as food additives. Many food products such as sauce, syrup, ice cream, instant foods, beverage and confectionery contain hydrocolloids in their formulations (Dogan & Kayacier, 2004).

The objective of this study was to compare the radiation effects on viscosity of xanthan gum, guar gum and locust bean gum solutions (1%, w/w) for selection of gum to be contained in *Bulgogi* sauce. The effects of high dose irradiation (up to 40 kGy) on viscosity and sensory property of *Bulgogi* sauce containing xanthan gum (1%, w/w) were also examined during storage at 35°C for 90 days.

II. MATERIALS AND METHODS

A. Materials

Xanthan gum, guar gum and locust bean gum powders were obtained from a commercial additives (MSC Co., Kyeongnam, Korea). The Soy sauce, onion, welsh onion, garlic, sesame and sugar were purchased form local store.

B. Preparation of gum solutions (1%, w/w)

The xanthan gum, guar gum or locust bean gum powders (10 g) were prepared in 1000 mL water, and then vigorously agitated for 30 min at 80°C in a water bath to completely dissolve the gums. Finally, gum solutions (1%, w/w) were prepared, cooled to room temperature. The gum solutions were individually placed into a 50 mL falcon tube (diameter: 30 mm, height: 115 mm).

C. Preparation of sauce containing xanthan gum (1%, w/w)

The raw materials of *Bulgogi* sauce were soy sauce (16%), onion (8%), welsh onion (3.2%), garlic (2.8%), sesame (1.0%), sugar (8%), xanthan gum (1.0%) and water (60%). The materials of sauce were placed into a pot and boiled at 100°C for 20 min. Xanthan gum solution (mix of sugar, xanthan gum and water) was then added to boiling sauce, and continuously boiled at 100°C for 10 min with gentle agitation. The prepared sauce was cooled to room temperature. The sauce was individually placed in an aluminium-laminated low-density polyethylene (Al-LDPE, Sunkyung Co. Ltd., Seoul, Korea), and aerobically packaged.

D. Gamma irradiation

Gum solutions (1%, w/w) and *Bulgogi* sauce was gamma-irradiated using a cobalt-60 irradiator (point source AECL, IR-79, MDS Nordion International Co. Ltd., Ottawa, Ontario, Canada) in the Advanced Radiation Technology Institute, Korea Atomic Energy Research Institute (Jeongeup, Korea). The doses applied in this study were 0 – 9 kGy (gum solutions) and 0 – 40 kGy (*Bulgogi* sauce). The source strength was approximately 300 kCi at 10 kGy/h of dose rate. Dosimetry was carried out using 5 mm diameter alanine dosimeters (Bruker Instruments, Rheinstetten, Germany). The dosimeters were calibrated against an international standard set by the International Atomic Energy Agency (Vienna, Austria).

E. Viscosity

The viscosity of the gum solutions (1%, w/w) was measured at room temperature using a Brookfield viscometer (DV-II + pro, Brookfield Engineering Laboratories, MA, USA) with the S21 spindle at 5 rpm.

F. Sensory evaluation

Sensory evaluations (color, texture, taste, flavor and overall acceptance) were conducted by 21 panels. Sensory scores of *Bulgogi* sauce were referred to using a 7 point descriptive scale where 1 = extremely dislike to 7 = extremely like. After irradiation, *Bulgogi* sauce was removed from pouch, served randomly to each panel during 15 min. Sample order was also randomized to account for sampling order bias. Water and unsalted crackers were provided, and panels were asked to expectorate and rinse their mouths between each sample. Results were expressed as the predominant score given by panels.

G. Statistical analysis

Samples were analyzed in triplicate and the results were presented as mean ± standard deviation. All data were analyzed by the generalized linear model procedures of the SAS® version 9.2 (SAS Institute, Cary, NC, USA). Tukey's multiple range tests were used to compare least squared means among treatments at $\alpha = 0.05$.

III. RESULTS AND DISCUSSION

A. Radiation on viscosity of gum solutions (1%, w/w)

Gamma irradiation produces significant changes in the viscosity of the gum solutions (1%, w/w), as shown in Table 1. As the absorbed dose increases, the gum solutions show a significant decrease ($p < 0.05$) of viscosity. The viscosity values (cp) of the non-irradiated gum solutions (xanthan gum, guar gum and locust bean gum solution) were 1248, 3965 and 1631 cp, respectively. The viscosity of 3 kGy-irradiated gum solutions (xanthan gum, guar gum and locust bean gum solution) were 927, 0 and 0 cp, respectively. This result, the viscosity of xanthan gum solution was stable ($p < 0.05$) when compared with guar gum or locust bean gum solution after gamma irradiation. Urban (1986) indicated that polysaccharides are generally degraded by ionizing radiation as a result of the free-radical-induced scission of the glycosidic bonds in the polysaccharide chains, and this process is accompanied by other less-specific chemical changes. Gupta, Shah, Sanyal, Variyar and Sharma (2009) also reported that in solutions, due to radiolysis of water, OH radicals are most reactive species formed. It abstracts hydrogen from carbohydrate to give a reactive free radical which is unstable and has little probability of encountering another radical in dilute solution.

Table 1. Viscosity (cp; mean ± standard deviation) of gamma irradiated gum solutions (1%, w/w)

Dose (kGy)	Xanthan gum	Guar gum	Locust bean gum
0	1248±91^{aC}	3965±174^{aA}	1631±118^{aB}
3	927±62^{bA}	0±0^{bB}	0±0^{bB}
6	381±29^{cA}	0±0^{bB}	0±0^{bB}
9	92±8^{dA}	0±0^{bB}	0±0^{bB}

$^{a\text{-}d}$Means within the same column with different letters were significantly different ($p < 0.05$).
$^{A\text{-}C}$Means within the same row with different letters were significantly different ($p < 0.05$).

B. Radiation effect on viscosity of Bulgogi sauce containing xanthan gum (1%, w/w)

On day 0, the viscosity of sauce was decreased ($p < 0.05$) by irradiation (Table 2). The viscosity of non-irradiated samples was very quickly decreased during storage compared to irradiated samples. Exposure to irradiation may also produce certain changes in the chemical properties of foods. Thus, the use of irradiation in colloidal foods may cause a change in the consistency and viscosity characteristics. The rheological properties of hydrocolloids and colloidal foods (soups, hot salep drink, sauce and milk chocolate) are particularly important when they are used in the formulation of any food for their effects on the textural attributes (Aliste, Vieira & Del Mastro, 2000). This result indicates that the viscosities of the sauces were highly maintained after irradiation up to 40 kGy regardless of storage periods, and the viscosity of non-irradiated sauces was obviously decreased ($p < 0.05$) during storage. The decrease of the viscosity of non-irradiated sauce may be related to glucose degradation by natural flora in sauce.

Table 2. Viscosity (cp; mean ± standard deviation) of gamma-irradiated sauce containing xanthan gum 1% (w/w) during storage at 35^{o}C for 90 days

Dose (kGy)	Storage (day)			
	0	30	60	90
0	9317±152^{aA}	5129±96^{cB}	4741±83^{dC}	4728±71^{dC}
10	8543±117^{bA}	7648±134^{aB}	7429±126^{aBC}	7264±125^{aC}
20	7682±121^{cA}	7514±87^{aA}	7158±104^{bB}	6893±116^{bC}
40	7124±96^{dA}	6863±118^{bB}	6594±97^{cC}	6428±102^{cC}

$^{a\text{-}d}$Means within the same column with different letters were significantly different ($p < 0.05$).
$^{A\text{-}C}$Means within the same row with different letters were significantly different ($p < 0.05$).

C. Radiation effect on sensory properties of Bulgogi sauce containing xanthan gum (1%, w/w)

On day 0, the sensory qualities (color, texture, taste and flavor) of sauce were decreased ($p < 0.05$) by irradiation (Table 3). However, the scores for color, texture, taste and flavor of samples irradiated up to 40 kGy were 5.2, 5.4, 5.1 and 4.6, respectively, which indicated the excellent qualities. The sensory property of non-irradiated sauce was compromised during storage, and its sensory qualities were not able to be evaluated after 30 days due to spoilage. The sensory qualities of irradiated sauces were not significantly changed during storage for 90 days, and the differences of sensory qualities of all samples (10, 20 and 40 kGy) were not observed ($p \geq 0.05$). The color of sauce became darker during storage, depending on radiation dose. This dark color was similar to intrinsic color of the soy sauce, and thus its color acceptance was increased during storage. Jo, Kim, Shin, Kang and Byun (2003) and Lee, Kim and Oh (2001) reported that the sensory qualities (odor, taste and color) of *Bulgogi* sauce irradiated up to 10 kGy were not changed. Moreover, our result shows that the sensory quality of sauce irradiated with high dose (40 kGy) was also not changed during storage.

Table 3. Sensory properties (mean ± standard deviation) of gamma-irradiated sauce containing xanthan gum 1% (w/w) during storage at 35°C for 90 days

Day	Dose (kGy)	Color	Texture	Taste	Flavor	Overall acceptance
0	0	6.9±0.5[a]	6.8±0.6[a]	6.9±0.8[a]	6.8±0.5[a]	6.9±0.7[a]
	10	6.4±0.4[a]	6.3±0.7[a]	6.3±0.5[a]	6.1±0.4[a]	6.4±0.6[a]
	20	5.9±0.5[ab]	5.9±0.4[ab]	5.7±0.5[ab]	5.3±0.7[ab]	6.1±0.8[ab]
	40	5.2±0.6[b]	5.4±0.6[b]	5.1±0.3[b]	4.6±0.5[b]	5.2±0.4[b]
30	10	6.6±0.6[a]	6.5±0.5[a]	6.2±0.7[a]	6.5±0.5[a]	6.4±0.6[a]
	20	6.3±0.4[a]	6.2±0.7[a]	5.9±0.4[a]	6.1±0.7[a]	6.1±0.6[a]
	40	6.1±0.5[a]	5.9±0.3[a]	5.6±0.5[a]	6.2±0.5[a]	5.8±0.4[a]
90	10	6.1±0.5[a]	6.2±0.6[a]	5.8±0.4[a]	6.1±0.6[a]	5.7±0.5[a]
	20	6.5±0.4[a]	5.8±0.3[a]	5.6±0.4[a]	5.7±0.4[a]	5.6±0.3[a]
	40	6.7±0.5[a]	5.4±0.5[a]	5.2±0.3[a]	5.4±0.4[a]	5.1±0.5[a]

[a-d]Means within the same column with different letters were significantly different ($p < 0.05$).

IV. CONCLUSION

The viscosity of xanthan gum was relatively stable to irradiation compared to guar gum and locust beam gum, and once xanthan gum (1%, w/w) was added to *Bulgogi* sauce followed by irradiation, the visocosity and sensory properties of *Bulgogi* sauce were not changed during storage. Therefore, use of xanthan gum in *Bulgogi* sauce may be useful in preventing viscosity decrease of the sauce after irradiation for safety purpose.

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