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Research Article

Effect of red ginseng extract on the quality characteristics of mayonnaise

Jung Soo Kim[1], Jiyoon Kim[1], Inju Nam[1], Soo Hyun Kim[1], Yu Min Seo[1], Jeong-Ho Lim[2], Kwang-Deog Moon[1,3]*

[1]*School of Food Science and Biotechnology, Kyungpook National University, Daegu 41566, Korea*
[2]*Food Safety and Distribution Research Group, Korea Food Research Institute, Wanju 55365, Korea*
[3]*Food and Bio-Industry Research Institute, Kyungpook National University, Daegu 41566, Korea*

Abstract Increasing consumer demand for healthy food leads to the pursuit of mayonnaise with fewer egg yolks. This study investigated the possibility of red ginseng extract (RGE) as an egg yolk alternative in mayonnaise. Mayonnaises were prepared by replacing different ratios (0%, 25%, 50%, 75%, and 100%) of RGE to egg yolks, and quality characteristics were analyzed. RGE was confirmed to have 17.51 mg/g of crude saponin, a water holding capacity of 0.21 g/g, and an oil holding capacity of 1.82 g/g. Antioxidant activities of mayonnaise were significantly increased by RGE content. In texture profile analysis, the cohesiveness, gumminess, and adhesiveness of mayonnaise decreased with the addition of RGE. Mayonnaise with 0% and 25% RGE substitution for egg yolk showed smaller oil droplets and higher viscosity and, therefore, the highest emulsion stability ($p<0.05$). In mayonnaises incorporated with high RGE concentrations (>75%), larger oil droplets increased, and emulsion properties were rapidly weakened. RGE also affected the sensory evaluation of mayonnaise; mayonnaises incorporated with 0% and 25% RGE showed high preference. RGE can be expected to play a positive role as a supplemental emulsifier and may expand the utility of red ginseng.

Keywords saponin, emulsifier, emulsion stability, antioxidant activity, sensory evaluation

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***Corresponding author**
Kwang-Deog Moon
Tel: +82-53-950-5773
E-mail: kdmoon@knu.ac.kr

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1. Introduction

Mayonnaise is a traditional condiment with unique flavor and creamy mouthfeel that is widely used in the world. Mayonnaise is generally manufactured using vegetable oil, egg yolk, vinegar, and other seasonings and is a semi solid emulsion (Sun et al., 2018). Mayonnaise is an oil-in-water (O/W) emulsion system in which oil droplets are distributed in an aqueous phase, and the emulsifier used is amphiphilic, which helps it interact with both phases (Rahmati et al., 2014). Egg yolk play a dominating role as an emulsifier in stability and texture of mayonnaise (Lu et al., 2021). However, egg yolks can be a risk factor for cardiovascular health due to their high cholesterol content (approximately 186 mg cholesterol/egg) (Zhuang et al., 2021). Additionally, eggs are a potentially allergenic food, and the possibility of infection with pathogenic *Salmonella* serovars is a concern (Myers and Ruxton, 2023). Recently, various studies have been conducted to replace egg yolks in mayonnaise due to health concerns. Ail and el Said (2020) developed mayonnaises with significant emulsion properties, antioxidant, and antimicrobial activities by replacing eggs with *Arabic* gum. Kim et al. (2022) utilized ultrasonicated chickpea aquafaba as an egg yolk substitute in plant-based mayonnaise. Choi et al. (2023) introduced a novel approach to developing mayonnaise using pea protein-xanthan gum conjugates prepared through the

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Maillard reaction. Mayonnaise that uses emulsifiers to replace egg yolk needs to consider quality characteristics, such as emulsion stability and texture.

Red ginseng is manufactured by steaming and then drying the washed ginseng (*Panax ginseng* Meyer); its water content is ≤15% and its appearance is red-brown (Hyun et al., 2020). Red ginseng has various biological effects such as antineoplastic, antioxidant, neuroprotection, and antistress (Park et al., 2017). Ginsenosides, saponins of ginseng, are major bioactive components and used as a key index for quality evaluation of ginseng (Piao et al., 2020). The steaming process for red ginseng production has higher pharmacological activities and bioactive components, compared with fresh ginseng (Jin et al., 2015). Saponins have amphiphilic structures with high surface activity (Yang et al., 2013). Therefore, saponins have been used in several industrial fields (food, pharmaceuticals, and cosmetics) due to their biological and physicochemical properties (Schreiner et al., 2021). Red ginseng is classified as a functional food, but its peculiar bitter taste limits its consumption and development as processed foods.

Saponins of red ginseng are known to have excellent functional effects and, interfacial properties, but there is a lack of research on their use as emulsifiers in mayonnaise. This study investigated the feasibility of using red ginseng extract (RGE) as an emulsifier to replace part of the amount of egg yolk in mayonnaise production. Moreover, prepared mayonnaises were compared with traditional mayonnaise in terms of microstructure and quality characteristics, such as emulsion properties, textural properties, and antioxidant activities.

2. Materials and methods

2.1. Materials

Red ginseng (six-year-old and out of grade) provided by local market in Punggi-eup (Gyeongsanbuk-do, Korea) in June 2021 was used. Mayonnaise was prepared using egg yolk (KC Feed Co., Ltd., Yeongcheon, Korea), canola oil (Ottogi Co., Ltd., Anyang, Korea), mustard (Heinz Co., Ltd., Pittsburgh, PA, USA), lemon juice (Polenghi Las Co., Ltd., San Rocco al Porto, Italy), salt (Chungjungone Co., Ltd., Seoul, Korea), and sugar (CJ CheilJedang Co., Seoul, Korea). Reagent-grade methanol, sodium carbonate anhydrous, diethyl ether, *n*-butanol (Duksan Pure Chemicals Co., Ltd., Seoul, Korea), 2,2′-azino-bis-(3-ethylbenzothiazoline-6-sulfonic acid) (ABTS), tannic acid, potassium persulfate (Sigma-Aldrich, St. Louis, MO, USA), 2,2-diphenyl-1-picrylhydrazyl (DPPH; Thermo Fisher Scientific, Waltham, MA, USA), Folin-Ciocalteu phenol reagent (Junsei Chemical Co., Ltd., Tokyo, Japan), sodium dodecyl sulfate (SDS; Biosesang Inc., Seongnam, Korea) and sodium lauryl sulfate (DC Chemical Co., Ltd., Seoul, Korea) were used.

2.2. Preparation of RGE

Red ginseng was washed and then steamed with 2 L of distilled water (DW) in boiling pot (OC-2000R, OCOO, Boryeong, Korea) for 6.5 h at ~112℃ to obtain RGE. RGE was used after boiling and concentrating to obtain a final moisture content of 54.49%, which is similar to the moisture content of egg yolk (54.38%). The proximate composition of RGE was determined by standard methods (AOAC, 2000). Carbohydrate, crude protein, crude fat, and crude ash of RGE were 35.34%, 6.18%, 0.39%, and 3.60%, respectively.

2.2.1. Determination of crude

Crude saponin was measured according to the method of Kim et al. (2024). RGE (6 g) was extracted with 30 mL of 80% methanol at 60℃ for 4 h. The extract was evaporated using a rotary vacuum evaporator (RV 10 digital, IKA, Staufen, Germany), then dissolved in DW (50 mL). The mixture washed twice with diethyl ether (50 mL) to remove fats. After that, aqueous layer was separated by mixing 50 mL of water-saturated *n*-butanol and repeated three times. The resulting *n*-butanol layer was evaporated. The evaporated residue was dried at 105℃ to reach a constant weight. Crude saponin content was calculated as follows:

$$\text{Crude saponin content (mg/g)} = \frac{\text{Weight of flask after drying (mg) - weight of flask (mg)}}{\text{Sample weight (g)}}$$

2.2.2. Determination of total phenolic content (TPC) and antioxidant activities

The TPC, DPPH, and ABTS assays were determined according to the method of Jiang et al. (2021). RGE (10 g) was homogenized in 80% methanol (20 mL), then centrifuged at 7,370 ×*g* at 4℃ for 20 min using a centrifuge (1580MRG, Gyrozen Co., Ltd., Gimpo, Korea). The supernatant, which is the extract, was used in further analyses.

The TPC was analyzed by the Folin-Ciocalteu reagent method. 0.5mL of 50% Folin-Ciocalteu reagent was added to 0.5 mL of diluted extract using 80% methanol, and incubated under a dark condition (15 min). Afterward, 10% sodium carbonate (5 mL) was added to the mixture and incubated for 1 h. The absorbance at 760 nm was measured from a UV-Vis spectrometer (Evolution 201, Thermo Fisher Scientific). The results are expressed as gallic acid equivalent (mg GAE/100 g).

The DPPH radical scavenging activity was determined by adding 0.1 mM DPPH (2 mL) to 0.2 mL of diluted extract using 80% methanol, followed by incubation under the dark condition (30 min). The absorbance at 518 nm measured from a UV-Vis spectrometer(Evolution 201, Thermo Fisher Scientific), and 80% methanol was used as the blank. The DPPH was measured as follows:

$$\text{DPPH radical scavenging activitiy (\%)} = \frac{\text{Absorbance of the extract}}{\text{Absorbance of the blank}} \times 100$$

To measure the ABTS radical scavenging activity, 7.4 mM ABTS (0.5 mL) was mixed with 2.45 mM potassium persulfate (0.5 mL) and incubated under dark condition (14 h) to obtain the ABTS cation radical solution. The solution (980 μL) was added to 20 μL of diluted extract using 80% methanol, and then incubated for 10 min. The absorbance at 734 nm was measured from a UV-Vis spectrometer (Evolution 201, Thermo Fisher Scientific), and 80% methanol was used as the blank. The ABTS was measured as follows:

$$\text{ABTS radical scavenging activity (\%)} = \frac{\text{Absorbance of the blank - absorbance of the extract}}{\text{Absorbance of the blank}} \times 100$$

2.2.3. Determination of physicochemical properties

The pH of RGE was measured with a calibrated pH meter (Orion 3 Star, Thermo Electron, Waltham, MA, USA). The total soluble solids (TSS) content of RGE was determined by a refractometer (Master-α, Atago, Tokyo, Japan). The appearance color testing of RGE was determined using a colorimeter (CR-400, Minolta, Osaka, Japan). Color values (CIE L*, a*, b*) were calibrated by a standard white plate (L*=97.1, a*=0.14, b*=1.82); lightness value (L*), redness value (a*), and yellowness value (b*).

2.2.4. Measurement of water holding capacity (WHC) and oil holding capacity (OHC) of RGE

The WHC and OHC were measured according to the modified methods reported Jiang et al. (2021). 0.5 g of RGE was mixed with DW (5 mL) and then centrifuged at 5,000 ×*g* for 10 min. After removing DW, the WHC value was measured as follows:

$$\text{WHC (g/g)} = \frac{\text{Sample weight after centrifugation (g)}}{\text{Initial sample weight (g)}}$$

The OHC was measured by mixing RGE (0.5 g) with 5 mL of canola oil. After centrifuging the mixture at 5,000 ×*g* for 10 min, excess canola oil was removed. The OHC value was measured as follows:

$$\text{OHC (g/g)} = \frac{\text{Sample weight after centrifugation (g)}}{\text{Initial sample weight (g)}}$$

2.3. Mayonnaise preparation

Mayonnaise was prepared according to the method of Kim et al. (2022), and the mayonnaise formulation is shown in Table 1. All ingredients except canola oil were placed in a measuring cup with a 78 mm diameter and mixed at 14,900 rpm for 10 sec using a hand mixer (HR2535/00, Philips Co., Ltd., Amsterdam, Netherlands). Then, canola oil was added slowly while mixing at 14,900 rpm for 5 min. Each mayonnaise was prepared by replacing different ratios (0%, 25%, 50%, 75%, and 100%) of egg yolk with RGE, and named CONT, RGE25, RGE50, RGE75, and RGE100. The emulsified mayonnaise was stabilized at 4℃ for 24 h before analysis.

2.4. Determination of TPC and antioxidant activities of mayonnaise

The TPC, DPPH, and ABTS assays of mayonnaise were analyzed based on methods described in Section 2.2.2.

2.5. Determination of physicochemical properties of mayonnaise

The pH, TSS, and color values of mayonnaise were

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Table 1. Formula of mayonnaise added with different ratios of egg yolk and red ginseng extract (RGE)

Ingredients (g)	Samples				
	CONT[1)]	RGE25[2)]	RGE50	RGE75	RGE100
Canola oil	120	120	120	120	120
Egg yolk	20	15	10	5	0
RGE	0	5	10	15	20
Mustard sauce	5	5	5	5	5
Lemon juice	10	10	10	10	10
Salt	1.5	1.5	1.5	1.5	1.5
Sugar	2	2	2	2	2

[1)]CONT stands for mayonnaise prepared egg yolk.
[2)]RGE25, RGE50, RGE75, and RGE100 stand for mayonnaise added with 25%, 50%, 70%, and 100% of RGE for egg yolk weight basis of CONT.

measured according to the methods described in Section 2.2.3. Texture profile analysis (TPA) was determined with a rheometer (Compact-II, Scientific, Tokyo, Japan). Mayonnaise placed in 100 mL beaker was measured by a two-bite compression test at room temperature (25℃). TPA complied with the following parameters: cylindrical probe of 20 mm, loadcell of 2 kgf, pre-test speed of 2 mm/sec, test and post-test speed of 1 mm/sec, compression distance of 10 mm, and clearance of 15 mm. The cohesiveness, gumminess, and adhesiveness (negative area) obtained from the force-distance curve were analyzed using the RDS40 software (Sunscientific, Tokyo, Japan).

2.6. Visual evaluation and optical microscopy of mayonnaise

A visual evaluation was performed by studio photo box (Shenzhen Puluz Technology, Guangdong, China) after filling 30 g of mayonnaise into a Petri dish (50 mm diameter, 15 mm height) without leaving any empty space. The microstructure was observed by optical microscope (IN300TC-FL, AmScope, Irvine, CA, USA). A drop of mayonnaise was placed on a microscope slide and covered with a coverslip. Micrographs were taken at ×200 magnification.

2.7. Viscosity of mayonnaise

Viscosity was analyzed using a rotational rheometer (HR-10, TA Instruments, New Castle, DE, USA). A plate-plate system with a diameter of 20 mm was used, and the gap was 1,000 μm. Viscosity was determined within shear rate range from 0.01 to 100 sec^{-1} at a test temperature of 4℃ (soak time 180 sec). The *x*- and *y*-axes of the graph are shown on a logarithmic scale.

2.8. Emulsion properties of mayonnaise

The emulsion stability index (ESI) was determined according to the modified method described by Drozłowska et al. (2020). 20 mg of mayonnaise was mixed with 0.1% SDS solution (20 mg) by vortexing for 10 sec. The absorbance at 500 nm was determined from a UV-Vis spectrometer (Evolution 201, Thermo Fisher Scientific), and 0.1% SDS solution was used as the blank. The absorbance values were measured at 0 and 10 min, respectively. The ESI was measured as follows:

$$\text{ESI (min)} = \frac{\text{Absorbance after 0 min}}{\text{Absorbance after 0 min - absorbance after 10 min}} \times 10$$

The heat stability index (HIS) was measured and calculated according to the ESI method after heating mayonnaise using a water bath (80℃ for 30 min) and then cooling.

2.9. Sensory evaluation of mayonnaise

The sensory evaluation was conducted with students (3 males and 17 females) from Kyungpook National University (KNU). Mayonnaise was rated using a 7-point scale (low points=bad or weak, and high points=good or strong) on appearance, smell, taste, texture, oily taste, bitterness, darkness, and overall acceptability. This sensory evaluation was safely conducted after receiving the exemption approval (No. KNU-2024-0011) from the KNU Institutional Review Board (IRB).

2.10. Statistical analysis

All experimental data were processed by ANOVA and Duncan's multiple range tests using the SPSS software package (Version 26; SPSS Inc., IL, USA). All statistical analyses were conducted at least in triplicate and the data were presented as the mean±standard deviation (SD), and differences were considered to be significant ($p<0.05$).

3. Results and discussion

3.1. Quality characteristics of RGE

Table 2 shows the crude saponin content, TPC, DPPH, ABTS, pH, TSS, color values, WHC, and OHC of RGE. The crude saponin content of RGE was 17.51 mg/g. Kim et al. (2022) reported that crude saponin content of the lowest-grade red ginseng was significantly high at 51.52 mg/g. We used the lowest grade of red ginseng for efficient saponin fractionation and the saponin of RGE was fractionated some part of red ginseng. Red ginseng shows more pharmacological effects than raw ginseng; in particular, antioxidant activity is high (Kim et al., 2019). The TPC, DPPH, and ABTS of RGE were confirmed to be 1,375.78 mg/g, 80.77%, and 99.23%, respectively. The pH, TSS, and color values of RGE can affect the quality characteristics of mayonnaise. RGE was strongly acidic with a pH of 4.5. TSS was 46.33 °Brix, and RGE was composed mostly of carbohydrates (35.34%). The L*, a*, and b* of RGE were 27.38, 0.74, and 2.51, respectively. Compared with the color values of red ginseng (L*=43.88, a*=8.56, b*=27.46) reported by Kim et al. (2022), RGE showed lower lightness, redness, and yellowness. WHC and OHC reflect the abilities of a material to retain water and oil under external forces, respectively (Wang et al., 2015). WHC and OHC of RGE were 0.21 and 1.82 g/g, respectively. According to Yang et al. (2023), suspensions prepared with soybean hull samples exhibiting higher WHC and OHC values demonstrated improved emulsion stability. These results confirm the potential of RGE as an emulsifier due to its ability to trap both water and oil. Saponins are surface-active components that are composed of one or more hydrophilic sugar moieties covalently bound to a hydrophobic triterpene or steroid backbone (Zhu et al., 2019). Therefore, we performed further analyses of mayonnaise incorporated with RGE after confirming the possibility of RGE as an emulsifier.

3.2. TPC and antioxidant activities of mayonnaise

The TPC, DPPH, and ABTS of mayonnaise developed with up to 100% egg yolk substitution by RGE are shown in Fig. 1. Major phenolic compounds found in red ginseng include maltol, salicylic acid, and vanillic acid (Hyun et al., 2020). The TPC of mayonnaise tended to increase as the RGE content increased (Fig. 1A). Lee et al. (2016) reported that the phenol content and antioxidant activity of RGE were linearly correlated. Antioxidant activities, DPPH (Fig. 1B) and ABTS (Fig. 1C), significantly increased with the increase in RGE content ($p<0.05$). As the RGE content increased and the egg yolk content decreased, the free radical scavenging significantly increased, indicating higher antioxidant activity. Similarly, Park et al. (2018) reported that the addition of RGE increased the TPC and antioxidant activities of dairy products. Increasing the intake of foods rich in natural antioxidants is known to lower risks of particularly cardiovascular diseases, degenerative diseases, and cancer (Pérez-Jiménez et al., 2008).

3.3. Physicochemical properties of mayonnaise

The physicochemical properties of mayonnaise added with

Table 2. Quality characteristics of red ginseng extract (RGE)

Sample	Crude saponin (mg/g)	TPC[1] (mg/g)	DPPH (%)	ABTS (%)	pH	TSS (°Brix)	Color values			WHC (g/g)	OHC (g/g)
							L*	a*	b*		
RGE	17.51 ±2.77[2]	1,375.78 ±7.38	80.77 ±0.87	99.23 ±0.13	4.50 ±0.01	46.33 ±0.29	27.38 ±0.25	0.74 ±0.09	2.51 ±0.04	0.21 ±0.01	1.82 ±0.04

[1]TPC stands for total phenolic content; TTS stands for total soluble solids; WHC stands for water holding capacity; OHC stands for oil holding capacity.
[2]All values are mean±SD (n=3).

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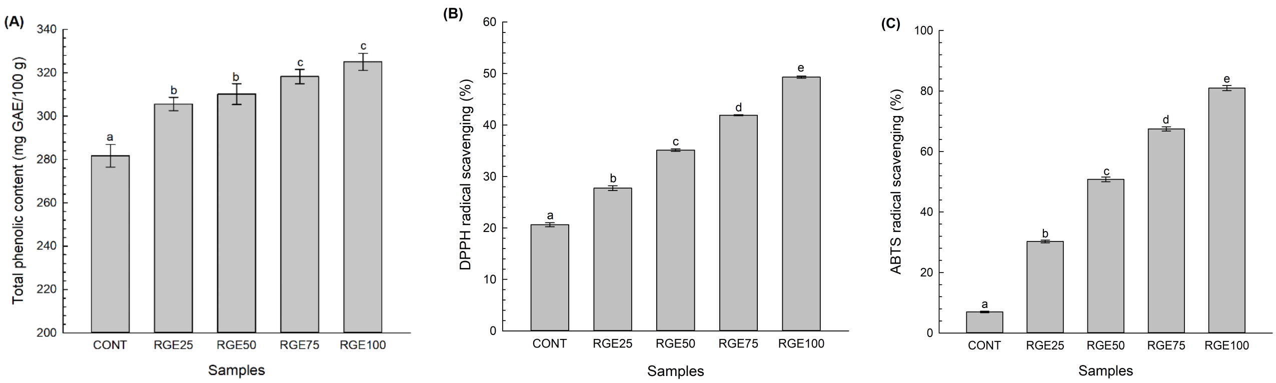

Fig. 1. Total phenolic content (A), DPPH radical scavenging (B), and ABTS radical scavenging (C) of mayonnaise added with different ratios of egg yolk and red ginseng extract (RGE). Different superscript letters on the bars indicate significant differences (p<0.05) between values.

different ratios of egg yolk and RGE are presented in Table 3. The emulsion structure of mayonnaise is affected by pH, and the stability and viscoelasticity of mayonnaise are enhanced when pH value reaches egg yolk's isoelectric point (IEP) of 5.7 (Mirzanajafi-Zanjani et al., 2019). The pH of CONT was the lowest at 3.35 and showed a tendency to increase with the increased in RGE content, but there was no significant difference. These results indicate that pH value of mayonnaise increased by pH 4.5 of RGE, which may affect the emulsion structure of mayonnaise. In addition, mayonnaises with RGE added, except for RGE100, is expected to be closer to the IEP of egg yolk, contributing to the stability of mayonnaise. CONT and RGE25 had the significantly highest TSS, and TSS tended to decrease as RGE increased (p<0.05). The L*, a*, b* color values of CONT were 85.27, -6.06, and 32.23, respectively. By adding RGE, the color values of mayonnaise tended to decreased in L* and b*, while a* increased. During the steaming and drying process, red ginseng takes on a dark reddish-black color due to the Maillard reaction (Jin et al., 2015). The bright yellow appearance of traditional mayonnaise showed a color change due to the addition of RGE, which may contribute to the sensory quality of mayonnaise. Cohesiveness refers to strength of internal bonds within foods and how deformed it can be before disruption (Raikos et al., 2020). Cohesiveness values were significantly high for CONT, RGE25, and RGE50, and the lowest for RGE75 and RGE100. Gumminess is the force required to break down a semi solid product into particles suitable for swallowing; therefore, higher hardness tends to mean higher gumminess (Rahman et al., 2021). The gumminess and adhesiveness of mayonnaise decreased according to the addition level of RGE (p<0.05). Similarly, Drozłowska et al. (2020) reported a

Table 3. Physicochemical properties of mayonnaise added with different ratios of egg yolk and red ginseng extract (RGE)

Samples	pH	TSS[5] (°Brix)	Color values			Cohesiveness (%)	Gumminess (gf)	Adhesiveness (gf)
			L*	a*	b*			
CONT[1]	3.35±0.02[3)a4)]	66.33±0.58[d]	85.27±0.02[e]	-6.06±0.02[a]	32.23±0.06[e]	108.33±0.55[b]	29.60±0.63[e]	-17.00±1.00[e]
RGE25[2]	3.40±0.03[ab]	65.67±0.29[d]	75.07±0.02[d]	-0.98±0.01[b]	27.93±0.03[c]	107.33±1.87[b]	19.67±1.17[d]	-11.00±0.00[d]
RGE50	3.41±0.05[ab]	63.83±0.29[c]	68.16±0.04[c]	0.02±1.38[c]	27.75±0.02[b]	106.77±0.96[b]	14.59±1.13[c]	-8.33±0.58[c]
RGE75	3.39±0.02[ab]	59.33±0.58[b]	60.42±0.02[b]	3.59±0.02[d]	28.21±0.01[d]	103.30±0.46[a]	8.26±0.04[b]	-5.00±0.00[b]
RGE100	3.44±0.05[b]	53.67±0.29[a]	49.42±0.01[a]	5.75±0.03[e]	25.33±0.03[a]	104.20±0.89[a]	6.25±0.06[a]	-4.00±0.00[a]

[1)]CONT stands for mayonnaise prepared egg yolk.
[2)]RGE25, RGE50, RGE75, and RGE100 stand for mayonnaise added with 25%, 50%, 70%, and 100% of RGE for egg yolk weight basis of CONT.
[3)]All values are mean±SD (n=3).
[4)]Different superscript letters indicate significant differences (p<0.05) between values in the same column.
[5)]TSS stands for total soluble solids.

decrease in the cohesiveness, gumminess, and adhesiveness of mayonnaise with increasing flaxseed meal extract. Changes in the texture of mayonnaise caused by RGE may affect consumer preference.

3.4. Visual evaluation and optical microscopy of mayonnaise

Photographs and microstructure of mayonnaise prepared with different ratios of egg yolk and RGE are shown in Fig. 2. Visual appearance of CONT showed a bright yellow color, and the mayonnaise was confirmed to be increasingly dark reddish-black color as the content of RGE increased. These results supported the instrumental color values (Table 3). In addition to the distribution of the fat phase, the size of the droplets and their interaction affect the texture and stability of the mayonnaise (Di Mattia et al., 2015). All mayonnaises prepared in this study were revealed to consist of spherical oil droplets densely dispersed in an aqueous phase. CONT and RGE25 had finely distributed, relatively small oil droplets, whereas the oil droplets tended to be larger depending on RGE content. The oil droplets in mayonnaise increased rapidly from the 75% RGE to 100% RGE ratio. Similarly, Wang et al. (2022) reported that the droplet size of mayonnaise gradually increased as soybean oil body was added instead of egg yolk. The increased size of the oil droplets due to RGE addition can affect the rheological property and stability of mayonnaise.

3.5. Viscosity of mayonnaise

The viscosity results of mayonnaise formulated with different ratios of egg yolk and RGE are presented in Fig. 3A. Mayonnaise is a semisolid food that exhibits pseudoplastic

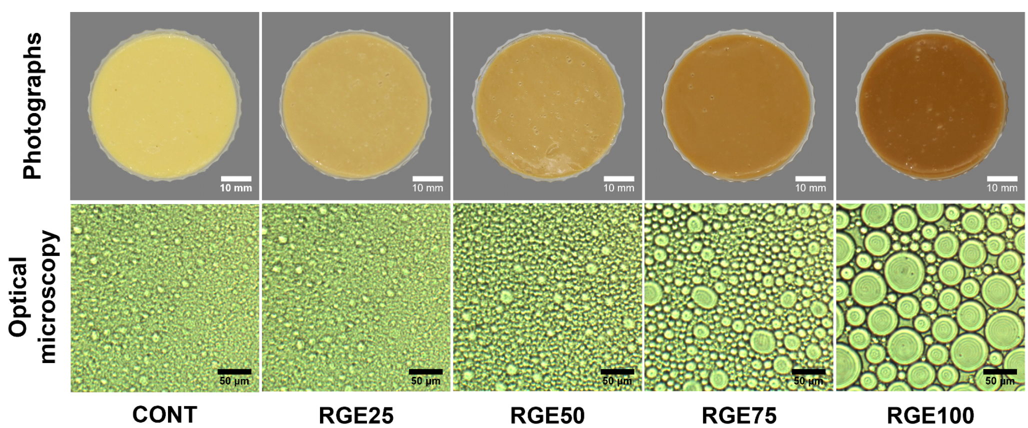

Fig. 2. Photographs and optical microscopy (magnification ×200) of mayonnaise added with different ratios of egg yolk and red ginseng extract (RGE).

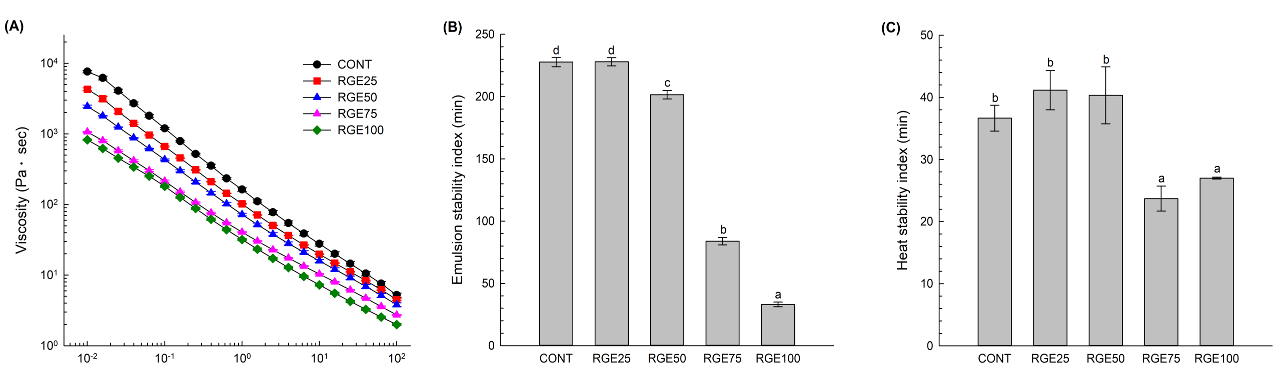

Fig. 3. Viscosity (A), emulsion stability index (B), and heat stability index (C) of mayonnaise added with different ratios of egg yolk and red ginseng extract (RGE). Different superscript letters on the bars indicate a significant difference ($p<0.05$) between values.

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behavior (Olsson et al., 2018). In all mayonnaises, viscosity decreased significantly with increasing shear rate, indicating shear-thinning. This shear-thinning behavior may be associated with deformation and disruption of aggregated droplets depending on shear rate (Heggset et al., 2020). Within the measured shear rate range, the viscosity of mayonnaise decreased with increasing RGE content, which could be because of the different microstructures of the mayonnaise (Fig. 2). Katsaros et al. (2020) reported that the apparent viscosity of mayonnaise decreased as the droplet size increased.

3.6. Emulsion properties of mayonnaise

The quality of mayonnaise, an emulsified food, depends on the emulsion stability, which is affected by content and type of emulsifier and temperature change (Kim et al., 2022). CONT and RGE25 displayed the significantly highest ESI values, followed by RGE50, RGE75, and RGE100 ($p<0.05$) (Fig. 3B). RGE75 and RGE100 exhibited ESI values of 83.83 and 33.11 min, respectively, showing an acute decrease between them. Various factors affect the emulsion stability of mayonnaise, such as the particle size of oil droplet and viscosity of emulsion (Kumar et al., 2021). CONT and RGE25 had high viscosity due to their microstructure of small oil droplets, which resulted in the highest emulsion stability. Saponins are water-soluble small amphophilic molecules (Ozturk and McClements, 2016), and therefore RGE can be considered an emulsifier containing 17.51 mg/g of saponin. A higher proportion of RGE than egg yolk sharply reduced the emulsion stability of mayonnaise, and proper REG content should be considered for high-stability mayonnaise. The emulsion stability of all mayonnaises was decreased by high temperature (80℃), and the HIS values tended to be significantly higher in CONT, RGE25, and RGE50 among the five formulations (Fig. 3C). RGE75 and RGE100 exhibited the least high-temperature resistance. Mayonnaises with smaller oil droplets and higher viscosity had higher HIS values. Ralla et al. (2017) reported that heating to 90℃ did not increase particle size in saponin-stabilized emulsions. High HIS values in RGE25 and RGE50 are considered to be due to the high-temperature resistance of saponin-stabilized emulsions.

3.7. Sensory evaluation of mayonnaise

The sensory evaluation of mayonnaise with different ratios of egg yolk and RGE is shown in Table 4. Appearance scores of CONT and RGE25 were significantly higher. Appearance scores of mayonnaises containing RGE tended to decrease by RGE content. The intensity of darkness showed higher scores as RGE content increased. These results can be confirmed in the color values (Table 3) and visual appearance (Fig. 2) of mayonnaise with RGE addition. Appearance preferences are considered to have been influenced by color of mayonnaise. Smell preference did not show significant differences between mayonnaises, indicating that RGE did not affect mayonnaise smell. Taste scores were significantly higher in CONT, RGE25, and RGE50, while RGE75 and RGE100 showed low scores. The intensity of oily taste did not appear difference between mayonnaise ($p>0.05$), and the intensity of bitterness showed a tendency to increase by RGE content. The bitter taste in ginseng is considered as a factor that affects consumer's acceptance and utilization of ginseng in food products (Chung

Table 4. Sensory evaluation scores of mayonnaise added with different ratios of egg yolk and red ginseng extract (RGE)

Samples	Appearance[5)]	Smell	Taste	Texture	Oily taste	Bitterness	Darkness	Overall acceptability
CONT[1)]	6.10±1.12[3)c4)]	5.15±1.23[a]	5.25±1.37[c]	5.65±1.23[c]	4.20±1.58[a]	2.00±0.86[a]	2.30±0.98[a]	5.60±1.23[c]
RGE25[2)]	5.50±1.05[c]	4.95±1.19[a]	5.10±1.12[c]	5.55±1.00[c]	4.10±1.52[a]	2.50±0.89[a]	3.15±0.99[b]	5.40±0.99[c]
RGE50	4.65±0.99[b]	4.90±1.12[a]	4.60±1.50[bc]	4.80±0.95[b]	4.05±1.54[a]	3.35±1.42[b]	4.55±0.83[c]	4.55±1.36[b]
RGE75	3.25±0.91[a]	4.75±1.21[a]	3.95±1.15[ab]	4.00±1.21[a]	3.95±1.70[a]	3.90±1.48[b]	5.55±1.05[d]	4.05±1.10[b]
RGE100	2.80±0.89[a]	4.35±1.18[a]	3.35±1.09[a]	3.70±1.26[a]	3.75±1.77[a]	4.85±1.50[c]	6.45±0.94[e]	3.05±0.94[a]

[1)]CONT stands for mayonnaise prepared egg yolk.
[2)]RGE25, RGE50, RGE75, and RGE100 stand for mayonnaise added with 25%, 50%, 70%, and 100% of RGE for egg yolk weight basis of CONT.
[3)]All values are mean±SD (n=20).
[4)]Different superscript letters indicate significant differences ($p<0.05$) between values in the same column.
[5)]Rating scale (score): 1 (bad) ↔ 7 (good) for appearance, smell, taste, texture, and overall acceptability; Rating scale (score): 1 (weak) ↔ 7 (strong) for oily taste, bitterness, and darkness.

et al., 2011). Therefore, taste preferences of mayonnaise with added RGE are considered to have been influenced by bitterness of RGE. Texture preference showed the highest scores in CONT and RGE25 ($p<0.05$), and texture preference decreased by RGE content. As can be seen in Table 3, mayonnaise with low cohesiveness, gumminess, and adhesiveness had lower texture preference. Overall acceptability scores were significantly higher in CONT and RGE25, and the score tended to decrease according to RGE content. RGE25 showed high preference along with CONT in the sensory evaluation, the utilization of RGE in mayonnaise is expected.

4. Conclusions

This study demonstrated the potential of RGE as an emulsifier and developed a mayonnaise with egg yolk replacement by RGE. RGE extracted from red ginseng (out of grade) contained saponin and showed WHC and OHC. RGE had excellent TPC and antioxidant activities, which led to the high free radical scavenging activity (DPPH and ABTS) of mayonnaise added with RGE. CONT exhibited small oil droplets in the microstructure and displayed shear-thinning behavior with high viscosity. RGE25 had a similar microstructure and viscosity to CONT, which resulted in high emulsion stability. However, a higher proportion of RGE than egg yolk resulted in lower emulsion properties of mayonnaise. In addition, a high ratio of RGE changed the color of mayonnaise from bright yellow to reddish-black and reduced the cohesiveness, gumminess, and adhesiveness of mayonnaise. The darkness, bitterness, and textural properties of mayonnaise added with RGE affected the appearance, taste, and textural properties, respectively. RGE25 was evaluated as highly preferred along with CONT. Therefore, the appropriate addition of RGE as an alternative emulsifier in egg yolk-reduced mayonnaise with emulsion stability can improve the health profile of this popular sauce. Further studies are needed to investigate the oxidation and storage stability of mayonnaise added with RGE.

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Conflict of interests

The authors declare no potential conflicts of interest.

Author contributions

Conceptualization: Kim JS, Moon KD. Methodology: Kim JS, Nam I. Formal analysis: Kim JS, Kim JY. Nam I. Validation: Kim JS, Kim JY. Lim JH. Writing - original draft: Kim JS, Kim SH, Seo YM. Writing - review & editing: Kim JS, Kim JY, Moon KD.

Ethics approval

This research was approved by IRB from the Kyungpook National University (approval No. KNU-2024-0011).

ORCID

Jung Soo Kim (First author)
https://orcid.org/0000-0002-2952-1067
Jiyoon Kim
https://orcid.org/0000-0002-7995-360X
Inju Nam
https://orcid.org/0000-0001-6300-9107
Soo Hyun Kim
https://orcid.org/0000-0002-7973-5100
Yu Min Seo
https://orcid.org/0009-0003-8988-3961
Jeong-Ho Lim
https://orcid.org/0000-0002-4806-2046
Kwang-Deog Moon (Corresponding author)
https://orcid.org/0000-0001-5277-3345

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