Feasibility of elder-friendly food applications of lingonberry (Vaccinium vitis-idaea L.) according to gelling agent as thickening additives

Dah-Sol Kim, Fumiko Iida, and Nami Joo

Department of Food and Nutrition, Japan Women’s University, Tokyo, Japan; Department of Food and Nutrition, Sookmyung Women’s University, Seoul, South Korea

ABSTRACT
The purpose of this study was to find nutritional composition of lingonberry and evaluate whether the liquid formulation of lingonberry juice according to gelling agent as thickening additives is applicable as an elder-friendly food. As a result, lingonberry comprised different kinds of nutrients and bioactive materials, as well as beneficial minerals and essential fatty acids, and contained antioxidative and antidiabetic abilities. These results suggest that lingonberry is an excellent health functional food especially suitable for the elderly. Considering the third level of the Korean Industrial Standards (viscosity ≤ 1,500 mPa s), samples added with guar gum 0.341%, xanthan gum 0.596%, and locust bean gum 0.384% are expected to have an appropriate viscosity to help the elderly with dysphagia. In addition, these gelling agents will help the elderly balance nutrition by allowing them to consume better lingonberry juice with high bioactive substances. In particular, among the three gelling agents used in this study, guar gum was found to be easy to adjust its viscosity even with a small amount, which is expected to be particularly helpful economically. These results are important in predicting the desired properties for administration to the elderly with dysphagia who will benefit the most from this formulation. By controlling the formulation parameter with the thickening agent, it is possible to easily produce a formulation having a viscosity suitable for the elderly. In conclusion, the findings of this study strongly suggest that the elderly’s food product industry should consider manufacturing liquid gel formulations because it could provide positive health benefit to elderly consumers with dysphagia. Whereas, since this research did not conduct sensory evaluation on the elderly subject to be actually consumed for the final developed product, further studies related to this is expected to be necessary for the elderly’s food product industry in the future.

ARTICLE HISTORY
Received 16 May 2022
Accepted 07 August 2022

KEYWORDS
Lingonberry; Antioxidant; Elder-friendly food; Viscosity; Thickening agent; dysphagia

Introduction
Lingonberry (Vaccinium vitis-idaea L.) gains significant importance in human diet for that rich source of vitamin C, essential fatty acids (FAs), and polyphenolic compounds conferring health benefits. In lingonberries, 63 ~ 71% of the total phenolic compounds is pro-anthocyanidin, which can defend against plant pathogens. Anthocyanin, which contribute to the red color of lingonberries, is one of the valuable phytochemicals showing protective effect against damage caused by radiation. Also, flavanols, which is one of the polyphenolic compounds in lingonberry, show antioxidative, anti-inflammatory, antibacterial, antiviral, antitumor, and vasoprotective activities. Furthermore, lingonberry has high content of resveratrol which are strong antioxidants with cancer chemopreventive activities, and they even help to reduce...
the threat of heart disease. Besides, lingonberries have advantages such as reducing cholesterol levels and treating kidney and bladder infections, stomach disorders, and rheumatic diseases, and lingonberry with these advantages can be used in juices, wines, pastries, jams, jellies, ice creams, and so on.[3]

According to previous studies,leri et al.[3] mentioned that lingonberry juice is the easiest to consume and helpful in protecting against urinary tract infection, and it possesses anti-inflammatory effects that protect the kidneys from ischemic-reperfusion injury. However, non-viscosity juice in the elderly can go down the wrong pipe, so moderate viscosity is required. In other words, liquid formulation is crucial for specific populations, such as the elderly with dysphagia who commonly have difficulties in swallowing. Thus, increasing the viscosity is widely practiced as a strategy for the management of dysphagia. High-viscosity liquids are frequently recommended reducing the risk of airway inversion and to increase the swallowing safety by reducing the swallowing velocity.[4] As such, the design of a special formulation of food for the elderly is now one of the most important tasks in Korean food industry. Accordingly, the Ministry of Food and Rural Affairs in Korea has quantified information on the hardness of chewable foods for the elderly in three levels,[5] and defined that as the Korean Industrial Standards (KS), classifying the first stage as chewing with teeth, the second stage as a chewing with gum, and the third stage as chewing with tongue. In addition, considering the physical characteristics of the elderly corresponding to the third stage, the appropriate viscosity (≤ 1,500 mPa.s) was quantified considering not only the difficulty of chewing but also the difficulty of swallowing. In other words, it reflected the fact that muscle weakness due to aging also affects the esophagus which can cause choking when drinking non-viscous beverages such as water or tea. Through the preparation of these standards, the government has attempted to expand various elder-friendly food industries, and supports further subdivision of the standards in consideration of various physical characteristics of the elderly. Therefore, recent research progress on the design of special food for the elderly from an industrial perspective, focusing on liquid food and viscosity using gelling agents.

Recently, gelling agents with different viscosities have been developed as potential age-appropriate consumption forms for the elderly with dysphagia. The gelling agents developed have good physico-chemical properties, with a nectar and honey consistency and a similar dissolution profile to marketed suspension. Gelling agents have been shown to be suitable as thickened liquids that the higher viscosity of gelling agents provides an advantage in swallowing, taste masking, and stability, and it reduces the risk of aspiration or choking.[6] Thus, this study evaluated the applicability of liquid formulations of lingonberry juice according to gelling agents to food for the elderly, and it provides a preliminary insight into the swallowability of gelling agents as thickening additives. This knowledge is important for predicting the desired properties of liquid formulations for their administration to targeted populations, such as the elderly with dysphagia, who will benefit most from this formulation.

Materials and methods

Sample preparation

Lingonberry juice as sample, extracted from wild lingonberries from northern Sweden, was purchased (Hafl, Hallands Fruktindustri AB, Sweden). For this study, lingonberry juice (300 g), oligosaccharide (60 g; added for the balance between sour and sweet), and each gelling agent (guar gum, xanthan gum, and locust bean gum; added 1% (3 g) ~ 9% (27 g) of lingonberry juice weight) were mixed for 3 minutes at 37°C. Oligosaccharide was produced by CJ Corp. (Seoul, Korea), and gelling agent was produced by ESFood (Gyeonggi-do, Korea). All these experiments were performed in three runs with whole the three treatments studied in each run.

Analysis of fatty acid profiles

Lingonberry (= 20 mg) was saponified with 0.5 N methanolic NaOH (3 mL) at 85°C for 10 minutes and cooled to room temperature.[7] After cooling, isooctane (3 mL) and saturated NaCl solution
(5 mL) was added. The upper isoctane layer containing the fatty acid (FA) methyl esters was then collected and passed through an anhydrous Na$_2$SO$_4$ column. The FA methyl esters were analyzed by gas–liquid chromatography using a gas chromatograph (Agilent technologies 7890-A, Palo Alto, CA, USA), equipped with a flame ionization detector and a fused silica capillary column (100 m × 0.25 mm i.d. × 0.2 μm film thickness; Supelco SP-2560, Bellefonte, PA, USA). Helium, at a flow rate of 1 mL min$^{-1}$, was used as the carrier gas. The injector and detector temperatures were maintained at 225 and 285°C, respectively. The oven temperature was initially held at 100°C for 4 minutes before increasing to 240°C at a rate of 3°C min$^{-1}$, after which the temperature was held at 240°C for 17 minutes.

**Analysis of mineral profiles**

Lingonberry (0.7 g) was weighed into a Teflon digestion flask, added by 10 mL of nitric acid and 3 mL of 30% hydrogen peroxide.$^8$ Digestion was performed in two steps, using 1000 W power at a maximum temperature of 200°C. After that, it was cooled at room temperature and the content was transferred to a 25 mL volumetric flask with 5% HCl solution (v/v). The mineral elements were quantified by inductively coupled plasma optical emission spectrometer (ICP-OES; Vista MPX, Varian, Mulgrave, Australia) equipped with radio frequency source of 40 MHz, charge coupled devices (CCD) simultaneous solid state detector, peristaltic pump, sea-spray nebulizer connected to cyclonic spray chamber, and high-purity argon (Ar; 99.996% air liquid). The system was controlled by ICP-OES Expert software: 1000 W of forward power, 1.5 L min$^{-1}$ of auxiliary Ar flow, 0.9 L min$^{-1}$ of nebulizer Ar flow, 15 L min$^{-1}$ of cooling Ar flow rate, 2 points of background correction, 10 seconds of integration and reading time, and 3 of replicate number. The analytical line wavelengths were 317.9 nm of calcium (Ca), 324.8 nm of copper (Cu), 234.4 nm of iron (Fe), 766.5 nm of potassium (K), 280.3 nm of magnesium (Mg), 589 nm of sodium (Na), 213.6 nm of phosphorus (P), 196 nm of selenium (Se), and 206.2 nm of zinc (Zn).

**Analysis of antioxidant effects**

*Total polyphenol content*: 40 μL of lingonberry and 800 μL of a 10-fold diluted folin ciocalteau reagent was added into a 10 mL screw cap tube and mixed well.$^5$ The tube was allowed to stand for 5 minutes. Then, 800 μL of 7% sodium carbonate aqueous solution (w/v) was added to the tube and mixed well. The volume in the tube was made up with nano pure water (360 μL), mixed well, and then allowed to stand for 2 hours at room temperature. Absorbance was read at 760 nm against the blank using a UV visible spectrophotometer (T60UV, PG instruments Ltd., Lutterworth, UK).

*Total flavonoid content*: 0.5 mL of lingonberry was briefly mixed with 1.5 mL of 95% ethanol, 0.1 mL of 10% aluminum chloride hexahydrate, 0.1 mL of 1 M potassium acetate, and 2.8 mL of deionized water (DW).$^5$ After incubation at room temperature for 40 minutes, the absorbance of the mixture was measured at 415 nm against a DW blank on a UV visible spectrophotometer (T60UV, PG instruments Ltd., Lutterworth, UK).

*Superoxide radical scavenging activity*: The former comprised a solution of 100 μM xanthine, 60 μM NBT in 0.1 M phosphate buffer (pH 7.4) and 0.07 U/mL xanthine oxidase in a total volume of 1 mL.$^9$ Then, 0.025 mL of lingonberry was added and this mixture was incubated at 25°C for 10 minutes. The optical density was read at 560 nm against a blank without the enzyme using a UV visible spectrophotometer (T60UV, PG instruments Ltd., Lutterworth, UK).

*DPPH radical scavenging ability*: 50 μL of lingonberry was placed in a cuvette, and 2 mL of 6 × 10$^{-5}$ M ethanolic solution of 2,2-diphenyl-1-picrylhydrazyl (DPPH) was added.$^5$ Absorbance measurements commenced immediately. Then, the decrease in absorbance at 515 nm was determined by UV visible spectrophotometer (T60UV, PG instruments Ltd., Lutterworth, UK) after 1 hour. The absorbance of the DPPH radical without antioxidant, i.e., the control, was measured daily, and which the percentage inhibition was calculated. The IC$_{50}$ value represented the concentration of lingonberry that caused 50% inhibition.
**ABTS radical scavenging activity:** 1 mL of the reaction mixture contained 10 μL lingonberries, 20 μL solution of myoglobin, 150 μL ABTS reagent (10 mM ABTS and 25 μL 3% H₂O₂). Then, the mixture was kept at room temperature in the dark, and after 10 minutes the optical density was measured at 405 nm using a UV visible spectrophotometer (T60UV, PG instruments Ltd., Lutterworth, UK).

**Ferric reducing antioxidant power:** Working the ferric reducing ability of plasma (FRAP) reagent was prepared by mixing 25 mL acetate buffer, 2.5 mL 2,4,6-Tris(2-pyridyl)-s-triazine solution, and 2.5 mL ferric chloride solution. Then, 300 μL freshly prepared FRAP reagent was warmed at 37°C, and 10 μL of lingonberry was added, along with 30 μL DW. Absorbance readings were taken after 4 minutes at 593 nm using a UV visible spectrophotometer (T60UV, PG instruments Ltd., Lutterworth, UK).

**Reducing power:** Lingonberry was mixed with 2.5 mL of 200 mM sodium phosphate buffer (pH 6.6) and 2.5 mL of 1% potassium ferricyanide, and the mixture was incubated at 50°C for 20 minutes. After, 2.5 mL of 10% trichloroacetic acid was added, and the mixture was centrifuged at 650 rpm for 10 minutes. The upper layer (2.5 mL) was mixed with 2.5 mL of DW, and 0.5 mL of 0.1% ferric chloride and absorbance was measured at 700 nm using a UV visible spectrophotometer (T60UV, PG instruments Ltd., Lutterworth, UK). Higher absorbance indicates higher reducing power.

### Analysis of antidiabetes effects

**α–Glucosidase inhibitory activity:** The enzyme solution was prepared by dissolving 1 mg of α-glucosidase in 100 mL of a phosphate buffer (pH 7), and 1 mL of the enzyme solution was diluted 25 times with a phosphate buffer (pH 7) before use. The reaction solution was prepared by mixing 25 μL of 10 mM p-nitrophenyl-D-glucopyranose as substrate and 50 μL of a 100 mM phosphate buffer (pH 7), and lingonberry (10 μL) was added to the reaction solution at a final concentration of 50, 100, 200, 500, 1000, 5000, 7500, and 10,000 μg/mL. A 1% acarbose was prepared with a phosphate buffer (pH 7), mixed with 2 N HCl of equal volume (1:1), and centrifuged to obtain a supernatant (10 μL). The supernatant was added to the lingonberry mixture at a final concentration of 0.1, 0.5, 1, 5, and 10 μg/mL, pre-incubated at 37°C for 5 minutes, and then 25 μL of the enzyme solution was added to each mixture and further incubated for 15 minutes. The enzyme reaction was stopped by adding 100 μL of 200 mM Na₂CO₃. Acarbose was used as the control, and it was carried out in the same method as above. Absorbance was measured by UV visible spectrophotometer (T60UV, PG instruments Ltd., Lutterworth, UK) at 400 nm, and the percent of α–glucosidase inhibition was calculated using the following formula.

\[
% \text{ of inhibition} = \frac{\text{Absorbance of control} - \text{Absorbance of sample}}{\text{Absorbance of control}} \times 100
\]

The inhibitory activity of each mixture for α-glucosidase was calculated from the concentration that inhibiting 50% of enzyme activity (IC₅₀).

**α–Amylase inhibitory activity:** The reaction mixture was mixed with 10 μL of different concentrations of lingonberry (final concentration of 0.05 to 11.00 mM), 10 μL of 0.05 mg/mL amylose, and 10 μL of 0.05 mg/mL of α-amylase in 20 mM sodium phosphate buffer (pH 6.8). This reaction mixture was pre-incubated at 37°C for 30 minutes and then the reaction was stopped in boiling water for 5 minutes. Next, 100 μL of the couple enzyme (peroxidase-glucose oxidase enzyme) and 100 μL of 2,2′-azino-bis-3- ethylenbenzthiazoline-6-sulfonic acid were added, and then incubated at 37°C for 30 minutes. Absorbance was measured by UV visible spectrophotometry (T60UV, PG instruments Ltd., Lutterworth, UK) at 475 nm. The percent of α-amylase inhibition was calculated using the aforementioned equation. IC₅₀ values were also calculated in the same way as for α-glucosidase.

### Analysis of viscosity

The viscosity was determined by using a rotational viscometer (VR-3000, model-L) at 37°C with a L-3 spindle rotation of 50 rpm. If it is faster than 50 rpm, the spindle may not rotate properly due to
viscosity, and if it is slower, it may not detect the viscosity sufficiently. Then, the accuracy of the viscosity value may decrease, so the condition was set in this way. The readings were recorded at 60 seconds of the measurement. The measurements were taken three times for each sample, and the readings were recorded as centipoises (mPa.s).

**Statistical analysis**

The results of this experiment were tested with a one-way analysis of variance. The test is performed using scheffe post-hoc test to analyze the significant differences between the test groups if the results are significant. Statistical analysis was performed using IBM SPSS statistics (Version 23.0, GraphPad Software Inc., San Diego, CA, USA), and it is determined to be statistically significant if the p-value is less than 0.05 (p < .05).

**Results and discussion**

**Fatty acid composition**

The FA composition of lingonberry is shown in Table 1. First of all, the total fat content of lingonberry was 0.679 ± 0.027 g, and 8 different FAs were detected in the detailed analysis. Linoleic acid (18:2n6c; omega-6 acid) is the most abundant FA with a mean value of 35.926 ± 1.288 g/100 g, followed by eicosapentaenoic acid (20:5n3; omega-3 acid), linolenic acid (18:3n3; omega-3 acid), oleic acid (18:1n9c; omega-9 acid), and vaccenic acid (18:1n7). Less plentiful are the saturated FAs; palmitic acid (16:0), stearic acid (18:0), and undecanoic acid (11:0). Although the predominant type of fat in fruits is healthy unsaturated fats, there is also some saturated fat in fruit as this study. Whether or not saturated plant fat is as bad for us as the fat in animal products is hotly debated, but limiting how much we eat is still recommended. Considering this, this study shows that lingonberry could be a good choice for food for the elderly due to its low saturated FA (13.616 ± 0.650 g/100 g). The consumption of saturated FA should be refrained from a sensible diet because it is connected to a higher prevalence of myocardial infarction cases, hyper-cholesterolemia, raised low-density lipoprotein (LDL) cholesterol and blood pressure, atheroma, and other disorders. Also, lingonberry is a great food because of its high unsaturated FA (86.384 ± 3.049 g/100 g) that is entailed lowering the danger of cancer and of chronic diseases such as cardiovascular disease, and autoimmune diseases. Especially, linoleic acid in lingonberry is well known that its consumption has been associated with decreased LDL cholesterol, and possibly with increased high-density lipoprotein cholesterol. Also, oleic and linolenic acids in lingonberry (8.377 ± 0.418 and 15.137 ± 0.437 g/100 g) maintain cell membranes, provide energy and offer vitamin E, a powerful antioxidant. Besides, eicosapentaenoic acid (18.779 ± 0.519 g/100 g) in lingonberry is important for proper fetal development, including neuronal, retinal, and immune function. Eicosapentaenoic acid may affect many aspects of cardiovascular function.

| Fatty acid | Composition (g/100 g) |
|------------|-----------------------|
| **Saturated fatty acid** | |
| C11:0 | 1.519 ± 0.063 |
| C16:0 | 7.382 ± 0.327 |
| C18:0 | 4.715 ± 0.260 |
| Total | 13.616 ± 0.650 |
| **Unsaturated fatty acid** | |
| C18:1n9c | 8.377 ± 0.418 |
| C18:1n7c | 8.165 ± 0.387 |
| C18:2n6c | 35.926 ± 1.288 |
| C18:3n3 | 15.137 ± 0.437 |
| C20:5n3 | 18.779 ± 0.519 |
| Total | 86.384 ± 3.049 |
| Total fat content (g) | 0.679 ± 0.027 |
| Mean ± S.D. | |
including inflammation, peripheral artery disease, major coronary events, and anticoagulation.\textsuperscript{[17]} That is why it is emphasized that the intake of omega-3, –6, and –9 acid, which is an essential fatty acid for health, is important.

Comparatively, lingonberry had higher values for unsaturated FA (86.384 ± 3.049 g/100 g) than that of celastrus berry (25.2 g/100 g), a natural antioxidative food recognized as beneficial to the elderly.\textsuperscript{[14]} According to this study, lingonberry is a superior food compared to celastrus berries to increase the unsaturated FAs which do significant roles in the human body such as diverse blood cholesterol levels control, alleviation of inflammation, heart rhythms stabilization, and multiple biological reactions.

\textbf{Mineral content}

The mineral content of lingonberry is shown in Table 2. Our analyses detected 8 different minerals. K is the most abundant mineral with a mean value of 186.921 ± 9.506 mg, followed Ca, P, Mg, Na, Fe, Zn, and Cu. Comparatively, lingonberry had higher values for Na, K, Ca, and Mg than those of blackberry, an antioxidant fruit recognized as beneficial to the elderly.\textsuperscript{[18]} This shows that lingonberry is a proper choice for food to increase the amount of mineral intake, which has an important function in the repair of cellular water balance and improves protein and carbohydrate metabolism.

Notably, the mean values of K in lingonberry is similar with blackberry (162 mg) known as food sources of mineral.\textsuperscript{[18]} This shows that lingonberry is a suitable food to increase the amount of K intake which is one of the most critical minerals in the body and it supports control fluid balance, muscle contractions and nerve signals. The mean values of Ca in lingonberry (32.734 ± 1.235 mg) is also similar with blackberry (29 mg), which aids in bones and dental growth and also assists in enzyme production and hormonal issue.\textsuperscript{[19]} Likewise, the mean values of P in lingonberry (19.867 ± 0.884 mg) is similar with blackberry (22 mg), which is an important part of nucleic acids and cell membranes and its lack generates food inefficiency and bone mineralization. In case of Na, the mean values (3.201 ± 0.150 mg) is three times more than that of blackberry (1 mg). The mean values of Mg in lingonberry (22.512 ± 0.967 mg) is also significantly higher than blackberry (0.646 mg), which improves enzymatic actions and retains the electrical ability in the nerves. Meanwhile, the mean value of Zn (0.218 ± 0.011 mg), Cu (0.153 ± 0.007 mg), and Fe (0.540 ± 0.019 mg) of lingonberry is lower than that of blackberry, and Se is not detected in lingonberry. According to this study, lingonberry is a superior food to increase the number of minerals intake which do critical roles in the human body such as various enzymatic actions, energy manufacture, the transfer of nerve impulses, and multiple biological actions.

\begin{table}[h]
\centering
\caption{Analyzed mineral content of lingonberry.}
\begin{tabular}{l|c}
\hline
Mineral & Content (mg) \\
\hline
Sodium & 3.201 ± 0.150 \\
Potassium & 186.921 ± 9.506 \\
Calcium & 32.734 ± 1.235 \\
Phosphorus & 19.867 ± 0.884 \\
Magnesium & 22.512 ± 0.967 \\
Iron & 0.540 ± 0.019 \\
Zinc & 0.218 ± 0.011 \\
Copper & 0.153 ± 0.007 \\
Selenium & N.D.\textsuperscript{1)} \\
\hline
\end{tabular}
\end{table}

\textsuperscript{1)} N.D. means not detected. Mean ± S.D.
Antioxidant effects

Total polyphenol content
The results of this study indicated that the high content of total polyphenol in lingonberry is distinguished (Table 3). The lingonberry contained 0.423 ± 0.016 g/100 g of total polyphenol content which has attracted considerable interest due to its many potential health benefits. Phenols like polyphenol are influential antioxidants and have been stated to illustrate antibacterial, antiviral, anticarcinogenic, antiinflammatory, and so on.[20] And recently, interest in natural food has grown because that might substitute synthetic food antioxidants. In particular, the elderly have significantly increased their interest in natural antioxidant foods in relation to anti-aging. Compared to previous study,[21] total polyphenol content of lingonberry was lower than that of bilberry (0.533 g/100 g), blackberry (0.511 g/100 g), black chokeberry (0.835 g/100 g), bog whortleberry (0.595 g/100 g), and crowberry (0.630 g/100 g) but higher than that of blueberry (0.211 g/100 g), cloudberry (0.311 g/100 g), elderberry (0.251 g/100 g), raspberry (0.201 g/100 g), red currant (0.105 g/100 g), and rowanberry (0.347 g/100 g). Thus, lingonberry could be a proper substitute especially for synthetic polyphenolic compounds and may influence the elderly’s health.[22]

Total flavonoid content
Further analysis of lingonberry shows higher total flavonoid content (0.499 ± 0.022 g/100 g) than blueberry (0.343 g/100 g), blackberry (0.171 g/100 g), strawberry (0.635 g/100 g), and raspberry (0.547 g/100 g), a great natural source of flavonoid recognized as beneficial to the elderly.[23] So lingonberry with high total flavonoid content may does a function in the stopping of lipid peroxidation, free radical scavenging, and anti-inflammatory action. That also may decrease the danger for the advance of atherosclerosis and insulin resistance, and they may decrease blood pressure. In particular, since these are common diseases in the elderly, interest in natural antioxidant foods has recently been increasing. Thus, lingonberry could be a proper substitute especially for synthetic flavonoid and may influence the elderly’s health. The safety limits of natural antioxidants are mostly not known, but they are hardly safer than synthetic antioxidants. Due to the composition and chemical characteristics of natural antioxidants, they are less volatile and more stable at high temperatures, which means that they better support food production processes such as cooking or baking, making them more effective in the protection of the final product.[24]

Superoxide radical scavenging activity
As shown in Table 3, the superoxide radical scavenging activity (SOD) of lingonberry (170.132 ± 3.504 μg/mL) was lower than that of black berry (478 μg/mL), elderberry (208 μg/mL), bilberry (411 μg/mL), boysenberry (391 μg/mL), strawberry (239 μg/mL), and raspberry (232 μg/mL) but higher than that of cherry (27 μg/mL) and blueberry (44 μg/mL), a great natural antioxidant source recognized as beneficial to the prevention of chronic diseases.[25] According to previous studies, superoxides can be dismantled to powerful oxidative kinds such as singlet oxygen and hydroxyl radicals, and can cause extreme damage to the cellular parts in a biological organization. [26] Among

| Physicochemical property | Status          |
|-------------------------|----------------|
| Antioxidation           |                |
| Total polyphenol content (g/100 g) | 0.423 ± 0.016 |
| Total flavonoid content (g/100 g) | 0.499 ± 0.022 |
| Superoxide radical scavenging activity (μg/mL) | 170.132 ± 3.504 |
| DPPH radical scavenging activity IC<sub>50</sub> (μg/mL) | 6.413 ± 0.300 |
| ABTS radical scavenging activity (%) | 85.707 ± 1.033 |
| Ferric reducing antioxidant power (μmol/g) | 8.051 ± 0.299 |
| Reducing power (μmol/g) | 0.121 ± 0.006 |
| Antidiabetes            |                |
| α-glucosidase inhibitory activity IC<sub>50</sub> (mg/mL) | 9.715 ± 0.322 |
| α-amylase inhibitory activity IC<sub>50</sub> (mg/mL) | 7.453 ± 0.235 |

Mean ± S.D.
them, superoxide anion radical (O$_2^-$) undergo the reduction of one electron from free molecular oxygen by a membrane bound enzyme titled nicotinamide adenine dinucleotide phosphate oxidase, which in cells are converted into other damaging reactive oxygen kinds such as hydroxyl radical and hydrogen peroxide. Hence, the removal of the superoxide anion radical created by the above enzymatic path would be advantageous in solving various health problems. Thus, this result suggests that lingonberry is an adequate antioxidative food especially for the elderly.

**DPPH radical scavenging activity**

The antioxidant activity of lingonberry was experimented with DPPH radical scavenging activity with 50% at 6.413 ± 0.300 mg/mL. Compared to previous study, [23] DPPH radical scavenging activity of lingonberry was lower than that of blueberry (32.27 mg/mL) but higher than that of blackberry (3.37 mg/mL), strawberry (3.23 mg/mL), and raspberry (4.60 mg/mL). Consumption of foods that have antioxidant properties like lingonberry is favorable to human health because they can defend the human body from damaging free radicals and prevent the advance of many chronic disorders. [27] So, this result suggests that lingonberry may support to decrease the danger of cancer and cardiovascular disorders.

**ABTS radical scavenging activity**

The consequence of this research showed that ABTS radical scavenging activity of lingonberry (85.707 ± 1.033%) is similar with that of Korean black raspberry (86.2%) and crowberry (86.5%), and twice to three times more than blueberry (34.3%) and strawberry (29.6%), a good source of antioxidants recognized as beneficial to the elderly. [28] This result can be said to be well correlated with the high concentration of phenols. The antioxidant activity of phenolic compounds is mainly due to their redox properties, which can play an important role in adsorbing and neutralizing free radicals, quenching singlet and triplet oxygen, or decomposing peroxides. [29] According to the results of one previous study, it was shown that there is the highest level of correlation between phenols and antioxidant activity. [30] When the correlations between phenols and the antioxidant activity were compared for the set of red and white wines separately, it became clear that the phenols values were better correlated with the antioxidant activity for red wines as opposed to white wines. The correlation coefficient observed between phenols and radical scavenging activity for white wines was markedly lower. This discrepancy may be explained by the fact that white wines do not contain polyphenolic compounds such as procyanidines or resveratrol, which exhibit good radical scavenging capacity and are mostly found in red grape skins. Therefore, it is believed that lingonberry indicated high antioxidant activity possibly due to the existence of phenols.

**Ferric reducing antioxidant power**

The antioxidant efficiency of lingonberry determined by the present ferric reducing antioxidant power (FRAP) assay relies on the redox latencies of the composite under research, identified by the intricacy of their molecules. [27] Compared to previous study, [23] FRAP of lingonberry (8.051 ± 0.299 μmol/g) was lower than that of partridgeberry (17.71 μmol/g), blueberry (16.24 μmol/g), blackberry (15.03 μmol/g) but similar with that of strawberry (8.00 μmol/g) and raspberry (7.57 μmol/g), a great natural source recognized as beneficial to the prevention of chronic diseases. This result indicates that lingonberry has potent antioxidant property.

**Reducing power**

Reducing power is also extensively applied in estimating antioxidant activity of polyphenols. The reducing power is commonly related with the existence of reductants, which use antioxidant action by cracking the free radical chains by giving a hydrogen atom. [31] So in this study, the iron reducing capacity of lingonberry was estimated from that capability to decrease the Fe$^{3+}$-ferricyanide compound to the ferrous form by giving an electron. As a result, the reducing ability of lingonberry was 0.121 ± 0.006 μmol/g (Table 3). Compared to previous study, [32] reducing power of lingonberry was
lower than that of mulberry (0.232 μmol/g) but higher than that of craneberry (0.051 μmol/g) and strawberry (0.049 μmol/g), a good natural food source of antioxidant. Here, we expect that the antioxidant activity and reducing power capacity of lingonberry was probably due to the existence of polyphenols, which can play as free radicals scavenger by presenting an electron or hydrogen.

**Antidiabetes effects**

Lingonberry was assayed for that anti-diabetic properties by obstruction of α-amylase and α-glucosidase enzymes. The enzymes α-amylase and α-glucosidase are accountable for carbohydrate ingestion, and the inhibition of these enzymes may decrease postprandial blood glucose levels by reducing the breakdown of polysaccharides into glucose. In this study, the IC$_{50}$ values of lingonberry for inhibiting α-glucosidase (9.715 ± 0.322 mg/mL) was lower than blueberry (21.3 mg/mL) but similar with bilberry (9.6 mg/mL), blackberry (9.5 mg/mL), and bog whortleberry (10.5 mg/mL), a good natural food source of antioxidant.[21] And the IC$_{50}$ values of lingonberry for α-amylase (7.453 ± 0.235 mg/mL) was lower than blueberry (16.6 mg/mL), raspberry (10.2 mg/mL), and blackberry (10.1 mg/mL) but higher than crowberry (5.3 mg/mL), bilberry (6.2 mg/mL), and black chokeberry (6.0 mg/mL). A previous study reported that anti-diabetic activity is associated with the content of phenolic compounds and flavonoids, and polyphenol content was shown to increase the anti-diabetic activities of fruits.[33] Dietary polyphenols come mainly from plant-based foods including fruits, vegetables, whole grains, coffee, tea, and nuts, which may influence glycemia and diabetes through different mechanisms, such as promoting the uptake of glucose in tissues, and therefore improving insulin sensitivity. Several animal models and a limited number of human studies have revealed that polyphenols decrease hyperglycemia and improve acute insulin secretion and insulin sensitivity.[34] Thus, we assume that α-glucosidase and α-amylase inhibitory activities of lingonberry were likely due to the presence of polyphenols.

**Viscosity of lingonberry juice**

According to Table 4 and Figure 1, with increasing the gelling agent, viscosity showed a significant increase linearly (p < .001). Given these changes, thickening agents and lingonberry juice are thought to interact considerably with each other, as thickening agents have a significant effect on the viscosity.

| Table 4. Viscosity of lingonberry juice added with thickening agent. |
|---------------------------------------------------------------|
| **Concentration of thickening agent (%)** | **Guar gum** | **Xanthan gum** | **Locust bean gum** | **F-value**$^1$ (p-value) |
|---------------------------------------------|--------------|-----------------|-------------------|-------------------------|
| 0.0                                         | 3.970 ± 0.187$^G$ | 3.970 ± 0.187$^F$ | 3.970 ± 0.187$^F$ | 0.000 (1.000) |
| 0.5                                         | 1,781.147 ± 80.059$^B$ | 177.392 ± 8.102$^E$ | 2,528.275 ± 109.132 $^{D_a}$ | 541.276*** (0.000) |
| 1.0                                         | 5,175.089 ± 205.798$^{D_a}$ | 1,491.723 ± 73.582$^{D_c}$ | 3,586.540 ± 174.495 $^{D_b}$ | 293.460*** (0.000) |
| 1.5                                         | 7,118.637 ± 345.293 $^{D_a}$ | 6,442.063 ± 312.911 $^{C_a}$ | 5,122.432 ± 245.987$^{D_b}$ | 31.334** (0.001) |
| 2.0                                         | 8,749.156 ± 418.492$^{D_c}$ | 8,013.241 ± 400.554$^B$ | 9,156.464 ± 451.233$^B$ | 3.332 (0.106) |
| 2.5                                         | 11,890.806 ± 591.422$^{D_a}$ | 10,895.314 ± 531.298$^A$ | 12,334.620 ± 605.879$^A$ | 4.744 (0.058) |
| 3.0                                         | 14,144.718 ± 701.331$^{D_a}$ | 10,967.501 ± 538.870$^{D_b}$ | 12,143.975 ± 604.504$^{D_b}$ | 19.855** (0.002) |

(1) One-way ANOVA was used, and different letters in the same column (A ~ G) and row (a ~ c) show a significant difference at ***p < 0.001, respectively. Mean ± S.D.
of lingonberry juice. To briefly explain how the thickening agent thickened the lingonberry juice, the viscosity of polysaccharide dispersions arises predominantly from physical entanglement of conformationally disordered “random coils.”[35] In dilute dispersion, the individual molecules of thickening agents can move freely and do not exhibit thickening. In concentrated system, these molecules begin to come into contact with one another; thus, the movement of molecules becomes restricted. The transition from free moving molecules to an entangled network is the process of thickening. Thus, thickening agents can be considered as entanglement of network producers. And the process of thickening involves the nonspecific entanglement of conformationally disordered polymer chains. It is essentially a polymer-solvent interaction. This thickening occurs above a critical concentration known as overlap concentration. Below this, the polymer dispersions exhibit Newtonian behavior but show a non-Newtonian behavior above this concentration. So intrinsic viscosity is an important parameter used to compare the viscosities of dispersions of thickening agents.

When look into gel concentration, there were significant (p < .01) different properties between all three gelling agents except for 2 and 2.5%. At 2 and 2.5% concentration of gelling agents, similar viscosities were shown. Based on these results, the evaluated linear regression equation for guar gum is “Y = 472,969X – 114.03” (where X is the concentration of guar gum and Y is the viscosity of lingonberry juice) with high accuracy (R² = 0.9939). In case of xanthan gum, it was evaluated as “Y = 434,628X – 1092.1” (where X is the concentration of xanthan gum and Y is the viscosity of lingonberry juice) with high accuracy (R² = 0.9393). In case of locust bean gum, it was evaluated as “Y = 440,019X – 189.39” (where X is the concentration of locust bean gum and Y is the viscosity of lingonberry juice) with high accuracy (R² = 0.9595). Considering the third level for KS (viscosity ≤ 1,500 mPa.s),[5] it is determined that the sample added with guar gum 0.341%, xanthan gum 0.596%, and locust bean gum 0.384% will have an appropriate viscosity to help dysphagia for the elderly. Viscosity characterization of lingonberry juice is the most important and generally performed practice.
since it correlates to the rheological attributes of the product, which, in turn, determines its sensory characteristics and consumer acceptability. The fluid gels were perceived to be easily swallowed and safe for consumption.\[4\] Especially, thin liquids as this study are the easiest to swallow compared to thickened liquids, as they require less effort in swallowing. In addition, thin liquids are perceived of as less viscous, less adhesive, and easier to maneuver in the mouth than thicker fluids. Thicker liquids have been indicated to have a harmful effect on the mouthfeel, as greater effort is needed by the throat muscles to pass the liquid through the oral cavity and swallow. This finding is in discovery with that of prior studies that report that a fluid with proper viscosity can be easily swallowed without causing any discomfort. Thus, a formulation with suitable viscosity for the elderly can be easily produced with gelling agents by controlling the formulation parameters.

In particular, among the three gelling agents (guar gum, xanthan gum, locust bean gum) in this study, guar gum was found to be able to easily adjust the viscosity even with a small amount, so guar gum would be economically helpful. In other words, guar gum is cost-effective since it has nearly eight times the water-thickening capability of other gelling agents and just a little amount is needed for making adequate viscosity. In addition, it has been revealed to decrease serum cholesterol and lower blood glucose standards. Therefore, guar gum is applied in an extensive range of food produce. And xanthan gum and locust bean gum is also a preferred method of thickening fluids since it does not modify the color or flavor of foods, so they are also frequently used for developing elder-friendly food. Above all, these gelling agents will help the elderly balance their nutrition by allowing them to consume better lingonberry juice with high antioxidant content. In addition, the thickening agents used in this study are also known to have antioxidant properties, and according to previous studies, 0.2% xanthan gum was able to protect human corneal epithelial cells from oxidative stress. Therefore, the level of activated oxygen species could be lowered to the cell values treated with buffers used for polymer solubilization.[36] Another previous study also reported that the incorporation of locust bean gum significantly increased the antioxidant activity of yogurt in a concentration-dependent manner.[37] Gum arabic has also been claimed to have an antioxidant effect, which have been reported to reduce the harmful effects of the free radical on patients with hemodialysis. Therefore, many studies have been conducted aimed at seeing the effect of gum arabic on oxidative stress and inflammatory markers in patients through regular hemodialysis.[38] Therefore, adding a thickening agent is also considered to be helpful in terms of nutrition effect when developing elder-friendly foods. Whereas, since this research did not conduct a bioavailability test and did not conduct a sensory evaluation on the elderly subject to actual intake, further studies related to this will be needed for the elderly’s food product industry.

**Conclusion**

In summary, lingonberry comprises different kinds of nutrients and bioactive materials containing minerals and essential fatty acids, and has antioxidative and antidiabetic abilities. But even though the promising health benefits of lingonberry have inspired efforts to develop and magnify their commercial production, increasing their production remains a challenge. Therefore, in this study, it was attempted to apply lingonberry to the elderly’s food. As a result, lingonberry juice can be formulated as an elder-friendly food using a gelling agent. Considering the third level for KS (viscosity ≤ 1,500 mPa.s), lingonberry juice added with guar gum 0.341%, xanthan gum 0.596%, and locust bean gum 0.384% will have an appropriate viscosity to swallow easily for the elderly with dysphagia. The findings of this study strongly suggest that the elderly’s food product industry should consider manufacturing liquid gel formulations, as they are preferred by consumers and could benefit the elderly with dysphagia.

**Disclosure statement**

No potential conflict of interest was reported by the author(s).
References

[1] Debnath, S. C.; Arigundam, U. In Vitro Propagation Strategies of Medicinally Important Berry Crop, Lingonberry (Vaccinium Vitis-idaea L.). *Agronomy*. 2020, 10(5), 744. DOI: 10.3390/agronomy10050744.

[2] Nile, S. H.; Park, S. W. Edible Berries: Bioactive Components and Their Effect on Human Health. *Nutr*. 2014, 30 (2), 134–144. DOI: 10.1016/j.nut.2013.04.007.

[3] Ieri, F.; Martini, S.; Innocenti, M.; Mulinacci, N. Phenolic Distribution in Liquid Preparations of Vaccinium Myrtillus L. and Vaccinium Vitisidaea L. *Phytochem. Anal*. 2013, 24, 467–475. DOI: 10.1002/pca.2462.

[4] Aziz, Z. H. A.; Katas, H.; Omar, M. S.; Shah, N. M.; Yusop, S. M.; Shafee, M. N.; Tarmizi, S. F. M. Preference, Perception, and Acceptability of Fluid Gels as a Potential Age-Appropriate Dosage Form for Elderly Patients with Dysphagia. *Gels*. 2022, 8(4), 218. DOI: 10.3390/gels8040218.

[5] Kim, D. S.; Joo, N. M. Feasibility of Elder-Friendly Food Applications of Sacha Inchi according to Cooking Method: Focusing on Analysis of Antioxidative Activity and Brain Neuron Cell Viability. *Foods*. 2021, 10, 2948. DOI: 10.3390/foods10122948.

[6] Dixit, A. S.; Parthasarathi, K. K.; Hosakote, G. S. Gels and Jellies as A Dosage Form for Dysphagia Patients: A Review. *Curr. Drug Ther.* 2011, 6(2), 79–86. DOI: 10.2174/157488511795304921.

[7] Kim, D. S.; Joo, N. M. Nutritional Composition of Sacha Inchi (Plukenetia Volubilis L.) as Affected by Different Cooking Methods. *Int. J. Food Prop*. 2019, 22(1), 1235–1241. DOI: 10.1080/10942912.2019.1640247.

[8] Wu, S.; Zhao, Y. H.; Feng, X.; Wittmeier, A. Application of Inductively Coupled Plasma Mass Spectrometry for Total Metal Determination in Silicon-Containing Solid Samples Using the Microwave-Assisted Nitric Acid-Hydrofluoric Acid-Hydrogen Peroxide-Boric Acid Digestion System. *J. Anal. At. Spectrom.* 1996, 4, 1–10.

[9] Kim, D. S.; Iida, F. Texture Characteristics of Sea Buckthorn (Hippophae rhamnoides) Jelly for the Elderly Based on the Gelling Agent. *Foods*. 2022, 11(13), 1892. DOI: 10.3390/foods11131892.

[10] Sulistiyani, S.; Safithri, M.; Sari, Y. P. Inhibition of α-Glucosidase Activity by Ethanolic Extract of Melia Azedarach L. Leaves. *Environ. Earth Sci.* 2016, 31, 1–5.

[11] Sansenya, S.; Winyakul, C.; Nanok, K.; Phudhawong, W. S. Synthesis and Inhibitory Activity of N-Acetylpyrrolidine Derivatives on α-Glucosidase and α-Amylase. *Res. Pharm. Sci.* 2020, 15(1), 14–25. DOI: 10.4103/1735-5362.278711.

[12] Benitez, E. I.; Genovese, D. B.; Lozano, J. E. Effect of Typical Sugars on the Viscosity and Colloidal Stability of Apple Juice. *Food Hydrocoll.* 2009, 23(2), 519–525. DOI: 10.1016/j.foodhyd.2008.03.005.

[13] Rana, V. S.; Das, M. Fatty Acid and Non-fatty Acid Components of the Seed Oil of Celastrus Paniculatus Willd. *Int. J. Fruit Sci*. 2017, 17(4), 407–414. DOI: 10.1007/s115538362.2017.1333941.

[14] Siri-Tarino, P. W.; Sun, Q.; Hu, F. B.; Krauss, R. M. Saturated Fatty Acids and Risk of Coronary Heart Disease: Modulation by Replacement Nutrients. *Curr. Atheroscler. Rep.* 2010, 12(6), 384–390. DOI: 10.1007/s11883-010-0131-6.

[15] Simopoulos, A. P. The Importance of the Omega-6/Omega-3 Fatty Acid Ratio in Cardiovascular Disease and Other Chronic Diseases. *Exp. Bio. Med*. 2008, 233(6), 674–688. DOI: 10.1881/0711-MR-311.

[16] Dunham, W. R.; Klein, S. B.; Rhodes, L. M.; Marcelo, C. L. Oleic Acid and Linoleic Acid are the Major Determinants of Changes in Keratinocyte Plasma Membrane Viscosity. *J. Invest. Dermatol.* 1996, 107(3), 332–335. DOI: 10.1111/1523-1747.ep12363174.

[17] Swanson, D.; Block, R.; Mousa, S. A. Omega-3 Fatty Acids EPA and DHA: Health Benefits Throughout Life. *Adv. Nutr*. 2012, 3(1), 1–7. DOI: 10.3945/an.111.000893.

[18] United States Department of Agriculture (USDA). Nutrition Comparison and Search. https://foodstructure.com/ (accessed April30, 2022).

[19] Bhownililk, D.; Chiranji, B.; Kumar, S.; K. P. A Potential Medicinal Importance of Zinc in Human Health and Chronic Disease. *Int. J. Pharm. Biomed. Sci*. 2010, 1(1), 5–11.

[20] Aberoumand, A.; Deokule, S. S. Comparison of Phenolic Compounds of Some Edible Plants of Iran and India. *Pak. J. Nutr*. 2008, 7(4), 582–585. DOI: 10.3923/pjn.2008.582.585.

[21] Ho, G. T. T.; Nguyen, T. K. Y.; Kase, E. T.; Tadesse, M.; Barsett, H.; Wagensteen, H. Enhanced Glucose Uptake in Human Liver Cells and Inhibition of Carbohydrate Hydrolyzing Enzymes by Nordic Berry Extracts. *Molecules*. 2017, 22(1806), 1–15. DOI: 10.3390/molecules22101806.

[22] Ivanov, I. G. Polyphenols Content and Antioxidant Activities of *Taraxacum Officinale* F.H. Wigg (Dandelion) Leaves. *Int. J. Pharmacogn. Phytochem*. *Res*. 2014, 6, 889–893.

[23] Rupasinghe, H. P. V.; Yu, L. J.; Bhullar, K. S.; Bors, B. Short Communication: Haskap (Lonicera Caerulea): A New Berry Crop with High Antioxidant Capacity. *Can. J. Plant Sci*. 2012, 92(7), 1311–1317. DOI: 10.4141/cjps2012-073.
[24] BTSA. E-Book: The Ideal Antioxidant for Your Product. Antioxidants. 1994, 1–29.
[25] Prior, R. L.; Sintara, M.; Chang, T.; Seeram, N. P.; Shukkitt-Hale, B. Multi-radical (ORACMRS) Antioxidant Capacity of Selected Berries and Effects of Food Processing. J. Berry Res. 2016, 6(2), 159–173. DOI: 10.3233/JBR-160127.
[26] Phaniendra, A.; Jestdi, D. B.; Periyasamy, L. Free Radicals: Properties, Sources, Targets, and Their Implication in Various Diseases. Indian J. Clin. Biochem. 2015, 30(1), 11–26. DOI: 10.1007/s12291-014-0446-0.
[27] Zihad, S. M. N. K.; Uddin, S. J.; Islam, M. T. Nutritional Value, Micronutrient and Antioxidant Capacity of Some Green Leafy Vegetables Commonly Used by Southern Coastal People of Bangladesh. Heliyon. 2019, 5(11), e02768.
[28] Bae, H. S.; Kim, H. J.; Kang, J.; Kudo, R.; Hosoya, T.; Kumazawa, S.; Jun, M.; Kim, O. Y.; Ahn, M. R. Anthocyanin Profile and Antioxidant Activity of Various Berries Cultivated in Korea. Nat. Prod. Commun. 2015, 10(6), 963–968.
[29] Zheng, W.; Wang, S. Y. Antioxidant Activity and Phenolic Compounds in Selected Herbs. J. Agric. Food Chem. 2001, 49(11), 5165–5170. DOI: 10.1021/jf010697n.
[30] Zegarac-Piljac, J.; Martinez, S.; Jorge, J. A.; Zulj, L. V.; Kovačević-Ganić, K. Correlation between the Phenolic Content and DPPH Radical Scavenging Activity of Selected Croatian Wines. Acta Aliment. 2007, 36(2), 1–9. DOI: 10.1556/AAlim.2007.0005.
[31] Pulido, R.; Bravo, L.; Saura-Calixto, F. Antioxidant Activity of Dietary Polyphenols as Determined by a Modified Ferric Reducing/Antioxidant Power Assay. J. Agric. Food Chem. 2000, 48, 3396–3402. DOI: 10.1021/jf9913458.
[32] Aly, A.; Maraei, R.; El-Leel, O. A. Comparative Study of Some Bioactive Compounds and Their Antioxidant Activity of Some Berry Types. Potr. S. J. F. Sci. 2019, 13(1), 515–523. DOI: 10.5219/1132.
[33] Yusuf, E.; Wojdylo, A.; Oszmiański, J.; Nowicka, J.; Periyan, S.; Wang, J.; Arslan, O.; Kuda, S.; Kumazawa, T.; Tornetta, S. Various Phenolic Compounds and Their Effects on α-Amylase, α-Glucosidase, Lipase, and Cholinesterase Activities of 12 Coloured Carrot Varieties. Foods. 2021, 10, 808. DOI: 10.3390/foods10040808.
[34] Aryaeian, N.; Sedehi, S. K.; Aralblou, T. Polyphenols and Their Effects on Diabetes Management: A Review. Med. J. Islam. Repub. Iran. 2017, 31, 134. DOI: 10.14196/mjiri.31.134.
[35] Saha, D.; Bhattacharya, S. Hydrocolloids as Thickening and Gelling Agents in Food: A Critical Review. J. Food Sci. Technol. 2010, 47(6), 587–597. DOI: 10.1007/s13197-010-0162-6.
[36] Amico, C.; Tornetta, T.; Scifo, C.; Blanco, A. R. Antioxidant Effect of 0.2% Xanthan Gum in Ocular Surface Corneal Epithelial Cells. Curr. Eye Res. 2015, 40(1), 72–76. DOI: 10.3109/02713683.2014.914542.
[37] Peker, H.; Arslan, S. Effects of Addition of Locust Bean Gum on Sensory, Chemical, and Physical Properties of Low-Fat Yogurt. J. Food Agric. Environ. 2013, 11(2), 274–277.
[38] Kaddam, L.; Fadl-Elmula, I.; Eisawi, O. A.; Abdelrazig, H. A.; Salih, M. A.; Lang, F.; Saeed, A. M. Gum Arabic as Novel Anti-Oxidant Agent in Sickle Cell Anemia, Phase II Trial. BMC Hematol. 2017, 17(4), 1–6. DOI: 10.1186/s12878-017-0075-y.