



# Quality characteristics of grain syrups containing ginger (*Zingiber officinale*)

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## Abstract

Korean traditional grain syrup (*Jocheong*) is prepared by removing moisture from saccharified-starch suspensions. The addition of ginger (0-6.4%) to grain syrup did not change the solid content (moisture content) or sugar content. The grain syrup resulted in increased Mn, P, Zn, Na, Mg, Ca, and P contents upon addition of ginger. The ginger-added grain syrup had increased total phenolic content and 2,2-diphenyl-1-picrylhydrazyl (DPPH) and 2,2'-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid (ABTS) radical-scavenging activities, compared with normal grain syrup. *Staphylococcus aureus* exhibited slight growth inhibition in medium containing ginger-supplemented grain syrup and the fungi did not grow at all on ginger (3.2%)-added grain syrup during 6 days of incubation. The addition of ginger may contribute to improving the nutritional quality of grain syrups, enhancing health functions and extending the storage period.

**Keywords:** antibacterial activity; antioxidant activity; mineral content; shelf-life; total phenolic content; grain syrup.

**Practical Application:** Improvement of nutritional and functional properties of grain syrup by addition of ginger.

## 1. Introduction

The highly viscous Korean grain syrup (*Jocheong*) is prepared by removing moisture from a saccharified-starch suspension (*Sikhye*, a traditional Korean drink) by heating. The saccharified-starch suspension is made from various starches saccharified by malting. Grain syrup has been used as a sweetener and snack for a long time in Korea and has also been used in the manufacture of several traditional foods such as *Yukwa* (fried glutinous rice cake). In addition, in order to enhance palatability and add characteristic taste and aroma, grain syrup has been manufactured by adding various ingredients such as corn, pumpkin, and pheasant meat.

The primary focus in research regarding grain syrup has been on improving manufacturing processes. The purpose of these studies was to improve and optimize such manufacturing processes by standardizing and improving saccharifying enzymes to be suitable for large-scale grain syrup production. Several studies concerning the preparation of grain syrup using microwaves (Kim & Kim, 1985) and optimum saccharification conditions (Kim & Kang, 1994) and quality characteristics (Rhee et al., 1992) dependent on storage temperature have been conducted. Another focus of grain syrup research is to impart new flavor and taste to sweeten the grain syrup by adding various subsidiary materials; however, scientific research data are currently insufficient. Grain syrups containing sweet persimmon (Bae et al., 2001), shiitake mushroom powder (Park & Na, 2005), apple (Yang & Ryu, 2010), steamed garlic powder (Kang & Shin, 2012), and *Gastrodia elata* liquid extract (Lee, 2015) have been reported.

Ginger (*Zingiber officinale*) has been used for a long time as a spice to enhance the flavor and taste of food in many countries. Ginger contains various hydrocarbons, ketones, alcohols, and

volatile aromatic ingredients, such as zingiberene and  $\gamma$ -cardinen, and other ingredients that impart a spicy ginger taste such as gingerol, shogaol, and zingerone (Ekundayo et al., 1988; Ravi Kiran et al., 2013; Yamamoto-Ribeiro et al., 2013). These compounds have been reported to suppress odor, improve food flavor, and increase the shelf-life of foodstuffs (Cao et al., 2013; Ahmed et al., 2019). Steamed ginger and ginger oleoresin exert chemical free-radical-scavenging activity *in vitro* (Stoilova et al., 2007; Tohma et al., 2017; Kim et al., 2018). Additionally, ginger extract improved antioxidant capacity by reducing malondialdehyde (MDA) levels in body fluids and by increasing the production of antioxidant enzymes superoxide dismutase (SOD) and catalase in formalin-treated rats *in vivo* (Rasyidah et al., 2014).

In Korea, ginger has traditionally been added to enhance the flavor of grain syrups, but there are few scientific studies or reports regarding this. The purpose of this study was to evaluate the effects of addition of ginger on mineral levels, antioxidant properties, and antibacterial activities of grain syrups.

## 2. Materials and Methods

### 2.1 Experimental materials

Non-glutinous rice (*Oryza sativa*) was harvested in Seosan, Chungcheongnam-do, Korea, in 2017 and polished in January 2018. Malt was purchased from Cheonan, Chungcheongnam-do, Korea, in 2017. Ginger (*Zingiber officinale*), produced domestically in 2017, was processed to juice using a grinder (DA280-S, Daesung Artlon Co., Ltd, Paju, Korea). Other first-grade reagents were purchased from Sigma (Sigma-Aldrich Co., St. Louis, MO, USA).

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## 2.2 Preparation of grain syrup

Rice (1 kg) was washed five times with tap water, soaked for 4 h, and cooked to hard-steamed rice using an electric rice cooker (CR-3021V, Yangsang, Korea). Hard-steamed rice was mixed with water (4 L) and malt powder (200 g) and was saccharified by malting at 75 °C for 14 h. The saccharified solution was filtered through a cotton cloth and mixed with the ginger juices. The mixture was slowly stirred at 70 °C for 2 h to remove moisture until the mass of the mixture was approximately 1,300 g and then cooled to room temperature to prepare the grain syrup.

## 2.3 Determination of solid and sugar contents

The solid content in the grain syrup was measured by drying under atmospheric pressure (Association of Official Analytical Chemists, 1990). The grain syrup (10 g) was dried in a dry oven (OF-11E Forced Convection Oven, Lab Companion, Daejeon, Korea) at 105 °C for 48 h. Sugar content (Brix%) was measured using a portable refractometer (N.O.W Tokyo Hand Refractometer, Tokyo, Japan) after dissolving the grain syrup (50 g) in 100 mL of distilled water.

## 2.4 Determination of reducing sugars and dextrose equivalents

Reducing sugar levels in the grain syrup were analyzed using the 3,5-dinitrosalicylic acid (DNS) method (Miller, 1959). DNS reagent (1%, 3 mL) was added to 1 mL of sample, which was prepared by dissolving 1 g of the grain syrup in 100 mL of water, and the mixture was then heated at 90 °C for 5 min and cooled rapidly. The optical absorbance of the reactants was measured at 550 nm using a spectrophotometer (V-1100D, Labinn Co., Japan). The amount of reducing sugar was calculated from a standard curve using maltose as a reference. In addition, the dextrose equivalent (DE, %) was calculated using the following formula (Korea Food and Drug Administration, 2006):

$$\text{DE (\%)} = (\text{Reducing sugar content, \%}) / (\text{Solid content, \%}) \times 100$$

## 2.5 Analysis of minerals

Mineral (Na, Mg, K, Ca, Mn, Si, Fe, Zn, and Pd) contents in the grain syrup were analyzed using an inductively-coupled plasma-optical emission spectrometer (ICP-OES; GBC Integra-XMP, Braeside, Australia). The grain syrup (5 g) was completely dissolved in 10 mL of 1% HNO<sub>3</sub> using a microwave oven, diluted to 50 mL, and then used as an analysis sample. Standard materials (Kanto Chemical Co., Tokyo, Japan) were diluted with 1% HNO<sub>3</sub> to quantify mineral contents.

## 2.6 Determination of total phenolic content

Total phenolic content in the grain syrup was measured using a partially-modified Folin-Ciocalteu method (Oh et al., 2004). Grain syrup (0.05 g) was mixed with 1 mL of 1N Folin-Ciocalteu's phenol reagent, left at room temperature for 5 min, and then mixed with 2 mL of 20% (w/v) Na<sub>2</sub>CO<sub>3</sub>. The optical absorbance of the supernatant was measured at 765 nm using

a spectrophotometer. The total phenolic content was expressed in mg gallic acid equivalents (GAE)/g dry weight (dw) using gallic acid as a standard.

## 2.7 Determination of antioxidant activity

2,2-Diphenyl-1-picrylhydrazyl (DPPH) radical-scavenging activity was determined using the method of Lee et al. (Lee et al., 2005) with certain modifications. The grain syrup (0.2 mL in methanol) was mixed with 4 mL of methanol and 0.5 mL of DPPH solution (1 mM). The mixture was vortexed vigorously for 15 s and left at room temperature for 30 min. Then, the optical absorbance of the solution was measured at 517 nm using a spectrophotometer. 2,2'-Azino-bis(3-ethylbenzothiazoline-6-sulfonic acid (ABTS) radical-scavenging activity was determined using a partially modified method described by Thaipong et al. (2006). The ABTS radical solution was prepared by dissolving 2.45 mM potassium persulfate and 7 mM ABTS in phosphate-buffered saline (pH 7.4) and was left in the dark at room temperature for 24 h to generate radicals. Then, 10 µL of grain syrup was added to 190 µL of ABTS solution and reacted in the dark for 30 min. Changes in optical absorbance of the reactants were measured using a spectrophotometer at 734 nm. The radical-scavenging activity was expressed as mg Trolox equivalents (TE)/g dw.

## 2.8 Determination of antibacterial activity

Antibacterial activity of the grain syrup was measured by growth inhibition assays involving *Staphylococcus aureus* (*S. aureus*), a food-poisoning bacterium. Precultured *S. aureus* (0.5 mL, OD<sub>600</sub> = 0.7) was inoculated into 100 mL of nutrient broth (beef extract 3.0 g/L and peptone 5.0 g/L) containing 25 g of the grain syrup and cultured in an incubator (SIF6000R, Lab Companion, Daejeon, Korea) with 150 rpm rotary agitation at 37 °C for 24 h. The growth of *S. aureus* was measured using optical absorbance at 600 nm with a spectrophotometer. In addition, 10 g of grain syrup containing ginger was placed in Petri dishes and incubated at 25 °C for 6 days. The effect of ginger on extending the storage period of the grain syrup was evaluated by visually observing the growth of fungi for 6 days.

## 2.9 Statistical analysis

All experiments were repeated at least three times, and data are expressed as means and standard deviation and were analyzed using one-way analysis of variance (ANOVA) and Duncan's multiple comparison test. SPSS v.24.0 (IBM SPSS Inc., Chicago, IL, USA) was used for statistical analysis, and *p* < 0.05 was considered to be statistically significant.

## 3. Results and Discussion

### 3.1 Sugar content in grain syrup containing ginger

The solid content of normal grain syrup was approximately 59.62%, and the addition of ginger (0–6.4%) did not affect this (Table 1). The sugar content (Brix%) of normal grain syrup was approximately 62.67 Brix%, and values for grain syrups containing 3.2%, 4.8%, and 6.4% of ginger were determined to be 59.67%, 63.33%, and 62.67 Brix%, respectively (Table 1).

However, no significant difference was observed in the sugar content of ginger-supplemented grain syrup, except for the grain syrup containing 4.8% ginger. In addition, normal grain syrup had approximately 32.45% (w/w) of reducing sugars, and the addition of 3.2%, 4.8%, and 6.4% ginger contributed approximately 25.35%, 34.16%, and 35.63% (w/w) reducing sugars to the grain syrups, respectively. Reducing sugar levels in the grain syrup increased significantly with the addition of ginger, excluding the 3.2% ginger-grain syrup sample. The content of reducing sugars in the grain syrup refers to the contents of glucose, fructose, and maltose, but not of sucrose, which is a non-reducing sugar (Yang & Ryu, 2010). Ginger carbohydrates consist of approximately 40–60% of starch and 2.2% (w/w) of reducing sugars (Lee et al., 2014). The addition of ginger to the grain syrup appears to have contributed to a significant increase in reducing sugar content in the grain syrup, although this was a minor amount. The DE of normal grain syrup was 54.43%, and the 3.2%, 4.8%, and 6.4% ginger-added grain syrups had 44.67%, 57.75%, and 61.05% DE, respectively. The higher DE of the grain syrup indicates greater saccharification of starch, and the sweetness of the grain syrup was elevated with increasing DE.

### 3.2 Mineral content in grain syrup containing ginger

The mineral contents, including of Na, Mg, K, and Ca, in ginger-supplemented grain syrups are shown in Table 2. Normal

grain syrup contained P, Mg, Ca, and Si at 811.62, 169.05, 128.92, and 187.48  $\mu\text{g/g}$ , respectively. Fe (3.10  $\mu\text{g/g}$ ) and Zn (2.37  $\mu\text{g/g}$ ) contents were relatively low in the normal grain syrup. The addition of ginger to the grain syrup increased the mineral contents dramatically, excluding of Si and Fe. Mn, P, and Zn contents were increased by 394.2%, 122.16%, and 115.19% in the ginger (6.4%)-added grain syrup, respectively. Additionally, the contents of Na, Mg, K, and Ca in the ginger-supplemented grain syrup increased by 7.8–57.1%. On the other hand, Si and Fe levels in 6.4% ginger-added grain syrup were decreased by 38.50% and 12.26%, respectively. The addition of ginger to grain syrup may greatly improve the mineral qualities and nutritional properties of grain syrups.

### 3.3 Total phenolic content (TPC) in grain syrup containing ginger

TPCs in normal grain syrup were approximately 687.71  $\mu\text{g GAE/g}$ . TPC in the grain syrup increased to approximately 897.13, 1009.58, and 1171.67  $\mu\text{g GAE/g}$  with addition of 3.2%, 4.8%, and 6.4% ginger, respectively (Table 3). In the case of 6.4% ginger-supplemented grain syrup, the TPC in the grain syrup was increased to approximately 70.4% as compared to the normal grain syrup. TPC of grain syrups was reported to be 0.5–7.3 mg GAE/g, depending on the type and amount of grains used in the manufacture of the syrup (Yang & Ryu, 2010; Lee et al., 2012; Lee,

**Table 1.** Solid content, sugar content, reducing sugar content, and dextrose equivalent in various grain syrups supplemented with ginger.

Grain syrup <sup>1)</sup>	Solid content <sup>2)</sup> (%)	Sugar content (Brix%)	Reducing sugar (w/w, %)	Dextrose equivalent (DE) (%) <sup>3)</sup>
A	59.62 $\pm$ 0.31 <sup>4)a</sup>	62.67 $\pm$ 0.58 <sup>a</sup>	32.45 $\pm$ 0.25 <sup>3)c</sup>	54.43 $\pm$ 5.42 <sup>c</sup>
B	56.76 $\pm$ 0.55 <sup>b</sup>	59.67 $\pm$ 0.58 <sup>b</sup>	25.35 $\pm$ 0.63 <sup>d</sup>	44.67 $\pm$ 7.21 <sup>d</sup>
C	59.15 $\pm$ 0.30 <sup>a</sup>	63.33 $\pm$ 0.29 <sup>a</sup>	34.16 $\pm$ 0.03 <sup>b</sup>	57.75 $\pm$ 2.19 <sup>b</sup>
D	58.38 $\pm$ 1.40 <sup>a</sup>	62.67 $\pm$ 0.58 <sup>a</sup>	35.63 $\pm$ 0.30 <sup>a</sup>	61.05 $\pm$ 1.93 <sup>a</sup>

<sup>1)</sup> A: Grain syrup without ginger, B: Grain syrup with ginger (3.2%), C: Grain syrup with ginger (4.8%), D: Grain syrup with ginger (6.4%); <sup>2)</sup> Solid content (%) = [(solid content (g) after drying/sample (g))  $\times$  100]; <sup>3)</sup> D.E.(%) = [Reducing sugar content (%) / Solid content (%)  $\times$  100]; <sup>4)</sup> Each value represents means  $\pm$  SD. <sup>a,b</sup> Means with different superscripts in the same column indicate statistically significant difference ( $p < 0.05$ ) by Duncan's multiple range test.

**Table 2.** Mineral contents in various grain syrups supplemented with ginger.

Grain syrup <sup>1)</sup>	Mineral content ( $\mu\text{g/g}$ ) <sup>2)</sup>								
	Na	Mg	K	Ca	Mn	Si	Fe	Zn	P
A	50.87 $\pm$ 0.11 <sup>2)d</sup>	169.05 $\pm$ 1.68 <sup>d</sup>	33.66 $\pm$ 0.05 <sup>d</sup>	128.92 $\pm$ 1.62 <sup>b</sup>	1.38 $\pm$ 0.04 <sup>d</sup>	187.48 $\pm$ 1.63 <sup>a</sup>	3.10 $\pm$ 0.06 <sup>b</sup>	2.37 $\pm$ 0.05 <sup>d</sup>	811.62 $\pm$ 9.04 <sup>d</sup>
B	56.98 $\pm$ 0.51 <sup>c</sup> ( $\blacktriangle$ 12.01%)	212.27 $\pm$ 1.18 <sup>c</sup> ( $\blacktriangle$ 25.57%)	58.73 $\pm$ 0.51 <sup>c</sup> ( $\blacktriangle$ 74.48%)	139.23 $\pm$ 1.37 <sup>a</sup> ( $\blacktriangle$ 8.00%)	7.28 $\pm$ 0.10 <sup>a</sup> ( $\blacktriangle$ 427.54%)	184.05 $\pm$ 2.18 <sup>b</sup> ( $\nabla$ 1.83%)	2.56 $\pm$ 0.05 <sup>d</sup> ( $\nabla$ 17.42%)	4.31 $\pm$ 0.02 <sup>c</sup> ( $\blacktriangle$ 81.86%)	970.97 $\pm$ 8.97 <sup>c</sup> ( $\blacktriangle$ 19.63%)
C	71.10 $\pm$ 1.98 <sup>a</sup> ( $\blacktriangle$ 37.77%)	244.21 $\pm$ 3.85 <sup>b</sup> ( $\blacktriangle$ 44.46%)	64.35 $\pm$ 0.78 <sup>b</sup> ( $\blacktriangle$ 91.18%)	140.41 $\pm$ 1.75 <sup>a</sup> ( $\blacktriangle$ 8.91%)	4.99 $\pm$ 0.07 <sup>c</sup> ( $\blacktriangle$ 261.59%)	108.44 $\pm$ 1.07 <sup>d</sup> ( $\nabla$ 42.16%)	3.84 $\pm$ 0.03 <sup>a</sup> ( $\blacktriangle$ 23.87%)	4.76 $\pm$ 0.07 <sup>b</sup> ( $\blacktriangle$ 100.84%)	1051.92 $\pm$ 5.44 <sup>b</sup> ( $\blacktriangle$ 29.61%)
D	67.18 $\pm$ 1.24 <sup>b</sup> ( $\blacktriangle$ 32.06%)	265.57 $\pm$ 0.54 <sup>a</sup> ( $\blacktriangle$ 57.10%)	74.78 $\pm$ 0.63 <sup>a</sup> ( $\blacktriangle$ 122.16%)	138.99 $\pm$ 1.02 <sup>a</sup> ( $\blacktriangle$ 7.81%)	6.82 $\pm$ 0.09 <sup>b</sup> ( $\blacktriangle$ 394.20%)	115.30 $\pm$ 1.25 <sup>c</sup> ( $\nabla$ 38.50%)	2.72 $\pm$ 0.02 <sup>c</sup> ( $\nabla$ 12.26%)	5.10 $\pm$ 0.08 <sup>a</sup> ( $\blacktriangle$ 115.19%)	1089.25 $\pm$ 4.76 <sup>c</sup> ( $\blacktriangle$ 34.21%)

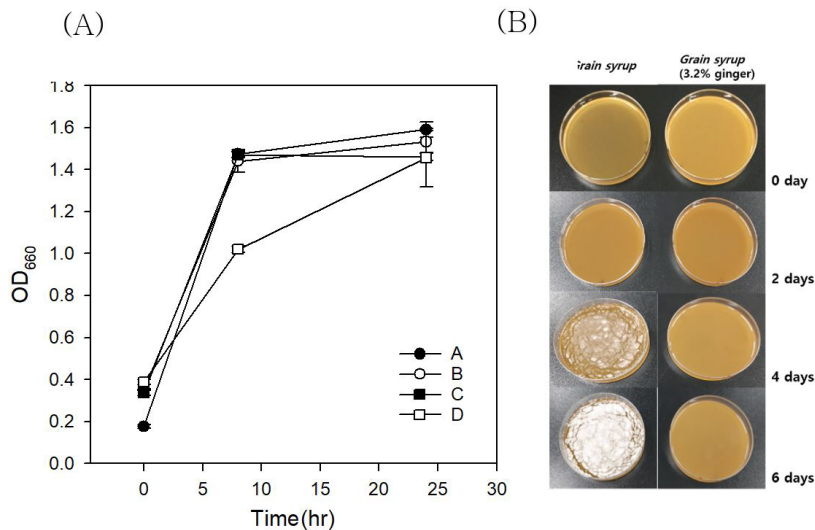
<sup>1)</sup> A: Grain syrup without ginger, B: Grain syrup with ginger (3.2%), C: Grain syrup with ginger (4.8%), D: Grain syrup with ginger (6.4%) <sup>2)</sup> Each value represents mean  $\pm$  SD. <sup>3)</sup> NR: Not Reported <sup>a-d</sup> Means with different superscripts in the same column indicate statistically significant differences at  $p < 0.05$  by Duncan's multiple range test.

**Table 3.** Total phenolic compound contents and DPPH and ABTS radical-scavenging activities in various grain syrups with added ginger

Grain syrup <sup>1)</sup>	Total phenolic compound ( $\mu\text{g GAE/g}$ )	DPPH ( $\mu\text{g TE/g}$ )	ABTS ( $\mu\text{g TE/g}$ )
A	687.71 $\pm$ 53.40 <sup>2)d</sup>	378.85 $\pm$ 9.38 <sup>2)d</sup>	1182.50 $\pm$ 55.28 <sup>c</sup>
B	897.13 $\pm$ 5.34 <sup>c</sup>	501.77 $\pm$ 17.14 <sup>c</sup>	1406.25 $\pm$ 43.75 <sup>b</sup>
C	1009.58 $\pm$ 18.07 <sup>b</sup>	548.85 $\pm$ 9.28 <sup>b</sup>	1649.58 $\pm$ 22.37 <sup>a</sup>
D	1171.67 $\pm$ 2.53 <sup>a</sup>	621.56 $\pm$ 2.17 <sup>a</sup>	1755.83 $\pm$ 104.35 <sup>a</sup>

<sup>1)</sup> A: Grain syrup without ginger, B: Grain syrup with ginger (3.2%), C: Grain syrup with ginger (4.8%), D: Grain syrup with ginger (6.4%) <sup>2)</sup> Each value represents the mean  $\pm$  SD. <sup>a-d</sup> Means with different superscripts in the same column indicate statistically significant difference at  $p < 0.05$  by Duncan's multiple range test.





**Figure 1.** Antimicrobial activity of various grain syrups supplemented with ginger. (A) Antibacterial activity against *S. aureus*, A: Grain syrup without ginger, B: Grain syrup with ginger (3.2%), C: Grain syrup with ginger (4.8%), D: Grain syrup with ginger (6.4%), (B) Antifungal activity.

2015; Lee & Lee, 2015). Ginger has approximately 150–200 mg GAE/g of TPC, which is approximately 200-times higher than that of normal grain syrup (Lee et al., 2014). Hence, TPCs in the grain syrups are anticipated to increase dramatically, depending on the amount of ginger added. The increased TPC content in grain syrup after adding ginger may impart antioxidant activity to otherwise normal grain syrup.

### 3.4 Antioxidant activity of grain syrup containing ginger

The antioxidant activity of ginger-supplemented grain syrups was analyzed by DPPH and ABTS free-radical-scavenging activity assays, as shown in Table 3. DPPH and ABTS free-radical-scavenging activities in normal grain syrup were approximately 378.85 and 1182.50  $\mu\text{g TE/g}$ , respectively. DPPH radical-scavenging activity in 6.4% ginger-supplemented grain syrup was approximately 621.56  $\mu\text{g TE/g}$ , representing an approximate 64% increase in antioxidant activity as compared to normal grain syrup. In addition, the ABTS radical-scavenging activity of ginger (6.4%)-supplemented grain syrup was approximately 1755.83  $\mu\text{g TE/g}$ , which was elevated by 48% as compared to normal grain syrup.

### 3.5 Antibacterial activity of grain syrup containing ginger

The antibacterial activity of grain syrup containing ginger is shown in Figure 1. Growth inhibitory effects on *S. aureus* were investigated using a medium containing ginger-supplemented grain syrup (Figure 1A). *S. aureus* exhibited approximately 30.62% and 8.17% growth inhibition in medium containing ginger (6.4%)-supplemented grain syrup after 7 and 24 h of incubation, respectively. In addition, the grain syrup (10 g) was maintained in a Petri dish at 30 °C for 6 days to confirm spoilage or otherwise (Figure 1B). Small white mold mycelia began to grow on the surface of the normal grain syrup from day 2 of incubation. By day 4, the white fungi grew to occupy approximately 20–30% of the Petri dish, and by day 6, the fungi were confluent on the surface of the Petri dish containing normal

grain syrup. However, fungi exhibited no growth whatsoever on grain syrup medium containing 3.2% ginger after incubation for 6 days (Figure 1B).

Ginger has been reported to exert antibacterial activity against food-poisoning bacteria such as *S. enteritidis*, *Escherichia coli* O157: H7, *Listeria monocytogenes* (Hara-kudo et al., 2004), *Bacillus subtilis*, and *S. aureus* (Sethi et al., 2013). Additionally, gingerol, shogol, zingerone, and zerumbone present in ginger exhibit antibacterial activities (Rahmani et al., 2014). Therefore, the addition of ginger to grain syrup may extend the shelf-life of grain syrup by inhibiting the growth of food-poisoning bacteria.

## 4. Conclusions

Slight changes in reducing sugar content and DE after ginger was added to grain syrups did not alter sugar characteristics. The addition of ginger to grain syrups increased Mn, K, and Zn contents, TPC, and antioxidant activities of the grain syrup. As a consequence, the addition of ginger to grain syrups may contribute to improving the mineral qualities of such syrups, enhance their antioxidant activities, and prolong storage half-life.

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