The effect of particle size and brewing time of Ginger (Zingiber officinale) powder to the characteristic and acceptance of the herbal product

L Ratnawati*, D Desnilasari, L E Yulianti, D Kristanti, D P Putri, E Sholichah, C E Andriansyah and A Herminiati

Research Center for Appropriate Technology, Indonesian Institute of Sciences, JL KS Tubun No.5, Subang, West Java, Indonesia

*Corresponding author and main contributor: lia.romeo@gmail.com

Abstract. Ginger is one of the famous herbals that traditionally medicinal used in Indonesia. In this study, we investigated the effect of particle size and brewing time of ginger powder to the characteristic (moisture content, extractable matter, color and antioxidant activity) and acceptance of the herbal product. This study conducted using a completely randomized design with 2 factors namely particle size (40, 20 and 10 mesh) and brewing time (5, 10, 15, and 20 minutes). The result showed that particle size significantly (p<0.05) affected the moisture content. It is also significantly affected the extractable matter, color, and antioxidant activity. The brewing time was significantly (p<0.05) affected the extractable matter, color, antioxidant activity, and acceptance of the panelist to the ginger extract as herbal product. The largest particle size with the longest brewing tends to produce the highest extractable matter i.e 15.7%. The larger particle size causes a decrease in the L-values, an increase in the a-values, and a decrease in the b-values. The shortest brewing time with 20 mesh tends to produce the highest antioxidant activity i.e 77.97%. In concluding the ginger powder with a 20-mesh particle size and a 5 minutes brewing time was chosen to be the best treatment based on its antioxidant activity and sensory evaluation. It has the characteristics of extractable matter, L, a, b, antioxidant activity and acceptance including color, aroma, taste, after taste and overall namely 10.04%, 30.40, 1.15, 4.07, 77.97%, 3.2, 3.27, 3.1, 3.3 and 3.33, respectively.

1. Introduction

Ginger (Zingiber officinale), a member of Zingiberaceae is widely used as a spice in foods and beverages. Furthermore, it has long been used in traditional medicine as a cure for some disease. Ginger contains active phenolic compounds such as gingerol, shogoal and paradol that have antioxidant [1], anti-cancer [2], anti-inflammatory [3], anti-angiogenesis [4] and anti-atherosclerotic properties [5,6].

Harvest time of ginger is continuously throughout the year, this causes an abundance of fresh ginger on the market. Fresh ginger is perishable and has a short shelf life, so the utilization of it was not optimum. Because has many health benefits and public interest on herbal product was increased, nowadays ginger has been processed in various types of food products such as syrup, instant powder, candy and snacks. Ginger powder is one type of processed ginger. Powdered product is a processed food product that has good solubility in water, easy to serve and has a long shelf life due to its low moisture content. The ginger powder can be utilized for development of different commercial products like cookies, candy, tea, tinctures, sodas, jam, beer and syrup.
Despite of their potential applications, available studies on the effect of particle size and brewing time of ginger powder is limited. Makanjuola [7] studied about influence of particle size and extraction solvent on antioxidant properties of extracts of tea, ginger and tea-ginger blend. The study suggests that particle size influences the extraction of antioxidants. The powder with the lowest particle size of 0.425 mm tends to produce aqueous extracts of tea, ginger and tea-ginger with highest antioxidant content. Zhao et al. [8] reported that superfine grinding of ginger had many significance characteristics: surface area of powder was increased; had the good fluidity, water holding capacity, water solubility index and protein solubility; and was well suited to manufacture instant and convenient foods.

The aim in this study was to investigate the effect of particle size and brewing time of ginger powder on characteristics and acceptance of the herbal product. The characteristics were analyzed include moisture content, extractable matter, color, antioxidant activity and sensory evaluation.

2. Materials and Methods

2.1. Materials
Ginger (Zingiber officinale var. Amarum) simplicia was obtained from Herbal Anugerah Alam (Yogyakarta). Tea bag was purchased from sunshine55.id (Jakarta). 2,2-diphenyl-2-picrylhydrazyl (DPPH) and ascorbic acid for standard were obtained from Sigma-Aldrich Corp. (St. Louis, Mo., USA). Analytical grade ethanol was purchased from Merck Ltd. (Merck Pte Ltd. Singapore). Distilled water was used throughout and obtained from water distiller (Nuve ND12, Turkey). Filter paper was used Whatman No. 41 (GE Healthcare, UK).

2.2. Ginger powder preparation and extraction
Ginger simplicia were crushed using dry mill (Philips HR 2115). The ginger powder were passed through sieves of the following sizes : 40, 20 and 10 mesh. Then, the sieved ginger powder was analyzed for moisture content. The sieved ginger powder was put in a tea bag (3 g) and sealed. The ginger powder in a tea bag were stored in PP plastic for further analysis.

The brewing was prepared by placing 3 g of ginger powder (in a tea bag) in 150 ml of distilled water at boiling temperature (98±2°C) and brewing for 5, 10, 15 and 20 minutes. The samples with different particle size and brewing time were then analysis for extractable matter, color and antioxidant activity. The selected samples based on the antioxidant activity were sensory evaluated.

2.3. Ginger powder and extract characterization

2.3.1. Moisture content. Moisture content of ginger powder was measured using gravimetric method according to procedure described by Indonesian National Standard (SNI 01-2891-1992) [9]. Briefly, 2 g of samples were dried in a air oven (Memmert, Germany) at 105°C until constant weight. The result was expressed in percentage of evaporated water.

2.3.2. Extractable Matter. Extractable matter was analyzed according to procedure described by World Health Organization (WHO) [10] with modifications. Briefly, 3 g of samples in a tea bag brewed using 150 ml of distilled water with the brewing time according to the treatment. Brewing samples were then filtered using whatman paper No.41. Transfer the filtrate to a tared beaker glass and evaporate to dryness on an oven (Memmert, Germany). Dry at 105 °C for 12 hours, cool in a desiccator for 30 minutes, then weigh without delay. Extractable matter was calculated using Equation 1 as follows:

$$\text{Extractable matter (%) } = \frac{\text{dry weight extract}}{\text{dry weight sample}} \times 100\% \tag{1}$$

2.3.3. Color Evaluation. The color of samples was measured according to procedure described by Raja et al. [11]. The ginger extract was measured using a chromameter (NH310, China). The lightness (L=0-100 (black-white)), greenness to redness (-a to +a) and blueness to yellowness (-b to +b) were evaluated.
2.3.4. **Antioxidant activity.** The antioxidant activity of samples was evaluated by using the 2,2-diphenyl-2-picrylhydrazyl (DPPH) according to the method described by Shen et al. [12] with some modifications. Briefly, 2 ml of DPPH (0.1 mM) already dissolved in ethanol (absolute, 100%) were mixed with 2 ml ginger extract and 1 ml ethanol (absolute, 100%). After incubation at room temperature for 30 minutes at 37°C, the absorbance was measured at 517 nm using an UV-Vis spectrophotometer (UV 1900, Shimadzu, Japan). Ascorbic acid was used as standard. The results were expressed as the percentage of inhibition of the DPPH radical and calculated using Equation 2 as follows:

\[
\text{Antioxidant activity (\%)} = \frac{\text{Absorbance of blank} - \text{Absorbance of sample}}{\text{Absorbance of blank}} \times 100% \tag{2}
\]

2.3.5. **Sensory evaluation.** Sensory evaluation was conducted according to the method described by Hariharan and Mahendran [13]. Sensory evaluation was carried out using 20-30 ml of samples from brewing results which have placed in a glass then they served to 30 untrained panelists. The panelists filled on the organoleptic test sheets to give score preference for each sample based on a numerical scale (1-5), starting from very dislike (1) to very like (5). The scoring includes preferences for color, taste, aroma, aftertaste and overall.

2.4. **Statistical analysis**

An Analysis of Variance (ANOVA) and Duncan test (confidence level, \(\alpha:0.05\)) were performed on the obtained results in order to establish significant differences. SPSS version 13 was used for data treatment and statistical analysis. All measurements were carried out in triplicate and the results were expressed as the mean value ± standard deviation (SD).

3. **Result and Discussion**

3.1. **Moisture content**

The moisture content of ginger powder was ranged between 10.11-11.40 % (figure 1). The moisture content of ginger powder in the present study had fulfilled Indonesian National Standard (SNI 3933-1994) : Ginger which required the maximum moisture content in dried ginger is 12 % [14].

![Figure 1. Moisture content of ginger powder with different particle size](image)

The moisture content of ginger powder with 40 mesh particle size was significantly different \((p<0.05)\) from ginger powder with 10 mesh particle size, but not significantly different \((p>0.05)\) from ginger powder with 20 mesh particle size. As could be seen in Figure 1, the moisture content of ginger powder with larger particle size (10 mesh) had higher moisture content than smaller particles size (40 mesh). This result in line with the previous studies conducted by Raja et al. [11], stated that *Carica* leaf powder...
with larger particle size also had higher moisture content. The larger particle size of ginger powder may still have water trapped in the plant tissue. In addition, ginger powder with smaller particle size, the evaporation of water vapor will be more optimal when drying due to the greater surface area. In the drying process, the particle size is closely related to surface area. The larger particle size would reduce the surface area so that the water evaporation not optimal.

3.2. Extractable matter and color evaluation

Extractable matter is the number of active constituents extracted with solvents from a given amount of herbal material [10]. The larger particle size and the longer the brewing time increases the extractable matter. The difference in particle size and brewing time were significantly affected extractable matter (p<0.05) (Table 1). The highest extractable matter (15.70%) was obtained from treatment with 10 mesh particle size and 20 minutes brewing time. Meanwhile, the lowest extractable matter (5.65%) was found in samples with treatment 40 mesh particle size and 5 minutes brewing time. Previous study by Sembiring et al. [15] suggested that the longer the extraction time the higher extractable matter. The extractable matter of red ginger (Zingiber officinale var. Rubrum) extract increased with increasing temperature and extraction time, it was optimal at 95°C for 15 minutes [16].

Based on Table 1, particle size was proportional to the extractable matter value. The smaller particle size, the lower extractable matter value. It is due to the possibility that during extraction of dried ginger with finer particle sizes, the material extracted was carbohydrate or starch. Ajayi et al. [17] reported that carbohydrate content dried ginger was higher than raw ginger, it was 16.7% and 68.7%, respectively. In the process of analyzing extractable matter, there are several stages of filtering using Whatman filter paper No.41. It caused the extracted carbohydrate/starch was restrained at filter paper. Therefore, the component that really extracted was the active component and other substances that are soluble in water.

Table 1. Extractable matter, L, a and b-values of ginger extracts with different particle size and brewing time

| Particle Size (mesh) | Brewing Time (minutes) | Extractable Matter (%) | L       | a       | b       |
|---------------------|------------------------|------------------------|---------|---------|---------|
| 40                  | 5                      | 5.65 ± 1.03<sup>Ab</sup> | 30.07 ± 0.01<sup>Bc</sup> | 1.19 ± 0.01<sup>Aa</sup> | 4.19 ± 0.03<sup>Ca</sup> |
| 10                  | 5                      | 5.91 ± 0.95<sup>Ab</sup> | 30.36 ± 0.03<sup>Bc</sup> | 1.15 ± 0.03<sup>Ab</sup> | 4.21 ± 0.01<sup>Cb</sup> |
| 15                  | 5                      | 7.15 ± 1.13<sup>Ab</sup> | 29.70 ± 0.02<sup>Ba</sup> | 1.36 ± 0.03<sup>Ad</sup> | 4.16 ± 0.01<sup>Cb</sup> |
| 20                  | 5                      | 8.28 ± 0.44<sup>Ac</sup> | 29.97 ± 0.02<sup>Ab</sup> | 1.29 ± 0.01<sup>Ac</sup> | 4.03 ± 0.00<sup>Ca</sup> |
| 10                  | 10                     | 10.04 ± 1.77<sup>Ba</sup> | 30.40 ± 0.02<sup>Bc</sup> | 1.15 ± 0.01<sup>Aa</sup> | 4.07 ± 0.03<sup>Ac</sup> |
| 15                  | 10                     | 10.36 ± 0.86<sup>Bab</sup> | 29.87 ± 0.04<sup>Bc</sup> | 1.33 ± 0.02<sup>Ab</sup> | 4.02 ± 0.01<sup>Ab</sup> |
| 20                  | 10                     | 10.82 ± 0.92<sup>Bbc</sup> | 29.92 ± 0.06<sup>Bb</sup> | 1.29 ± 0.03<sup>Ad</sup> | 4.02 ± 0.02<sup>Ab</sup> |
| 10                  | 20                     | 11.55 ± 0.82<sup>Bbc</sup> | 30.00 ± 0.01<sup>Bb</sup> | 1.25 ± 0.03<sup>Ac</sup> | 4.03 ± 0.03<sup>Ab</sup> |
| 10                  | 5                      | 12.57 ± 0.95<sup>Ca</sup> | 29.70 ± 0.23<sup>Ac</sup> | 1.39 ± 0.02<sup>Ba</sup> | 4.11 ± 0.02<sup>Bc</sup> |
| 10                  | 10                     | 14.27 ± 0.67<sup>Cab</sup> | 29.86 ± 0.01<sup>Ac</sup> | 1.37 ± 0.02<sup>Bb</sup> | 4.06 ± 0.03<sup>Bb</sup> |
| 15                  | 10                     | 15.23 ± 0.51<sup>Cb</sup> | 29.42 ± 0.07<sup>Aa</sup> | 1.51 ± 0.05<sup>Bd</sup> | 4.12 ± 0.01<sup>Bb</sup> |
| 20                  | 15                     | 15.70 ± 1.01<sup>Cc</sup> | 29.37 ± 0.03<sup>Ab</sup> | 1.44 ± 0.02<sup>Bc</sup> | 4.00 ± 0.02<sup>Ba</sup> |

The capital letters denote significant difference (p<0.05) between the different particle size. The small letters denote significant difference (p<0.05) between different brewing time. Data are means of triplicates (n=3) = SD

The L-values indicates the sample lightness, the greater value showed that lighter the color of sample. The a-values indicates the greenness to redness color. The positive value indicates the redder color. The b-values shows a blueness to yellowness color. The positive value indicates yellower color. The L-values of ginger extracts with various particle size and brewing times were significantly different (p<0.05). Table 1 shows that the treatment of 20 mesh particle size and 5 minutes brewing time had the
highest L-values (30.40), while the treatment of 10 mesh particle size and 20 minutes brewing time had the lowest L-values (29.30). It is shown that the ginger extracts from smaller particle and faster brewing time were much lighter than those from larger particle and longer brewing time. This results in accordance to the previous studies conducted by Ibrahim et al. [16], stated that the lightness value of ginger juice tends to decrease (dark) along with the increase in extraction temperature and extraction time.

Based on the instrumental measurements, ginger extracts from larger particle and longer brewing time were much redder than finer particle and faster brewing time as shown by the high and positive a-values (table 1). The a-values of ginger extracts with various particle size and brewing times were significantly different (p<0.05). The a-values tends to increase with increasing temperature and extraction time [16]. The red color in ginger extracts comes from Edulan II compounds which are classified as carotenoid groups [18]. In contrary, the b-values of ginger extract from larger particle sizes and longer brewing time were showed decreased. The particle size and brewing time were significantly affected on b-values of ginger extracts (p<0.05). It is shows that smaller particle and faster brewing time produce a yellower ginger extract. The yellow color comes from oleoresin contained in ginger. Ginger oleoresin is bright yellow, yellow to dark brown. Ginger oleoresin components consist of gingerol, zingiberen, shogaol, essential oils and resins [16]

3.3. Antioxidant Activity
The antioxidant activity of ginger extracts was evaluated using DPPH assay and the results are shown in table 2.

| Particle Size (mesh) | Brewing Time (minutes) | Antioxidant activity (%) |
|---------------------|------------------------|--------------------------|
| 40                  | 5                      | 74.91 ± 0.16<sup>ba</sup> |
|                     | 10                     | 71.60 ± 1.58<sup>b</sup> |
|                     | 15                     | 69.08 ± 0.90<sup>bc</sup> |
|                     | 20                     | 64.29 ± 0.40<sup>d</sup> |
| 20                  | 5                      | 77.97 ± 0.92<sup>ba</sup> |
|                     | 10                     | 75.37 ± 1.26<sup>lb</sup> |
|                     | 15                     | 63.79 ± 2.39<sup>lc</sup> |
|                     | 20                     | 60.79 ± 2.49<sup>bd</sup> |
| 10                  | 5                      | 66.44 ± 1.01<sup>a</sup> |
|                     | 10                     | 65.40 ± 1.56<sup>Ab</sup> |
|                     | 15                     | 64.38 ± 0.43<sup>Ac</sup> |
|                     | 20                     | 65.18 ± 0.26<sup>ad</sup> |

The capital letters denote significant difference (p<0.05) between the different particle size. The small letters denote significant difference (p<0.05) between different brewing time. Data are means of triplicates (n=3) = SD

The antioxidant activity of ginger extracts was showed in ranged 60.79-77.97%. It is shows that the antioxidant activity of ginger extracts in this study had high activity. This refers to the statement of Wulansari and Chairul [19], if the antioxidant activity using the DPPH method has results above 50%, it is indicated as high antioxidant activity; 20–50% shows moderate antioxidant activity; while the result below 20% indicates low antioxidant activity. Other research by Eleazu et al. [20] reported that 75% inhibition of DPPH radical for their best ginger variety, but Shukla et al. [2] reported that higher value 74.33 to 91.25% for ginger sungro-sung variety.

The data showed that the particle size of ginger in this study significantly affected the antioxidant activity of the ginger extracts (table 2). The biggest the particle size has the lowest antioxidant activity
of the ginger powder. This was indicated that the smaller particle would increase the contact surface area. The contact surface area ginger powder with solvent would be maximize the extraction of active compound [21]. Makanjuola [7] reported that size reduction of plant substrates before extraction maximizes the surface area, which in turn enhances the mass transfer of active compound from plant material to the solvent. The antioxidant activity of 40 mesh ginger powder was not significantly different with 20 mesh ginger powder. This also has been reported by Makanjuola [7] that although it is a known fact that a reduction in particle size could always lead to increased extraction efficiency, however, a critical particle size is reached such that any further reduction in the particle size could lead to no further increase-or a reduction-in extraction efficiency. The brewing time in this research showed significantly different to the the antioxidant activity. The result showed that the longer brewing time could decreasing gradually the antioxidant activity. The antioxidant activity, total phenol content, and gingerol content of ginger (Zingiber officinale Rosc.) decreased with increasing the time of thermal processing [18]. The longer the contact time of material with heat is possibility cause the bioactive compound damage. Other research with Centella asiatica by Ariffin et al. [22] with treatment were brewing time in 1 to 20 minutes (at 100°C) showed that the antioxidant activity increased gradually until 10 minutes later become stable. The increasing temperature and extraction time of red ginger (Zingiber officinale var. Rubrum) extract affect the increasing of antioxidant activity and total phenol, it was optimal at 95°C for 15 minutes [16].

3.4. Sensory Evaluation
The sensory evaluation of ginger extracts with different brewing time are shown in Table 3.

Table 3. Sensory evaluation of ginger extracts with the different brewing time

| Particle Size (mesh) | Brewing Time (minutes) | Color | Aroma | Taste | Aftertaste | Overall Acceptance |
|----------------------|------------------------|-------|-------|-------|------------|--------------------|
| 20                   | 5                      | 3.20\textsuperscript{a} | 3.27\textsuperscript{ab} | 3.10\textsuperscript{a} | 3.30\textsuperscript{a} | 3.33\textsuperscript{ab} |
| 10                   | 3.43\textsuperscript{a} | 3.33\textsuperscript{ab} | 3.30\textsuperscript{a} | 3.30\textsuperscript{a} | 3.43\textsuperscript{ab} |
| 15                   | 3.10\textsuperscript{a} | 3.03\textsuperscript{a} | 2.93\textsuperscript{a} | 3.07\textsuperscript{a} | 3.07\textsuperscript{a} |
| 20                   | 3.87\textsuperscript{b} | 3.63\textsuperscript{b} | 3.33\textsuperscript{a} | 3.53\textsuperscript{a} | 3.63\textsuperscript{b} |

Notes: Different uppercase letters in the same column indicate significant differences (p<0.05).

Based on the extractable matter value and the antioxidant activity of ginger extract, the best particular size for extraction was 20-mesh. This data showed that color parameter of ginger extracts with different brewing time was not significantly different, except the ginger extracts with 20 minutes brewing time was significantly different from other treatments. The panelist preferable for color parameters were ranged from 3.10-3.87 (rather like). The treatment with 20 minutes brewing time had highest score on color parameter. From table 3 could be seen that aroma of ginger extracts was not significantly different, except the samples with 15 minutes brewing time was significantly different from the samples with 20 minutes brewing time. The panelists rated the aroma in the range of 3.03-3.63 (rather like). The treatment with 20 minutes brewing time had highest score on aroma. The major of hydrocarbon groups that influenced the aroma of ginger were α-pinene, camphene, β-phellandrene and ar-curcumene. In addition, the presence of geranyl acetate from volatile oil that have a ginger-like odor contributing to the most ginger aroma [18].

The taste score for samples were ranged between 2.93-3.33 (dislike to rather like) (table 3). From the statistical analysis, the brewing time was not significantly affected (p>0.05) on the taste. The highest taste score was 20 minutes brewing time treatments. As could be seen from Table 3, that aftertaste of ginger extracts was not significantly different (p>0.05). The aftertaste score for samples were ranged 3.07-3.53 (rather like). The highest aftertaste score was 20 minutes brewing time treatments. The taste and aftertaste in this sensory evaluation was to describe the pungency of ginger extracts. The compounds
responsible for the pungency taste of ginger are zingerone, 6-gingerol, 8-gingerol, 10-gingerol, shogaol and 1-dehydro-10-gingerdione [23; 24].

Table 3 showed that overall acceptance of ginger extracts with different brewing time was not significantly different, except the ginger extracts with 15 minutes brewing time was significantly different from the ginger extracts with 20 minutes brewing time. The overall acceptance score for samples were ranged 3.07-3.63 (rather like) with the highest score for overall acceptance was 20 minutes brewing time. This result supported by data of the extractable matter and a-values (table 1). The ginger extract which brewed for 20 minutes had the highest of extractable matter and a-values. This result indicated that the brewing of ginger extract for 20 minutes produced a brownish yellow extract with the stronger aroma and taste of ginger.

Although the panelist acceptance of ginger extract with a 20-minute brewing time had the highest score, the selection of the best treatment was based on the highest antioxidant activity, namely the 20-mesh particle size and 5 minutes brewing time. It is also based on the results of sensory evaluation between ginger extract of 5 and 20 minutes of brewing time were not significantly different for the taste, aroma, aftertaste and overall acceptance.

4. Conclusion

The particle size significantly affected the moisture content, extractable matter, color, and antioxidant activity. The brewing time was significantly affected the extractable matter, color, antioxidant activity, and acceptance of the panelist to the ginger extract as herbal product. The largest particle size with the longest brewing tends to produce the highest extractable matter. The larger particle size causes a decrease in the L-values, an increase in the a-values, and a decrease in the b-values. The shortest brewing time with 20 mesh tends to produce the highest antioxidant activity. In concluding the ginger powder with a 20-mesh particle size and a 5 minutes brewing time was chosen to be the best treatment based on its antioxidant activity and sensory evaluation.

Acknowledgments

The authors are grateful to Research Center for Appropriate Technology for providing the experimental facilities and to the Indonesian Institute of Sciences for financial support.

References

[1] Stoilova I, Krastanov A, Stoyanova A, Denev P and Gargova S 2007 Antioxidant activity of a ginger extract Food Chem 102 764-770
[2] Shukla Y and Singh M 2007 Cancer preventive properties of ginger: a brief review Food Chem Toxicol 45 683-690
[3] Mashhadi N S, Ghasvand R, Askari G, Hariri M, Darvishi L and Mofid M R 2013 Anti-oxidative and anti-inflammatory effects of ginger in health and physical activity: review of current evidence Int J Prev Med 4 36-42
[4] Kim E C, Min J K, Kim T Y, Lee S J, Yang H O, Han S, Kim Y M and Kwon Y G 2005 [6]-Gingerol, a pungent ingredient of ginger, inhibits angiogenesis in vitro and in vivo. Biochem Bioph Res Co 335 300-308
[5] Boroujeni H R, Gharipour M, Samani M A and Boroujeni H M 2016 The protective effects of ginger on the development of coronary atherosclerosis: an experimental animal study Der Pharmacia Lettre 8 105-109
[6] Gunathilake K D P P and Rupasinghe H P V 2015 Recent perspective on the medicinal potential of ginger Botanics: Targets and Therapy 5 55-63
[7] Makanjuaola S A 2017 Influence of particle size and extraction solvent on antioxidant properties of extracts of tea, ginger and tea-ginger blend Food Sci Nutr 1-7
[8] Zhao X, Yang Z, Gai G and Yang Y 2009 Effect of superfine grinding on properties of ginger powder J Food Eng 91 217-222
[9] Badan Standarisasi Nasional (BSN) SNI 01-2891-1992 Cara uji makanan dan minuman (How to test food and drinks) Jakarta

[10] World Health Organization (WHO) 1998 Quality control methods for herbals materials Switzerland ISBN 978 92 4 150073 9

[11] Raja K S, Taip F S, Azmi M M Z, Shisir M R I 2019 Effect of pre-treatment and different drying methods on the physicochemical properties of Carica papaya L. leaf powder J Saudi Agr Sci 18 150-156

[12] Shen Q, Zhang B, Xu R, Wang Y, Ding X, Li P 2010 Antioxidant activity in vitro of the selenium-contained protein from the Se-enriched Bifidobacterium animalis 01 Anaerobe 16 380-386

[13] Hariharan G and Mahendran T 2016 Physico-chemical, sensory and microbial evaluation of ginger-lime ready-to-serve (RTS) functional beverage, sweetened by palmyma sugar candy Imperial J Interdisciplinary Res 2 1545-1552

[14] Badan Standarisasi Nasional (BSN) SNI 3933-1994: Ginger Jakarta

[15] Sembiring B B, Ma'mun, Ginting E I 2006 Pengaruh kehalusan bahan dan lama ekstraksi terhadap mutu ekstrak temulawak (Curcuma xanthorriza Roxb) (Effect of fineness of the ingredients and extraction time on the quality of temulawak extract (Curcuma xanthorriza Roxbi)) Bul Littro 17 53-58

[16] Ibrahim A M, Yunianta, Sriherfyna F H 2015 Effect of Temperature and Extraction Time on Physicochemical Properties of Red Ginger (Zingiber officinale) var. Rubrum Extract with The Additional of Honey Combination as Sweetener for Functional Drink J Pangan dan Agroindustri 3 530-541

[17] Ajayi O A, Ola O O, Akinwunmi O O 2017 Effect of drying method on nutritional composition, sensory and antimicrobial properties of Ginger (Zingiber officinale) Int. Food Res J. 24 614-620

[18] Purnomo H, Jays F and Widjanarko B 2010 The effects of type and time of thermal processing on ginger (Zingiber officinale Roscoe) rhizome antioxidant compounds and its quality) Int. Food Res J 17 335-347

[19] Wulansari D, Chairul 2011 Penapisan aktivitas antioksidan dan beberapa tumbuhan obat Indonesia menggunakan radikal 2,2-diphenyl-1 picrylhydrazyl (DPPH) (Antioxidant screening activity of several Indonesian medicinal plants using 2,2-diphenyl 1-1 picrylhydrazyl (DPPH)). Majalah Obat Tradisional 16 22 – 25

[20] Eleazu C, Amadi C, Iwo G, Nwoso P, Ironua C 2013 Chemical Composition and Free Radical Scavenging Activities of 10 Elite Accessions of Ginger (Zingiber officinale Roscoe) J. Clin. Toxicol. 3 155–159

[21] Maulida R, Guntarti A 2015 The influence of particle size of black rice (Oryza sativa L.) on extract yield and total anthocyanin content Pharmaciana 5 9–16

[22] Ariffin F, Chew S H, Bhupinder K, Karim A A, Huda N 2011 Antioxidant capacity and phenolic composition of fermented Centella asiatica herbal teas J Sci Food Agric 91 2731–2739

[23] Jayashree E, Visvanathan R, John Z T 2014 Quality of dry ginger (Zingiber officinale) by different drying methods J Food Sci Tecnol 51 3190-3198

[24] Tiwari S, Saha S N, Tiwari A, Patel Y K 2020 Ginger Physico Chemical Properties and It’s Consumer Products processing: A Review Int Arch App Sci Technol 11 159-169