

Article

Effects of Spray-Drying Temperatures and Carriers on Physical and Antioxidant Properties of Lemongrass Leaf Extract Powder

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Abstract: This research was conducted to identify influences of spray-drying temperatures and carriers on physical and antioxidant properties of lemongrass leaf extract powder. Two variables including: inlet temperatures (110 °C, 120 °C, 130 °C, 140 °C and 150 °C) and carriers (Gum Arabic, Maltodextrin and Gum Arabic: Maltodextrin mixture) were studied. Loose density, moisture content, solubility, total phenolic content (TPC), total flavonoid content (TFC) and antioxidant capacity of the obtained powder were analyzed. Overall, moisture content, TPC and TFC were reduced; however, loose density, solubility and antioxidant capacity were enhanced when temperature increased. Among all powder samples, the one produced at 110 °C had the highest TPC (3.02 mg GAE/100 g DW) and TFC (541.82 mg CE/100 g DW) compared to the others. However, due to high moisture content, which is not suitable for the shelf life of powder product, this condition cannot be recommended as a favorable condition for lemongrass powder manufacturing. The powder samples produced by mixing with Maltodextrin at 130 °C retained the high levels of antioxidant capacity, TFC, TPC and had the highest water-soluble ability and lowest moisture content as compared to the others, matching well with quality requirements for an instant powder product.

Keywords: lemongrass powder; spray-drying; inlet temperatures; carriers; total phenolic content; total flavonoid content; antioxidant capacity

1. Introduction

Lemongrass (*Cymbopogon citratus* L.), a native plant, is mostly grown in tropical and savannah regions. Asia, Indonesia, Taiwan, India, Taiwan, and China are well-known countries that have a long history of lemongrass cultivation and production [1]. Due to owning a fresh and strong lemon-like odor, lemongrass is widely used in deodorants, instant herbal teas, skin care products, fragrances, insect repellents and for aromatherapy. Previous studies have identified and isolated numbers of phenolic compounds from lemongrass, which work as antioxidants and pose several positive health effects [2,3]. Moreover, it has been proven that extracts of *C. citratus* leaves have antimicrobial activity against many kinds of microorganisms [4–7]. However, most of the industrial processes are using the plant stalks only. Thus, in order to reduce the production's waste and fully utilize the benefit of the lemongrass plant, the solution of using lemongrass leaf, a wasted part of the lemongrass plant, should be paid more attention.

Spray drying is a process by which a liquid will be turned into dried particles by a hot drying gas medium [8]. The spray-drying process reduces water activity of products, retards bacterial degradation and extends the product's shelf life. Nowadays, spray drying is widely used in pharmaceutical, food

and chemical industries. Several powder products have been produced using spray drying such as milk, fruits juices, herbal extracts, enzymes, essential oil, aromas and medicines [9]. The advantages of spray drying is the capacity of processing different types of materials and obtaining a dried product with pre-specified properties relating to the good quality and healthy substance content of products. Processing factors affecting particle size, loose density and nutrient contents of the spray-dried powder include inlet and outlet drying temperature [10], humidity, feed flow rate of drying gas [11], liquid material and atomizer speed [11]. Among these factors, spray drying carriers or spray drying aids can facilitate the spray-drying process. Starch, modified starch, maltodextrin, solid corn syrup and gum Arabic etc., are kinds of high molecular weight carbohydrates commonly used as spray-drying carriers. The main functions of spray-drying carriers are to increase glass transition temperature of product, and reduce stickiness and wall deposition during spray-drying. According to Quek et al. [12], maltodextrins and gum Arabic are mainly used in spray drying due to their high solubility and low viscosity that are important properties of the spray-dried powder. Additionally, there are few reports found that the combination of gum Arabic and maltodextrin in spray drying was more efficient than using them separately [13,14]. Based on these reasons above, this research was carried out in order to make use of and diversify products from the lemongrass leaves. Effects of two factors including spray-drying temperature and type of carriers on the quality of the powder obtained were investigated.

2. Materials and Methods

2.1. Sample Preparation

Fresh lemongrass leaves collected from a farm in Tien Giang province, Vietnam, were transported to the International University laboratory in the day. The leaves were washed under running tap to remove dirt and any impurities. They were left at room temperature for 1 day. To produce an extract, 100 g lemongrass leaves were cut into small pieces, simmered into a conical flask containing 500 mL of distilled water at 50 °C for 1 h [15]. The mixture was filtered twice with cheesecloth before final filtering with Whatman no.1 paper. The leaf extract was kept in air tied bottles and stored at 4 °C until being used [15].

Carrier solutions were separately prepared by dispersing maltodextrin (MD); gum Arabic (GA) or the mixture of maltodextrin and gum Arabic powder into 40 °C distilled water at 7:3 (*w/w*) ratio. The carrier solutions were mixed with lemongrass leaf extract using Wids Homogenizer (Wids, Frankfurt, Germany). The ratio between lemongrass extracts and carrier solutions was 3:1 in dry basis as described by Kanakdande et al. [16]. The mixture was spray-dried using a Lab Plant SD06 spray dryer (Keison, Chelmsford, UK). The lemongrass spray-dried powders were stored in airtight bottles at 4 °C for further analysis.

2.1.1. Study on Effects of Temperature on the Powder Properties

To examine effects of spray-drying temperature on physical and antioxidant properties of the lemongrass leaf powder, a mixture of lemongrass leaf extract and gum Arabic at ratio 3:1 was spray-dried at different temperatures of 110 °C, 120 °C, 130 °C, 140 °C and 150 °C with the same feed flow rate at 280 mL/h and air speed at exhaust about 1.4 m/s [17].

2.1.2. Study on Effects of Carriers on the Powder Properties

To examine effects of different carriers on physical and antioxidant properties of the lemongrass leaf powder, mixtures of lemongrass leaf extract and carriers including gum Arabic (GA), maltodextrin (MD) and mixture of maltodextrin: gum arabic (MX) at ratio 7:3 were separately sprayed at 130 °C and 280 mL/h [16].

2.2. Analytical Methods

2.2.1. Determination of Loose Density

According to Murakami et al. [18], loose density of powder was determined by pouring powder sample into 100 mL glass cylinder. When the sample volume reached 1 mL, weight of sample was measured. The loose density was calculated by dividing weight to volume of the obtained powder.

$$\text{Loose density (g/mL)} = \frac{\text{weight of sample at 1 mL}}{\text{volume of sample}} \quad (1)$$

2.2.2. Determination of Moisture Content

Moisture contents of the powders collected were measured following AOAC method 976.05. In detail, samples were dried at 105 °C until obtaining constant weight. The moisture content was determined by the weight difference between the initial weight and final weight and expressed as percentage.

$$\text{Moisture content (\%)} = \frac{\text{Final weight} - \text{initial weight}}{\text{weight of sample}} \times 100 \quad (2)$$

2.2.3. Determination of Water Solubility of Powder

The water solubility of the obtained powders was determined using a method of Takasi and Seibi [19], with some modifications. Briefly, 0.1 g of each sample was dissolved into 1 mL of distilled water at 30 °C. The mixture was then centrifuged at 9500 rpm for 10 min. The supernatant was dried at 105 °C until reaching moisture content of the initial sample. The weight of the solids remained was used to calculate the solubility of the samples.

$$\text{Water solubility of powder (\%)} = \frac{\text{weight of solids remained}}{(100\% - \text{MC}) \times \text{weight of sample}} \times 100 \quad (3)$$

2.2.4. Extraction of Total Phenolic Content

Total phenols were extracted based on the method of Vinson et al. [20]. In detail, 0.1 g of lemongrass powder was weighed into a 50 mL screw-cap glass tube and extracted twice using 10 mL of 1.2 M HCL in 50% methanol (*v/v*) (Merck, Darmstadt, Germany) at room temperature for 30 min in the dark with occasional shaking. The extracts were centrifuged at 6000 rpm at 4 °C for 10 min (Z326 K, Hermle Labortechnik GmbH, Wehingen, Germany). The supernatants were collected, combined and stored at −20 °C for further analysis.

2.2.5. Determination of Total Phenolic Content

Total phenolic content was determined based on the Folin-Ciocalteu method as described by Singleton et al. [21]. In brief, 0.5 mL extract was mixed with 2.5 mL Folin-Ciocalteu (F-C) (2N) (Sigma-Aldrich, Steinheim, Germany) and incubated for 5 min. After that, 2 mL of sodium carbonate solution (75 g/L) (Merck, Darmstadt, Germany) was added to the mixture and incubated for another 2 h at 25 °C. After, the absorbance of lemongrass samples was measured using a UV-visible spectrophotometer at a wavelength 765 nm and the calibration curve was prepared by Gallic acid (Merck, Darmstadt, Germany) as the standard chemical. The obtained results were expressed as mg Gallic acid-equivalents (GAE)/100 g powder.

2.2.6. Determination of Total Flavonoid Content

Total flavonoid content (TFC) was measured using the aluminum chloride colorimetric method in which catechin was used as the standard [22]. Briefly, 0.5 mL of extract or catechin solution

(Merck, Darmstadt, Germany) was mixed with 2 mL of distilled water before adding 0.15 mL of 5% NaNO_2 (Merck, Darmstadt, Germany). After 5 min, 0.15 mL AlCl_3 (10%) (Merck, Darmstadt, Germany) was also added along with 1 mL of 1 M NaOH (Merck, Darmstadt, Germany). Then, distilled water was used to make the final volume of 10 mL. The solution was mixed completely and the absorbance was measured versus prepared reagent blank at 510 nm. TFC was expressed as mg catechin equivalents (CE)/100 g powder.

2.2.7. Determination of Antioxidant Capacity

Antioxidant capacity was determined based on 1,1-diphenyl-2-picrylhydrazyl (DPPH) free radical scavenging ability following a method of Tomoko et al. [23], in which the antioxidant activity led to the change of purple color of DPPH (Merck, Darmstadt, Germany). The absorbance was detected using a UV-spectrophotometer at 517 nm. The calibration curve was prepared using Trolox as the standard. Firstly, DPPH solution was prepared by dissolving 3.9 mg of DPPH in 100 mL methanol. Then, 1.5 mL of DPPH solution was added to test tube containing 0.5 mL of lemongrass extracts. The mixture was incubated for 15 min at 25 °C before measuring absorbance.

2.3. Data Analysis

All the experiments were performed triplicate and data presented by mean + standard deviations. Different mean values were analyzed using Minitab software version 17.0. Tukey's test was used to make the comparison between samples with $p < 0.05$.

3. Results and Discussion

3.1. Effects of Different Spray-Drying Temperatures on Physical and Antioxidant Properties of the Lemongrass Leaf Extract Powder

3.1.1. Loose Density

Loose density is associated with the processing, handling and shelf life of the instant powder products [24]. Figure 1 is illustrating the loose density of the lemongrass leaf powders spray-dried at different temperatures. In general, the loose density decreased with increasing of temperatures. As the temperature increased from 110 °C to 150 °C, the loose density dropped from 0.35 g/mL to 0.25 g/mL, respectively. A negative correlation between loose density and spray-drying temperature were obtained ($R = -0.99$) in agreement with findings from previous studies [10,25]. Under high temperature conditions, evaporation was facilitated faster [26], the products with high porosity of fragmented structure and low shrinkage were made. This led to lower density of the spray-dried powders [27]. The products containing higher moisture have higher bulking weight because of the presence of higher amounts of water [11]. Fazaeli et al. [28] and Chegnini and Ghobadian [10] reported that the increasing temperature caused deduction of the loose density of the spray-dried powder. In detail, as the spray-drying temperature increased, the loose densities of mulberry powder and orange juice powder were decreased from 0.45 g/mL to 0.40 g/mL [28] and from 0.35 g/mL to 0.30 g/mL [10], respectively.

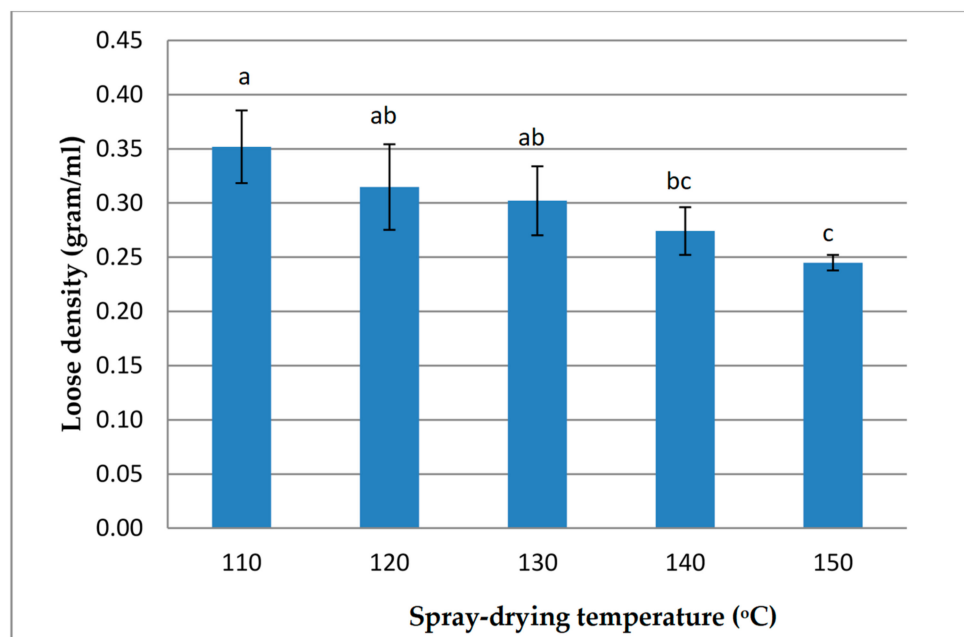


Figure 1. Loose density (g/mL) of lemongrass leaf extract powders at different spray-drying temperatures. All data are the mean \pm SD. Values with different letters are significantly different ($p < 0.05$).

3.1.2. Moisture Content

As can be seen from Figure 2, moisture content of lemongrass powders were ranging from 8.49% to 13.11%. The higher temperatures, the lower moisture contents obtained. An increasing of inlet temperature led to an increasing rate of water evaporation during spray-drying process. As a result, lemongrass powder spray-dried at 110 °C had the highest moisture content (13.11%); meanwhile the powder heated at 150 °C had the lowest value (8.49%). Similar trends were also reported for orange juice, tomato, cactus pear and black carrot powders [10,27,29,30]. It has been reported that moisture contents of spray-dried Gac powders were from 4.5% to 5.3% [31], mulberry powder from 2.2% to 2.5% [28] and tomato juice powders were from 2.9% to 12.4% [27]. As compared to those, the lemongrass leaf extract powders obtained from the current study had higher moisture contents. These differences may due to the origin of materials and spray-drying conditions employed. To sum up, the higher temperatures applied, the lower moisture contents of the powder were obtained.

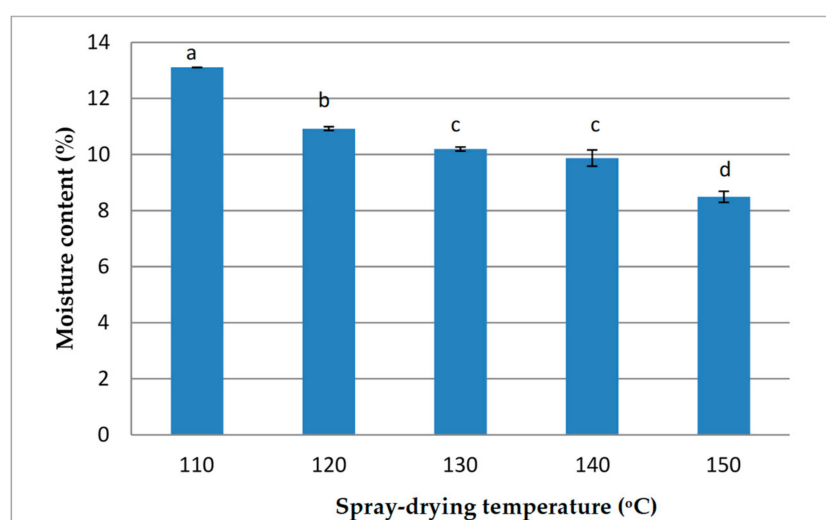


Figure 2. Moisture content (%) of lemongrass leaf extract powders at different spray-drying temperatures. All data are the mean \pm SD. Values with different letters are significantly different ($p < 0.05$).

3.1.3. Water Solubility of Powder

The water solubility of the powder produced at different temperatures is illustrated in Figure 3. In general, the solubility of the powders obtained increased with the rise of spray-drying temperatures. As the inlet temperature rose from 110 °C to 150 °C, the solubility increased from 66.60% to 85.73%. The highest value obtained at 150 °C (85.73%) and the lowest level is of powder produced at 110 °C (93.69%). This observation supported previous research, which were studying tomato powder [27], black mulberry powder [28] and watermelon juice powder [11]. The results could be explained by the fact that the increasing inlet temperatures produced larger particle size powder [32]. The large particles were heavier and thus may be easily sunk; whereas the small ones were lighter therefore just floating on the water's surface. Consequently, the latter caused uneven wetting and reconstitution, therefore reducing the solubility of the powder.

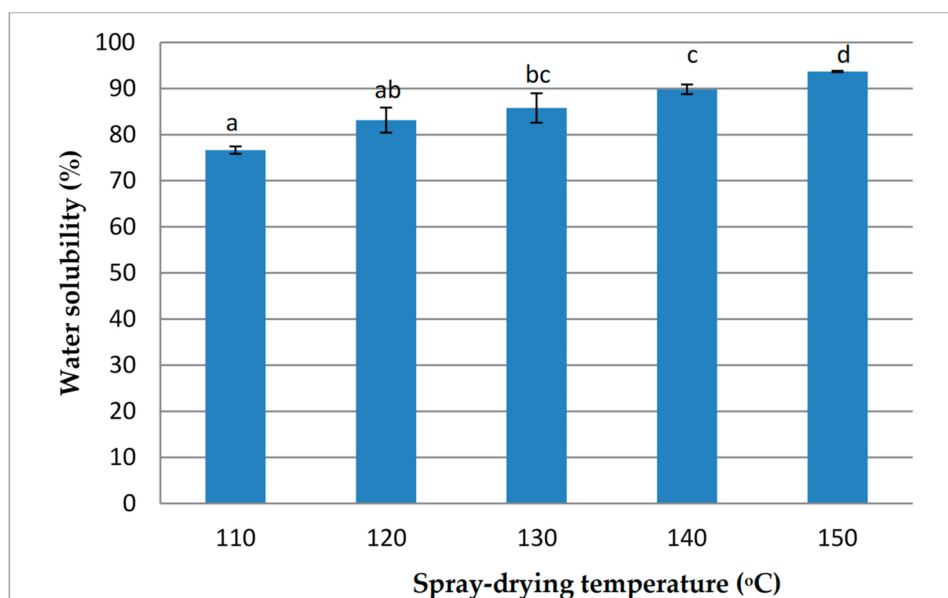


Figure 3. Water solubility (%) of lemongrass leaf extract powders at different spray-drying temperatures. All data are the mean \pm SD. Values with different letters are significantly different ($p < 0.05$).

3.1.4. Total Phenolic Content

It has been known that lemongrass plants contain relatively high amounts of phenolic compounds that may bring positive effects for human health. Nevertheless, the phenolic compounds have been reported to be highly sensible to temperature, therefore they are easily decomposed when exposed to heat treatments [33]. Increasing of spray-drying temperatures led to reducing total phenolic content (TPC) of lemongrass leaf extract powder (Figure 4). When the temperature elevated from 110 °C to 150 °C, TPC was reduced from 3.02 to 2.12 mg GAE/100 g DW. The highest TPC was achieved at 110 °C and the lowest one was collected at 150 °C. Similar observations were found in a research of Misha et al. [34] of which the TPC of amLa juice powder decreased from 250 to 150 mg GAE/100 g DW when spray-drying inlet temperature increased from 125 °C to 175 °C.

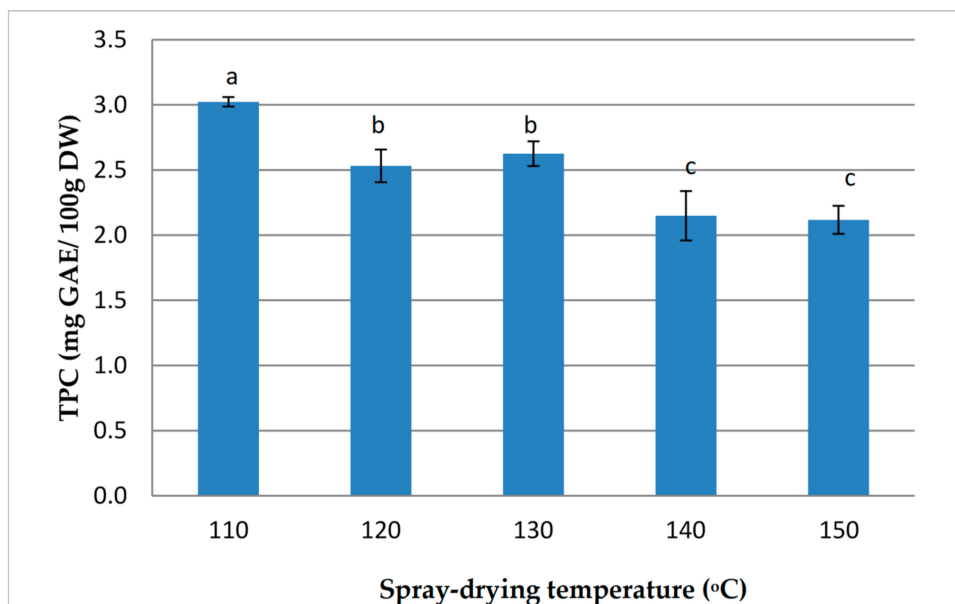


Figure 4. Total phenolic content (TPC) of lemongrass leaf extract powders at different spray-drying temperatures. All data are the mean \pm SD. Values with different letters are significantly different ($p \leq 0.05$).

3.1.5. Total Flavonoid Content

TFC of lemongrass leaf extract powders were demonstrated in Figure 5. In general, TFC of the lemongrass powder was reduced by increasing of spray-drying temperature. TFC reduced from 541.82 to 258.20 mg CE/100 g DW when temperature increased from 110 °C to 150 °C. The highest and lowest flavonoid contents were measured at 110 °C and 150 °C, respectively. A similar observation in spray-drying *Eugenia dysenterica* was reported [35]. Indeed, when the temperature increased from 90 °C to 150 °C, TFC of spray-dried *Eugenia dysenterica* powder decreased from 58% to 57%. Because flavonoid compounds are subgroups of phenolic compounds, which are very sensible to heat, increasing of spray-drying temperature led to the degradation of flavonoid compounds.

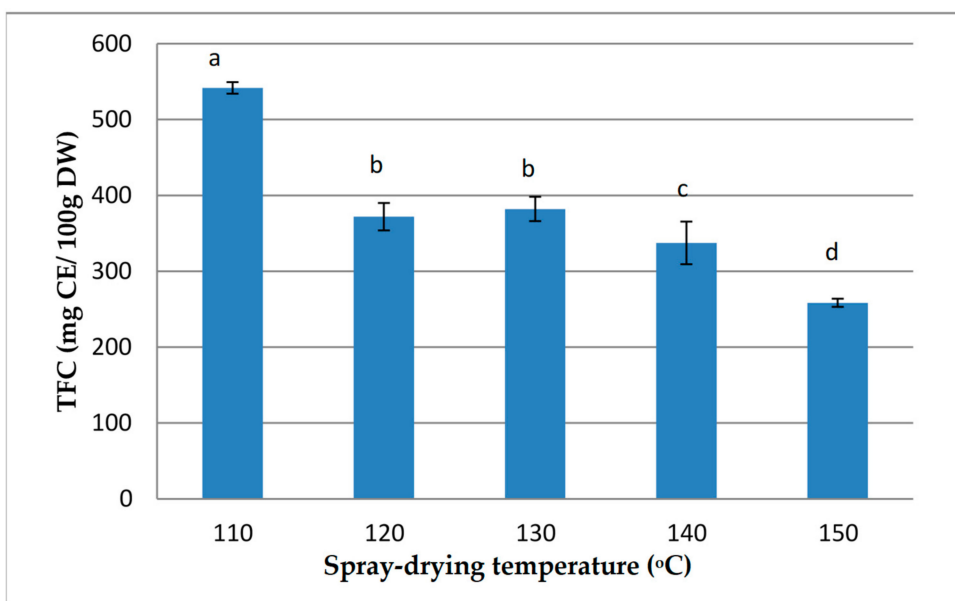


Figure 5. Total flavonoid content (TFC) of lemongrass leaf extract powders at different spray-drying temperatures. All data are the mean \pm SD. Values with different letters are significantly different ($p < 0.05$).

3.1.6. Antioxidant Capacity

Figure 6 showed that antioxidant capacity of the powders increased with increasing of spray-drying temperatures. Indeed, the powders produced at 130 °C, 140 °C and 150 °C had the highest antioxidant capacities whereas the ones dried at 120 °C and 110 °C had the lowest values. This trend could be explained by a possible reason: high spray-drying temperatures may associate with the activation of some phenolic compounds, resulting in an increasing of antioxidant capacity of the powder [36,37]. Nadeem et al. [37] reported that the antioxidant capacity of sage powder significantly increased from 130 $\mu\text{mol TE/g DW}$ to 145 $\mu\text{mol TE/g DW}$ as inlet temperature rose from 145 °C to 165 °C. Tonon et al. [36] also recorded the same tendency for spray-dried acai juice powder.

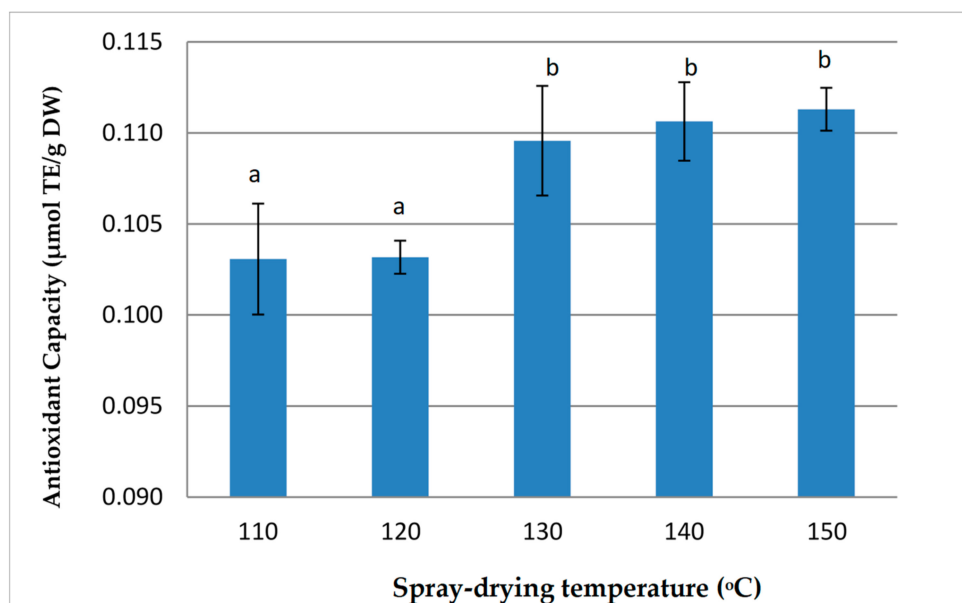


Figure 6. Antioxidant capacity of lemongrass leaf extract powders at different spray-drying temperatures. All data are the mean \pm SD. Values with different letters are significantly different ($p < 0.05$).

3.2. Effects of Different Spray-Drying Carriers on Physical and Antioxidant Properties of Lemongrass Leaf Extract Powder

3.2.1. Loose Density

The loose density of lemongrass leaves extract powders using different spray-drying carriers are shown in Figure 7. Although the loose densities of all powders collected were not significantly different between each other, the powder made with gum Arabic had a higher value at 0.27 g/mL. Tonon et al. [36] recorded the same observation in spray-drying acai juice powder. They found that using gum Arabic as a carrier could produce the powder with a higher loose density as compared to employing Maltodextrin. Moreover, it was explained that the heavier the material is, the easier it accommodates into spaces between particles, thus occupying less space and leading to higher loose density. Since maltodextrin has a higher molecular weight than gum Arabic [36], lemongrass leaf extract powder mixed with the former should have higher loose density.

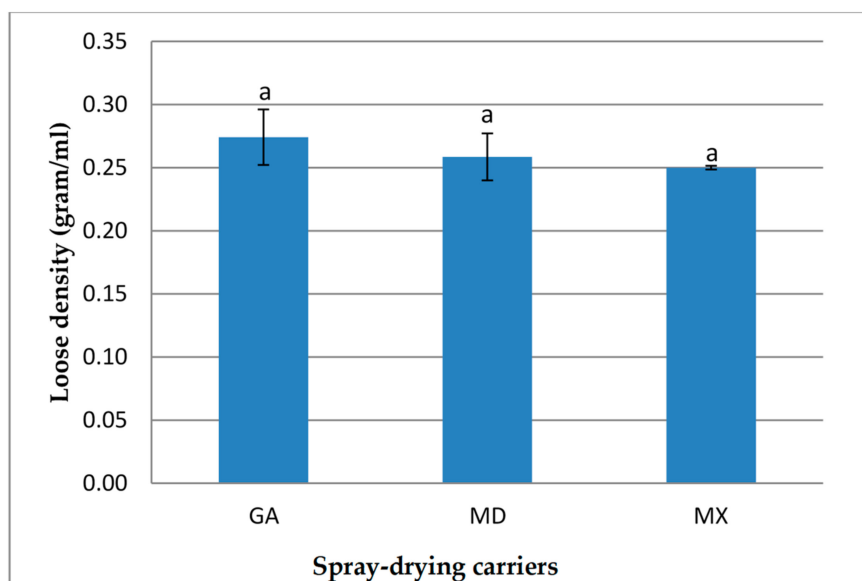


Figure 7. Loose density (g/mL) of lemongrass leaf extract powders using different spray-drying carriers. All data are the mean \pm SD. Values with different letters are significantly different ($p < 0.05$).

3.2.2. Moisture Content

As shown in Figure 8, moisture contents of lemongrass leaf extract powders produced from different carriers were significantly different ($p \leq 0.05$). The highest and lowest moisture contents were obtained in the powders using gum Arabica and maltodextrin with 10.9% and 7.6%, respectively. Meanwhile, the powder produced using the mixture contained 8.5% of moisture content. This could be explained by a fact that the higher hygroscopicity the powder has, the higher moisture content it achieved [38,39]. It was found that the powder prepared by gum Arabic always had higher hydroscopicity than maltodextrin ones [36]. Thus, during handling process after spray-drying, the powder mix with gum Arabic was believed to have a capability of absorbing water from surrounding environments faster than maltodextrin, leading to the higher moisture content they have.

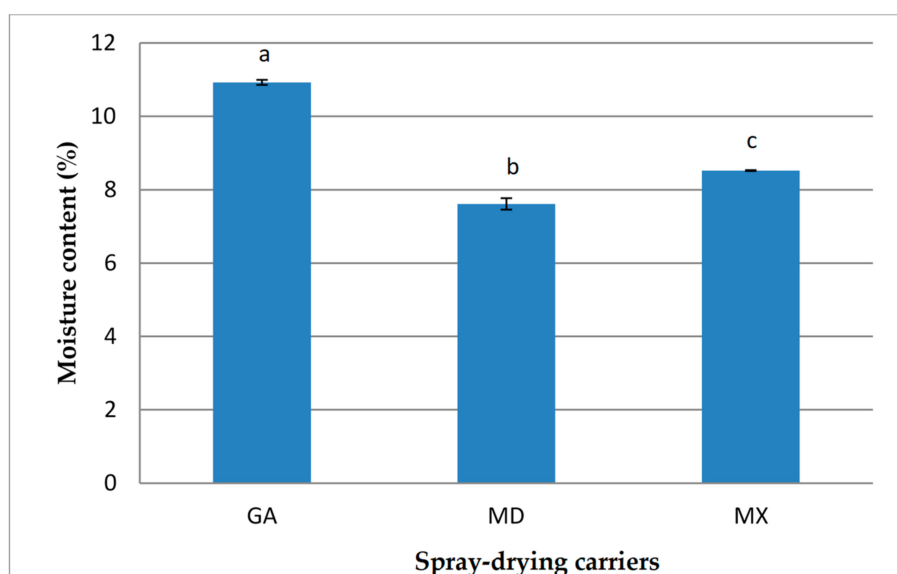


Figure 8. Moisture content (%) of different lemongrass leaf extract powders using different spray-drying carriers. All data are the mean \pm SD of three replicates. Values with different letters are significantly different ($p \leq 0.05$).

3.2.3. Water Solubility of Powder

Figure 9 shows the solubility of different lemongrass leaf extract powders prepared using different kinds of carriers: gum Arabic, maltodextrin and the gum: maltodextrin mixture. Among three types of carriers, the maltodextrin lemongrass powder had the highest solubility (91.57%), followed by the gum Arabic: maltodextrin powder (85.36%) and the gum Arabic powder (83.15%) (Figure 9). The influence of carriers on the solubility may be related to the moisture content of samples. Low moisture content seemed to be associated with fast dissolution [27]. Since the moisture contents of the powders decreased in the order: Gum Arabic, Gum Arabic: Maltodextrin mixture and Maltodextrin (Figure 8), the solubility of these types of powder should be increased in the same order. On the other hand, this result could be explained based on the analysis of particle surface of powder. Regarding to microstructures obtained by spray-dryer using maltodextrin and gum Arabic as carriers, the maltodextrin samples present several forms of particles with larger average particle size. Meanwhile, gum Arabic samples appeared to be more uniform in shape and had a better distribution [39]. Furthermore, Tonnon et al. [35] also reported that the larger particles were easier dissolved in water as they were easier sunk, whereas the smaller ones tend to float on the water surface, leading to uneven wettability and thus having lower water solubility. These records can explain for the highest solubility of Maltodextrin samples obtained from the current work. To compare with results collected by Chauca et al. [39] for mango juice powder, the lemongrass leaf extract powder seemed to have higher water solubility. According to their study, the mango juice powder mixed with maltodextrin had higher solubility as compared with that of gum Arabic one: 85% vs. 80%, respectively.

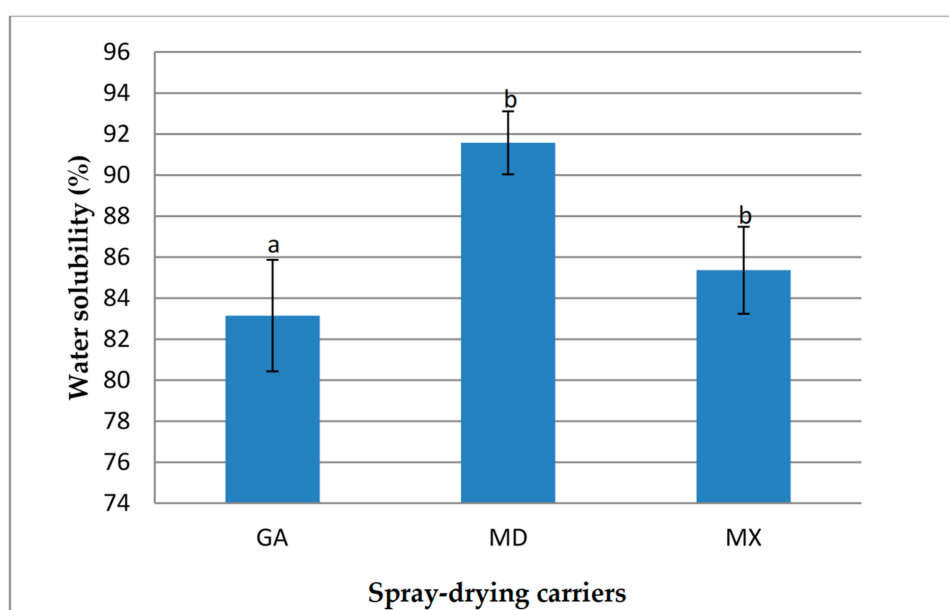


Figure 9. Water solubility (%) of different lemongrass leaves extract powders using different spray-drying carriers. All data are the mean \pm SD of three replicates. Values with different letters are significantly different ($p \leq 0.05$).

3.2.4. Total Phenolic Content

TPC of lemongrass leaf powders produced by different carriers are shown in Figure 10. There was an insignificant difference between gum Arabic and maltodextrin powders ($p < 0.05$). In contrast, the powder produced using the gum Arabic: maltodextrin mixture had the lowest amount (2.12 mg GAE/100 g DW). Published studies have suggested the combination between two kinds of carriers for better encapsulating. However, the finding from the current work showed that using the carriers solely was better in term of maintaining TPC.

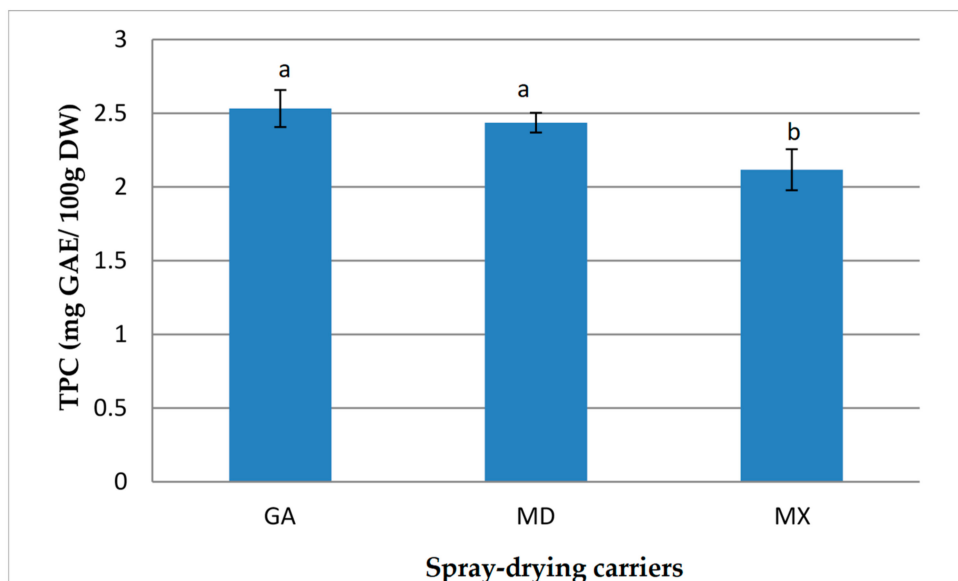


Figure 10. TPC of lemongrass leaf extract powders using different spray-drying carriers. All data are the mean \pm SD. Values with different letters are significantly different ($p < 0.05$).

3.2.5. Total Flavonoid Content

As shown in Figure 11, TFC of different lemongrass leaf extract powders prepared with different carriers were significantly different ($p \leq 0.05$). It could be seen that the powder obtained from using the mixture of gum Arabic: maltodextrin had the highest content of total flavonoid compounds with 393.14 mg CE/100 g DW. In contrast, maltodextrin lemongrass powder had the lowest TFC with 329.10 mg CE/100 g DW. However, there was no significant difference in TFC between maltodextrin and gum Arabic lemongrass powder (372.00 mg CE/100 g DW).

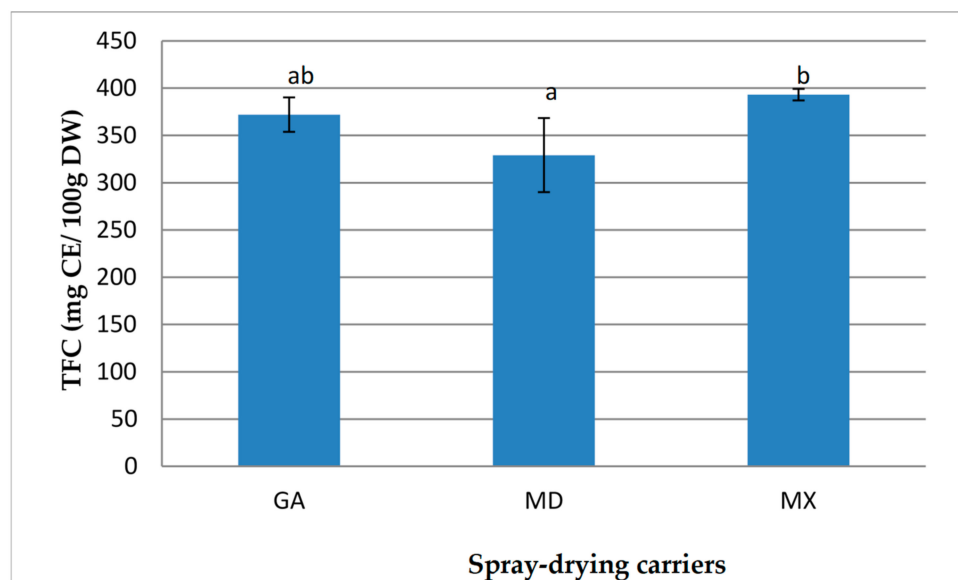


Figure 11. TFC of lemongrass leaf extract powders using different spray-drying carriers. All data are the mean \pm SD. Values with different letters are significantly different ($p < 0.05$).

3.2.6. Antioxidant Capacity

It can be seen from Figure 12, antioxidant capacity of the lemongrass powders prepared using different carriers were significantly different ($p < 0.05$). Maltodextrin sample was recorded with the

highest AC ($0.1288 \mu\text{mol TE/g DW}$). The followings were gum Arabic lemongrass powder ($0.1032 \mu\text{mol TE/g DW}$) and the mixture of gum Arabic: maltodextrin one ($0.0962 \mu\text{mol TE/g DW}$). Comparing with the research on acai powder [36], the same observation was found that acai powder made from maltodextrin could obtain higher antioxidant capacity than gum Arabic at the same concentration. This result could be explained by the fact that the higher solubility of the powder, the higher antioxidant capacity the powder has [36]. Because of the high solubility, when passed through the spray-dryer, maltodextrin powder tended to make a matrix that could entrap the extract and carrier at the same time and produce microencapsulated juice. Nevertheless, gum Arabic, which has lower water soluble activity, tended to produce a powder that contained extract and carrier particles separately. In this case, the extract was not encapsulated totally, leading to the higher degradation of antioxidants under heat treatment [36]. In combination with the obtained results, the maltodextrin powder has higher solubility as compared to the gum Arabic one (Figure 9), therefore it should contain higher levels of antioxidant compounds.

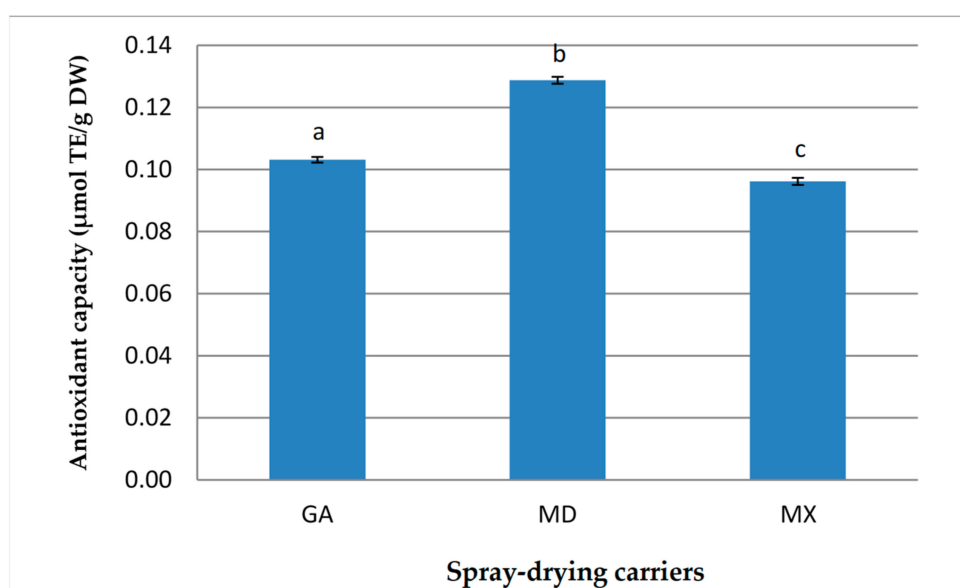


Figure 12. Antioxidant capacity of lemongrass leaf extract powders using different spray-drying carriers. All data are the mean \pm SD. Values with different letters are significantly different ($p < 0.05$).

4. Conclusions

In general, the results obtained from this study showed that the inlet spray-drying temperatures and carriers significantly affected the loose density, moisture content, water solubility, TPC, TFC and antioxidant capacity of lemongrass leaf extract powder. The elevation of spray-drying temperature resulted in the decreasing of moisture content, loose density, TPC and TFC; meanwhile the solubility and antioxidant capacity of the powder increased. Among types of carriers studied, maltodextrin should be used as a potential spray-drying one as it could help to form a powder having relatively high antioxidant capacity, total phenolic, flavonoid content, high water solubility and low moisture content. It is suggested from the current work that to produce the lemongrass leaf extract powder with high antioxidant properties, high loose density, water solubility and low moisture content, applying inlet temperature at 130°C and using maltodextrin as the carrier should be considered.

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