CREATIVE SCIENCE

Journal home page: csj.snru.ac.th

Effect of drying methods on the water soluble phenolics, flavonoids and antioxidant activities in baby jackfruit leaves (*Momordica cochinchinensis* (Lour.) Spreng.) powder

Amornrat Wongklom*, Krittiyapron Siriwan, Saowanee Krairam

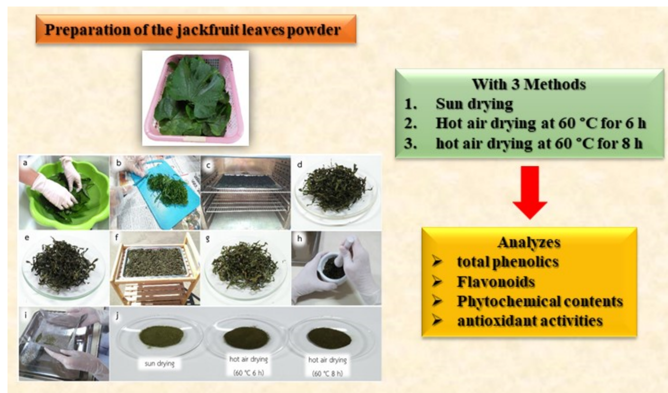
Program of Chemistry, Faculty of Science, Ubon Ratchathani Rajabhat University, Ubon Ratchathani, 34000 Thailand

***Corresponding Author**: amornrat_dekarnkon@hotmail.com

DOI: https://doi.org/10.55674/cs.v15i1.240449

Received: 17 April 2020; **Revised:** 1 January 2022; **Accepted:** 31 January 2022; **Available online:** 1 January 2023

Abstract



The study of effect of drying methods on the water soluble phenolics contents and antioxidant activities in baby jackfruit leaves (*Momordica cochinchinensis* (Lour.) Spreng.; MC) powder were investigated. Three different drying methods were sun drying, hot air drying at 60 °C for 6 h and 8 h. The powder samples were extracted by water as extracting solvent with control 80 °C for 45 min. The extract samples had phytochemicals such as saponin, tannin and terpenoid, phenolics and flavonoids which were analyzed the total phenolics and flavonoids contents. The results found that total phenolics contents were 12.03, 7.78, and 7.08 mg GAE g^{-1} powder and total flavonoids contents were 6.41, 3.49, and 3.35 mg CE g^{-1} powder, respectively. Then, DPPH free radical scavenging activities, ABTS free radical scavenging activities, total antioxidant capacities and reducing powers were investigated. The results showed that DPPH free radical scavenging activities were 6.40, 3.23, and 2.56 mg AAE g^{-1} powder, respectively. ABTS free radical scavenging activities were 17.76, 13.46, and 12.42 mg AAE g^{-1} powder, respectively. Total antioxidant capacities were 28.58, 26.87, and 26.23 mg AAE g^{-1} powder and reducing powers were 5.02, 2.72, and 2.43 mg AAE g^{-1} powder, respectively. The results indicated that the sun dried MC powder showed the values of phytochemicals, phenolics, flavonoids and antioxidant activities higher than the hot air dried MC powder at 60 °C 6 h and 8 h. The drying temperature and time were effect on the water soluble effective compounds and antioxidant activities in baby jackfruit leaves (*Momordica cochinchinensis* (Lour.) Spreng.) powder.

Keywords: baby jackfruit leaves; drying methods; antioxidant activities

1. Introduction

Gack or Gak has the English name; baby jackfruit, cochinchin gourd, spiny bitter gourd, sweet gourd, and the scientific name; *Momordica cochinchinensis* (Lour.) Spreng., Family; Cucurbitaceae. The baby jackfruit leaves can be used as a green drug to neutralize the poison by young shoots and leaves have a bitter taste. It can reduce blood sugar in diabetic patients, cure hemorrhoids, nourish the blood and body [1, 2]. Baby jackfruit is a plant that contained some important substances known as phytochemicals, especially lycopene and beta-carotene which can reduce the risk of various diseases, especially cancer and diabetes [1, 2].

In the present, baby jackfruit has been processing into various products, such as some drinks, foods, tea, and various beauty products. In particular, it is used to produce tea into leaves and powder form. Since tea producing process is a simple process, resulting is produced in a community enterprise. Especially, baby jackfruit leaves (*Momordica cochinchinensis* (Lour.) Spreng.) was often processed to herbal tea. The herbal tea processing base on the drying method to reduce the moisture content (<10% of basis weight) to protect the growth of mold and pathogenic microorganism in leaves or powder tea, resulting reduced quality tea [3]. There are many drying method include sun [4, 5], under shade [6, 7], vacuum [8], hot air (oven) [8, 9], microwave [10], and freeze drying [8, 11, 12]. In addition, the high quality herbal tea must have a high of the active ingredient compounds [3, 13] and antioxidant activities [13 – 16]. Mostly, the community enterprises choosed a simple drying method, such as sun or shade drying was used in a process that not used drier but several limitations due to drying efficiency depending on the weather which cannot the heat level and temperature can be controlled, making it difficult to control the quality of dry herb. In addition, they are not be able to enough eliminate the moisture contents after drying, may be over 10%. The hot air drying uses a dryer, can control the drying temperature in all weather conditions, convenient and fast. Therefore, the different drying methods such as sun and oven drying at 60 °C for 6 – 8 hours were studied. They are simple, eliminate the moisture contents and save cost. The antioxidant properties of baby jackfruit leaves (*Momordica cochinchinensis* (Lour.) Spreng.) powder were studied by using DPPH scavenging activity, ABTS radical scavenging activity, total antioxidant capacity, and reducing power. The moisture content, phytochemicals, total phenolics and flavonoids contents of the different drying methods were studies. The obtained data can be used as the guideline for further development such as a commercial baby jackfruit leaves tea product.

2. Materials and methods

Preparation of the baby jackfruit leaf powder

The baby jackfruit (*Momordica cochinchinensis* (Lour.) Spreng; MC) leaves were sampling from Ban Nong Lai School, Nong Khon Subdistrict, Mueang Ubon Ratchathani District, Ubon Ratchathani Province. The baby jackfruit is a biennial ivy, trunk is a creeping vine, about 20 meters long. The flowers are similar to the gourd flowers, fruit have a width of 5 – 8 cm and 6 – 12 cm long. The leaves look like a single, dark green leaf, alternately arranged by branches and stems. The edges of the leaves are serrated, 3 – 5 lobes deep and the stem of the leaf is 5 – 8 cm. It was washed by tap water three times and then allowed to drain. All of them were sliced to a width that does not exceed 2 mm and weighing 300 g of sliced leaves to be dried in three different drying methods as follows; 1) sun drying (16 h; 29 – 34 °C) 2) hot air drying at 60 °C for 6 h and 3) hot air drying at 60 °C for 8 h, by hot air circulating in the cabinet at a wind speed of 1.5 m/s per square meter of the surface area of the tray and have a pipe system to direct the hot air upward through each tray to distribute the hot air evenly.

After drying, the dried leaves were ground and sieved through a 60-mesh sieve. All of them divided into two parts, the first part was analyzed for moisture contents and water activities, and the second part was stored in a desiccator for analysis of phytochemicals, total phenolics, total flavonoids, DPPH free radical scavenging activities, ABTS free radical scavenging activities, total antioxidant capacities, and reducing powers. The procedure for preparing the MC leaf powder was shown in Fig. 1.

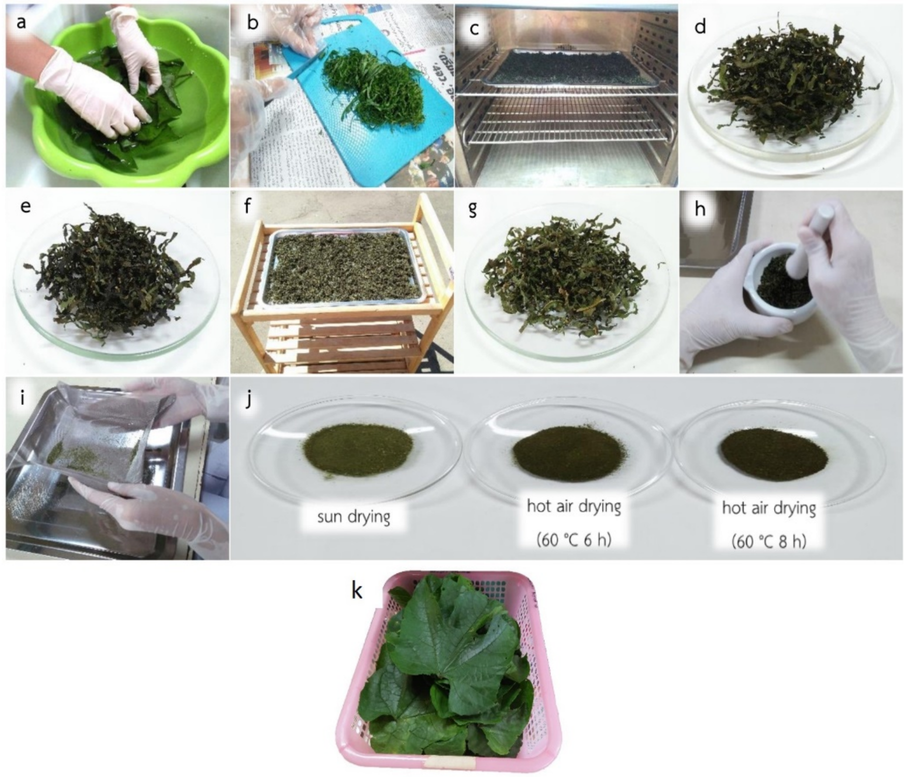


Fig. 1 Preparation of the MC leaf powder; wash the MC leaves (a), sliced into thin slices (b), hot air drying method (c), the hot air dried MC leaves (d, e), sun drying method (f), the sun dried MC leaves (g), grind (h), sieve (i), the MC leaf powder (j), MC leaves (k)

Preparation of extract

In accordance with the objective to produce the MC tea, the water-soluble effective components were extracted with modified method from M. Zheng *et al.* [3]. One gram of the dried MC leaf powder was extracted for 45 min at 80 °C using 150 mL of water. The water extract was filtered pass through filter paper NO.1 and then the extract observed to clear the solution. The MC leaf powder extract was a brownish yellow color and used to analyze the contents of water-soluble effective components, namely phytochemicals, total phenolics, flavonoids, as well as antioxidant activities.

% Moisture content analysis

Analysis of moisture content was followed by AOAC, 1990. The MC leaf powder was weighed about 2 g and baked by a hot air oven at 105 °C for 6 h, until achieving a constant weight (not over 3 mg) [17].

Determination of phytochemical

One gram of MC leaf powder was extracted by 14 mL distilled water at 95 ^{o}C for 5 min. The extract was set up to cool at room temperature, then filter through filter paper NO. 1. Saponin and tannin were determined following the method which reported by S. Shankar *et al.* [18]. Terpenoid was determined following the method from report of K. Sobha *et al.* [19].

Determination of total phenolics contents

Total phenolics contents (TPC) in the MC leaf powder were determined by the Folin-Ciocalteu colorimetric method [3]. A 1 mL extract and 1 mL of gallic acid standard solutions were mixed into a series of the 15 mL vial with 0.50 mL Folin-Ciocalteu reagent, shaken for 30 seconds with a vortex mixer, respectively. After sitting at room temperature for 5 min, the mixture was added with 5 mL 5% (w v^{-1}) Na_2CO_3, and place for 60 min at room temperature. The absorbance of the extract and standard solutions were measured spectrophotometrically at 750 nm. TPC was calculated by the absorbance of extract according to the standard curve as milligrams of gallic acid equivalents per gram of powder (mg GAE g^{-1} powder).

Determination of total flavonoids contents

Total flavonoids contents (TFC) of the MC leaf powder water extracts were determined by the formation of an aluminum-flavonoid complex [13]. Briefly, 600 µLwater extracts and catechin standard solutions were mixed into 2.40 mL distill water, 180 µL 5% (w v^{-1}) $NaNO_2$ and shook well. After sitting for 5 min, 180 µL 10% (w v^{-1}) $AlCl_3$ was added into the mixture, following 1.20 mL 1 M NaOH and 2.40 mL distill water, after sitting for 1 min. After incubation in dark for 5 min, absorbance was measured at 510 nm [20] and TFC was expressed in milligrams of catechin equivalents per gram of powder (mg C Eg^{-1} powder).

DPPH scavenging activity assay

DPPH radical scavenging activities of the MC leaf powder water extracts were determined following the method which reported by Zheng *et.al.* [3]. The method is based on the scavenging of DPPH by antioxidants, which upon a reduction reaction decolorizes the DPPH methanol solution. The assay measures the reducing ability of antioxidants toward the DPPH radical. Aliquot (0.20 mL) of the water extract and ascorbic acid standard solutions were mixed to 5 mL of 0.20 g L^{-1} DPPH solution. After being energetically mixed, the mixture was lifted in the dark at room temperature for 30 min. Then, the absorbance was measured at 517 nm. The percentage of inhibition (%I) of DPPH free radical was calculated using the formula:

$$\%I = [(A_{blank} – A_{sample}) / Ablank] \times 100.$$

DPPH free radical scavenging activities were expressed as milligrams of ascorbic acid equivalents per gram of powder (mg AAE $g^{-}1$ powder).

ABTS scavenging activity assay

ABTS cation radical activity was assayed by the method of Zheng *et.al.* [3]. The 2,2-Azino-bis (3-ethylbenzothiazoline-6-sulfonic acid) diammonium salt was stable radical which solution was green. When added extracts, the extracts will inhibit ABTS radicals was lighten the color of the solution. ABTS cations radical was generated by reacting 7.40-mM ABTS with 2.40 mM potassium persulfate (1 : 1, v $v^{-}1$). Then that was diluted to give an absorbance of 1.00 ± 0.20 at 734 nm. The MC leaf powder water extract and ascorbic acid standard solution (0.20 mL) were mixed into 5 mL diluted ABTS+• solution and lift in dark for 7 min. The absorbance was measured at 734 nm using a spectrophotometer. Results were calculated as milligrams of ascorbic acid equivalents per gram of powder (mg AAE g^{-1} powder).

Total antioxidant capacity assay

The assay was based on the reduction of Mo (VI) to Mo (V) and subsequent formation of a green phosphate/Mo(V) complex in acid pH with modified by N. Chahmi *et al.* [13]. A 0.30 mL of the extract was mixed to 3 mL of reagent solution (0.60 mol L^{-1} sulphuric acid, 28 mmol L^{-1} sodium phosphate, and 4 mmol L^{-1} ammonium molybdate, 1 : 1 : 1). The mixtures were incubated at 95 °C for 90 min and then cooled to room temperature. The absorbance was measured at 695 nm. The total antioxidant capacities were expressed as milligrams of ascorbic acid equivalents per gram of powder (mg AAE g^{-1} powder).

Reducing power assay

Reducing power assay was estimated according to the report of S.C. Liu *et al.* [15]. The reduction reaction of complexes $Fe^{3+}(CN^{-})_6$ to $Fe^{2+}(CN^{-})_6$, which makes the solution a darker blue was measured. An 1 mL MC leaf powder water extract was mixed into 1 mL sodium phosphate buffer (0.20 M, pH 6.60) and 1 mL 1% (w v^{-1}) K3Fe(CN)6, and incubated at 50 °C for 20 min. After adding 1 mL 10% (w v^{-1}) trichloroacetic acid, the mixture was centrifuged at 3700xg for 10 min. Briefly, the 2 mL supernatant was mixed into 2 mL distilled water and 0.40 mL 0.10% (w $v^{-}1$) $FeCl_3$. The absorbance was measured at 700 nm. The reducing power was expressed as milligrams of ascorbic acid equivalents per gram of powder (mg AAE g^{-1} powder).

3. Results and Discussion

Moisture content of powder

The MC leaves were dried by three different drying methods, including a) sun drying (16 h; 29 – 34 ºC), b) hot air drying (60 °C 6 h), and hot air drying (60 °C 8 h) and then ground for analysis of the moisture contents and water activities of the MC leaf powder.

The moisture contents in the MC leaf powder from three different drying methods were shown in Table 1. The results indicated that drying temperature and time had an effect on moisture contents [3 – 5]. The hot air dried MC leaf powder (60 °C 8 h; 5.19%; aw 0.28) had moisture content and water activity lower than the hot air dried (60 °C 6 h; 5.44%; aw 0.29) and the sun dried powder (6.47%; aw 0.32) due to hot air drying used oven which controls a stable temperature at 60 °C for 6-8 h, a long time drying got the lowest moisture content in the powder.

Table 1 Moisture content and water activity of the MC leaf powder from three different drying methods

drying method	moisture content (%)	water activity (a_w)
sun drying	6.47	0.32
hot air drying (60 °C 6 h)	5.44	0.29
hot air drying (60 °C 8 h)	5.19	0.28

Increased drying time (8 h) can pull more water out of the leaf than using a shorter drying time (6 h) under the same drying temperature (60 °C), resulting in lower moisture content. The sun drying used to get the MC leaf in an open of the sunlight which not control a stable temperature for 16 h at 29 – 34 °C. In addition, the leaves may be absorbed by the moisture content in the air around an area, resulting in higher moisture content. This research corresponds to Chen *et.al.* [21], was found the hot air dried samples had moisture content (9.71 ± 0.46%) lower than the air dried (10.39 ± 0.32%) and freeze dried sample (11.78 ± 0.90%), respectively [21]. The research indicated that temperature and time required for drying affected on moisture contents, when high temperature and long drying times, the moisture content will be reduced [24].

Phytochemical content

Phytochemicals contents in the MC leaf powder by three different drying methods were shown in Table 2. The MC leaf powder extract had phytochemicals. The highest of phytochemicals contents existed in the sun dried MC leaf powder among the hot air dried at 60 °C for 6 h and hot air dried powder at 60 °C for 8 h because the sun dried powder has a higher moisture content than the hot air dried powder (60 °C 6 h and 8 h), resulting to the water soluble phytochemicals remained in the powder more than hot air dried powder. The drying temperature is high and time is long, the moisture content is reduced. The water soluble phytochemicals may evaporate with water in the drying process, resulting in phytochemicals contents in the dried powder were low [5, 18, 19].

Table 2 Phytochemical of the MC leaf powder from three different drying methods

drying method	saponin	tannin	terpenoid
sun drying (16 h)	+++	++	+++
hot air drying (60°C 6 h)	++	++	++
hot air drying (60°C 8 h)	+	+	++

Total phenolics and flavonoids contents

The water soluble phenolics and flavonoids contents in MC leaf powder by three different drying methods were shown in Table 3. The highest of the water soluble phenolics and flavonoids contents existed in the sun dried MC leaf powder (12.03 ± 0.09 mg GAE g^{-1} powder, 6.41 ± 0.12 mg CE g^{-1} powder) among the hot air dried at 60 °C for 6 h (7.78 ± 0.07 mg GAE g^{-1} powder, 3.49 ± 0.10 mg CE g^{-1} powder) and hot air dried powder at 60 °C for 8 h (7.08 ± 0.04 mg GAE g^{-1} powder, 3.35 ± 0.20 mg CE g^{-1} powder) because the sun dried MC leaf powder has a higher moisture content than the hot air dried powder (60 °C 6 h and 8 h), resulting to the water soluble phenolics and flavonoids remained in the powder more than hot air dried powder. Hot air drying is the method which had control temperature at 60 °C and time for 6 h and 8 h, resulting to lower moisture content than the sun drying method. The drying time is longer, the moisture content is reduced. The water soluble phenolic and flavonoids may evaporate with water in the drying process, resulting in the hot air dried powder (60 °C 8 h) had lower phenolics and flavonoids contents than the hot air dried powder (60 °C 6 h). The research showed that the water soluble phenolics and flavonoids were related to moisture contents in the samples. The highly temperature dried samples cause soluble phenolics and flavonoids to evaporate with water during the drying process [22, 24]. The process of hot-air drying requires higher temperature and increased airflow, which are needed to promote water evaporation and reduce the relative humidity, and finally results in the deterioration of phenolic and flavonoids substances in raw materials. Some antioxidant substances will decompose through the mechanism of hydrolysis of esters or glycosides such as rutin (quercetin-3-orutinoside) may be decompose into protocatechuic acid [21, 22, 25].

DPPH free radical scavenging activity, ABTS free radical scavenging activity, total antioxidant capacity and reducing power

DPPH radical is a stable free radical that can donate hydrogen when reacts with antioxidant compounds and reduce to diphenyl picryhydrazine. These showed the ability of extracts to neutralize free radicals which possess unpaired electrons [23]. The DPPH free radical scavenging activities in the MC leaf powder were shown in Table 4. The highest of DPPH free radical scavenging activities existed in the sun dried MC leaf powder (6.40 ± 0.16 mg AAE g^{-1} powder) among the hot air dried at 60°C for 6 h (3.23 ± 0.07 mg AAE g^{-1} powder) and the hot air dried powder at 60°C for 8 h (2.56 ± 0.08 mg AAE g^{-1} powder). Since the sun dried powder contained total phenolics, flavonoids, and phytochemicals higher than the hot air dried powder at 60 °C for 6 h and 8 h, respectively. An increase in the DPPH inhibition caused by antioxidants might be due to the scavenging ability of radicals by hydrogen donation [23]. It can also be seen that the water extract was active in relation to the water soluble phenolics, flavonoids, and phytochemicals in the MC leaf powder. Therefore, it can be deduced that drying methods (drying temperature and time) had an effect on the antioxidant activities of the MC leaf powder.

The $ABTS^{+}$ free radical activities assay were generated by potassium persulfate in order to determine its hydrogen donation ability [23]. The $ABTS^{+}$ radical scavenging activities in the MC leaf powder were shown in Table 4. The highest of $ABTS^{+}$ radical scavenging activity existed in the sun dried MC leaf powder (17.76 ± 0.25 mg AAE g^{-1} powder) among the hot air dried at 60°C for 6 h (13.46 ± 0.24 mg AAE g^{-1} powder) and the hot air dried powder at 60°C for 8 h (12.42 ± 0.18 mg AAE g^{-1} powder) because the sun dried MC leaf powder had the highest water soluble phenolics, flavonoids and phytochemicals contents compared with the hot air dried powder at 60 °C for 6 h and 8 h, respectively. The research was found the $ABTS^{+}$ radical scavenging activity related to the water soluble phenolics, flavonoids [24] and phytochemicals contents because active compounds can give hydrogen radical to ABTS free radicals that ABTS is not free radicals [23]. In addition, drying temperature and time also have an effect on ABTS antioxidant activities [23, 24].

The antioxidant capacity assay was based on the reduction of Mo (VI) to Mo (V) by the formation of a green phosphate Mo(V) complex at acid pH [13]. The total antioxidant capacities in MC leaf powder were shown in Table 4. The highest of total antioxidant capacities existed in the sun dried MC leaf powder (28.58 ± 0.41 mg AAE g^{-1} powder) among the hot air dried at 60 °C for 6 h (26.87 ± 0.17 mg AAE g^{-1} powder) and for 8 h (26.23 ± 0.20 mg AAE g^{-1} powder) in the same drying temperature. An increase in the total antioxidant capacities relates to the water soluble phenolics, flavonoids [24], and phytochemicals contents in the MC leaf powder [18, 19].

Table 3 Total phenolics and flavonoids contents of the MC leaf powder from three different drying methods

drying method	Total phenolics contents (mg GAE g^{-1} powder; n = 5)	Total flavonoids contents (mg CE g^{-1} powder; n = 5)
sun drying	12.03 ± 0.09	6.41 ± 0.12
hot air drying (60 °C 6 h)	7.78 ± 0.07	3.49 ± 0.10
hot air drying (60 °C 8 h)	7.08 ± 0.04	3.35 ± 0.20

Table 4 DPPH free radical scavenging activity, ABTS free radical scavenging activity, total antioxidant capacity and reducing power of the MC leaf powder from three different drying methods

drying method	DPPH free radical scavenging activity	ABTS free radical scavenging activity	total antioxidant capacity	reducing power
	mg AAE g^{-1} powder; n = 5			
sun drying	6.40 ± 0.16	17.76 ± 0.25	28.58 ± 0.41	5.02 ± 0.29
hot air drying (60 °C 6 h)	3.23 ± 0.07	13.46 ± 0.24	26.87 ± 0.17	2.72 ± 0.11
hot air drying (60 °C 8 h)	2.56 ± 0.08	12.42 ± 0.18	26.23 ± 0.20	2.43 ± 0.11

Reducing power is assessed by ferric to ferrous ion reduction assay [13] which the results were shown in Table 4. The highest of reducing power existed in the sun dried MC leaf powder (5.018 ± 0.292 mg AAE g^{-1} powder) because the sun dried powder had the highest of water soluble phenolics, flavonoids and phytochemicals contents, compared with the hot air dried powder at 60 °C for 6 h and for 8 h. The reducing power is related to total phenolics, flavonoids and phytochemicals contents [24] because these antioxidants can give free electrons in the reduction reaction.

4. Conclusion

Three different drying methods include sun drying, hot air drying at 60 °C for 6 h and hot air drying at 60 °C for 8 h method were affected on the water soluble total phenolics, flavonoids, phytochemical contents, and antioxidant activities of the MC leaf powder. The sun dried MC leaf powder has total phenolics, flavonoids, phytochemical, and antioxidant activities higher than the hot air dried powder at 60 °C for 6 and for 8 h, respectively. The sun drying method was an appropriated drying for MC leaf tea which had high antioxidant and antioxidant activity as well and utilized drying method by a community enterprise.

5. Acknowledgement

This work was supported by Ubon Ratchathani Rajabhat University of Thailand.

6. References

[1] K. Brieger, S. Schiavone, F.J.Jr. Miller, K.H. Krause, Reactive oxygen species: from health to disease, Swiss. Med. Wkly. 142 (2012) 1 – 14.

[2] L. Zheng, Y. Zhang, Y. Liu, X.O. Yang, Y. Zhan, Momordicacochinchinensis Spreng. seed extract suppresses breast cancer growth by inducing cell cycle arrest and apoptosis, Mol. Med. Rep. 12 (2015) 6300 – 6310.

[3] M. Zheng, Q. Xia, S. Lu, Study on drying methods and their influences on effective components of loquat flower tea, LWT – Food Sci. Technol. 63 (2015) 14 – 20.

[4] A.G. Pirbalouti, E. Mahdad, L. Craker, Effect of drying methods on qualitative and quantitative properties of essential oil of two basil landraces, Food Chem. 141 (2013) 2440 – 2449.

[5] J. Yuan, L.J. Hao, G. Wu, S. Wang, J. Duan, G.Y. Xie, M.J. Qin, Effect of drying methods on the phytochemicals contents and antioxidant properties of chrysanthemum flower heads harvested at two developmental stanges, J Funct Foods. 19 (2015) 786 – 795.

[6] M.T. Ebadi, M. Azizi, F. Sefidkon, N. Ahmadi, Influence of different drying methods on drying period, essential oil content and composition of Lippia citriodora Kunth, J. Appl. Res. Med. Aromat. Plants. 2 (2015) 182 – 187.

[7] J. Rodriguez, C. Ortuno, J. Benedito, J. Bon, Optimization of the antioxidant capacity of thyme (Thymus vaulgaris L.) extracts: Management of the drying process, Ind Crops Prod. 46 (2013) 258 – 263.

[8] L.F. Ballesteros, M.J. Ramirez, C.E. Orrego, J.A. Teixeira, S.I. Mussatto, Encapsulation of antioxidant phenolic compounds extracted from spent coffee grounds by freeze-drying and spray- drying using different coating materials, Food Chem. 237 (2017) 623 – 631.

[9] J.C. Nunes, M.G. Lago, V.N. Castelo-Branco, F.R. Oliveira, A. G. Torres, D. Perrone, M. Monteiro, Effect of drying method on volatile compounds, phenolic profile and antioxidant capacity of guava powders, Food Chem. 197 (2016) 881 – 890.

[10] Y. Tian, Y. Zhao, J. Huang, H. Zeng, B. Zheng, Effect of different drying methods on the product quality and volatile compounds of whole shiitake mushrooms, Food Chem. 197 (2016) 714 – 722.

[11] M.B. Hossain, C. Barry-Ryan, A.B. Martin-Diana, N.P. Brunton, Effect of drying method on the antioxidant capacity of six Lamiaceae herbs, Food Chem. 123 (2010) 85 – 91.

[12] K. An, D. Zhao, Z. Wang, J. Wu, Y. Xu, G. Xiao, Comparison of different drying methods on Chinese ginger (Zingiber officinale Roscoe): Changes in volatiles, chemical profile, antioxidant properties, and microstructure, Food Chem. 197 (2016) 1292 – 1300.

[13] N. Chahmi, J. Anissi, S. Jennan, A. Farah, K. Sendide, M.E.Hassouni , Antioxidant activities and total phenol content of Inula viscosa extracts selected from three regions of Morocco, Asian Pac J Trop Biomed. 5(3) (2015) 228 – 233.

[14] N. Tlili, H. Mejri, F. Anouer, E. Saadaoui, A. Khaldi, N. Nasri, Phenolic profile and antioxidant activity of Capparis spinosa seeds harvested from different wild habitats, Ind Crops Prod. 76 (2015) 930 – 935.

[15] S.C. Liu, J.T. Lin, C.C. Hu, B.Y. Shen, T.Y. Chen, Y.L. Chang, C.H. Shih, D.J. Yang, Phenolic compositions and antioxidant attributes of leaves and stems from three inbred varieties of Lycium Chinense Miller harvested at various times, Food Chem. 215 (2017) 284 – 291.

[16] J. Oh, H. Jo, A.R. Cho, S.J. Kim, J. Han, Antioxidant and antimicrobial activities of various leafy herbal teas, Food Control. 31 (2013) 403 – 409.

[17] Association of official analytical chemists (AOAC), official method of analysis, 15th, 1990.

[18] S. Shankar, S. Settu, G. Segaran, R. D. V. Sundar, L. Ravi, Phytochemical constituents of Dracaena mahatma leaves and their anti-bacterial, anti-oxidant and anti-inflammatory significance, Biotechnol. Res. Innov. 2 (2018) 1 – 8.

[19] K. Sobha, R. K. Anantha, V.R. Govada, M.K. Verma, An Investigation into phytochemical constituents, antioxidant, antibacterial and anti-cataract activity of Alternanthera sessilis, a predominant wild leafy vegetable of South India, Biocatal. Agric. Biotechnol. 10 (2017) 197 – 203.

[20] K.D.R.R. Silva, M.S.F. Sirasa, Antioxidant properties of selected fruit cultivars grown in Sri Lanka, Food Chem. 238 (2016) 203 – 208.

[21] X. Chen, X. Li, X. Mao, H. Huang, T. Wang, Z. Qu, J. Miao, W. Gao, Effects of drying processes on starch-related physicochemical properties, bioactive components and antioxidant properties of yam flours, Food Chem. 224 (2017) 224 – 232.

[22] N.D. Thi, H. Eun-Sun, Effects of Drying Methods on Contents of Bioactive Compounds and Antioxidant Activities of Black Chokeberries (Aronia melanocarpa), Food Sci Biotechnol. 25(1) (2016) 55 – 61.

[23] O.R. Alara, N.H. Abdurahman, S.K. Abdul Mudalip, O.A. Olalere, Effect of drying methods on the free radicals scavenging activity of Vernonia amygdalina growing in Malaysia, JKSUS. 5 (2017) 81 – 86.

[24] A. Wongklom, Effect of different drying methods on the water soluble total phenolics and flavonoids contents, and antioxidant activities of sunchoke (Helianthus tuberosus L.) powder, SNRUJST. 10(3) (2018) 170 – 177.

[25] B. Nayak, R.H. Liu, J.M. Tang, Effect of processing on phenolic antioxidants of fruits, vegetables, and grains: A review, Crit. Rev. Food Sci. Nutr. 55 (2015) 887 – 918.