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Research Article

The Impact of Different Drying Temperatures on Black Ginger Slices in Relation to Different Applications of Growing Media

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ABSTRACT

Black ginger (*Kaempferia parviflora* Wall. Ex. Baker) or "halia hitam" in Malay has been traditionally used as health-promoting herbs in relieving body pains, allergies, gastrointestinal disorders, and fungal infections. Recently, black ginger has increased attention from many researchers to identify its medicinal value to treat diseases. In line with that, the objective of the study is to determine the impact of drying temperatures of black ginger rhizomes slices on the different applications of growing media. The experiment was arranged in a complete randomized design with two factors viz. i) different growing media [cocopeat, cocopeat+rice husk biochar, cocopeat+palm kernel shell biochar, cocopeat+sugarcane bagasse biochar, and cocopeat+coconut shell biochar] and ii) two different drying temperature (50 °C & 75 °C) with three replications. The postharvest parameters were total phenolic compound (TPC), total antioxidant (TA), water activity (Aw), and mineral nutrients content. In conclusion, rhizomes planted in Cocopeat+600g biochar substrates such as sugarcane bagasse, rice husk, palm kernel shell, and coconut shell could be suggested as effective growing media for black ginger cultivation under fertigation system and continued with 75 °C drying temperatures without adversely affecting the postharvest quality of black ginger.

Key words: Biochar, black ginger, drying method, soilless system

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INTRODUCTION

Kaempferia parviflora Wall Ex. Baker or black ginger is a medicinal plant in the family Zingiberaceae. Its rhizome has been long used as a folk medicine for many centuries. Black ginger has been specifically studied for its pharmacological effect on antiallergenic (Tewtrakul *et al*., 2007; Tewtrakul *et al*., 2008), anti-inflammatory (Tewtrakul *et al*., 2009), anti-cancer (Banjerdpongchai *et al*., 2008; Tewtrakul & Subhadhirasakul, 2008), cardioprotective (Malakul *et al*., 2011), and anti-obesity activity (Akase *et al*., 2011). In Thailand, black ginger has been known as a health-promoting herb and is used for the treatment of colic disorders. Besides, the rhizomes of black ginger were widely used in making a tonic drink to relieve impotency (Yenjai *et al*., 2004).

Nowadays, the higher demand for herbal products is considered crucial to ensure the quality and validity of the products at the safety standard level. Fresh ginger usually contains 85-95% water and is highly perishable and susceptible to microbial spoilage (Mishra *et al*., 2004). Thus, immediate preservation of raw herbs after harvest to avoid deterioration and spoilage is highly needed. Most herbal products are processed either in form of dried products, powdered, or oil extraction. Among these three processes, dried products could inhibit microbial growth and forestall certain biochemical content. Drying is one of the most practiced food storage procedures that are important to prolong the shelf life of food, besides decreasing the cost of packaging and transporting the food (Chang *et al*., 2006;

Doymaz, 2007).

In line with that, this experiment was conducted to investigate the impact of drying temperatures on sliced black ginger cultivated in different types of growing media. Black ginger rhizomes are the most valuable and commonly used in dried slices. To date, no information is available on the appropriate drying temperature in providing the optimum quality standards for black ginger. Conventionally, herbs and spices were dried under the sun drying. However, drying under direct sunlight for a longer period is not advised as it might cause the volatilization of nutrients. Recently, many studies found that black ginger rhizomes had a higher bioactive compound that is important as health-promoting, stimulating, and vitalizing agents for the human body. However, no comparative studies were available for chemical composition in dried rhizomes of black ginger. To the best of my knowledge, this is the first experiment conducted on the impact of different drying temperatures of black ginger slices with different application growing media. In addition, different growing media were used in the present study to avoid soil-borne diseases and pests as claimed by Yaseer Suhaimi *et al*. (2015). They reported that the ginger family is widely cultivated on soil and this in turn reduces the farmer profits. Thus, to increase the growth, yield and postharvest qualities of black ginger, the adoption of a soilless culture system by using different growing media could be the most preferable alternative to be discovered as reported by Nurul Azilla and Wan Zaliha, (2017).

MATERIALS AND METHODS

Plant materials and experimental location

The experiment was conducted in a greenhouse at the Faculty of Fisheries and Food Science, Universiti Malaysia Terengganu. Black ginger and rice husk biochar were collected from MARDI (Malaysian Agricultural Research and Development Institute), Serdang, and BERNAS Rice Mill, Tumpat, Kelantan respectively. While, palm kernel shell biochar was obtained from the Malaysian Palm Oil Board (MPOB), Bandar Bangi, Selangor. While, coconut shell and sugarcane bagasse substrates were collected from Gong Badak, Kuala Terengganu. The coconut shell and sugarcane bagasse are then further processed into biochar by the conventional method of pyrolysis. Based on Nurul Azilla and Wan Zaliha, (2017), the best rate of biochar substrate was 600 g per polybag combined with cocopeat and further used in the present study.

Experimental design

The experiment was arranged in a Complete Randomized Design (CRD) with 15 black ginger rhizomes grown on different growing media viz. i) cocopeat (CP), ii) cocopeat+rice husk biochar (CPRH), iii) cocopeat+palm kernel shell biochar (CPPKS), iv) cocopeat+sugarcane bagasse biochar (CPSB), and v) cocopeat+coconut shell biochar (CPCS)] with three replications. After six months of cultivation, all fifteen harvested ginger rhizomes were immediately transferred to the Postharvest Technology Laboratory at Universiti Malaysia Terengganu and the rhizomes were thoroughly washed to remove dirt. Each of the black ginger rhizomes was cut into slices (2-3 mm) and weighed at 30 g and then placed into the brown paper bags. The sliced ginger was in the paper bag and then dried at different drying temperatures (50 °C & 75 °C) until the weight become constant. The postharvest parameters such as total phenolic compound (TPC), total antioxidant (TA), water activity (a_w), and mineral nutrients content were evaluated.

Parameter evaluations

Mineral nutrients of leaves and rhizomes

The samples were grounded into powder form by using a blender. Approximately, 100 mg of the samples were weighed and wrapped in tin foil or pressed into pellets by using a manual pressing tool. The samples were directly analyzed by loading them into a carousel with 60 positions. Nutrient elements such as phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), iron (Fe), copper (Cu), boron (B), and manganese (Mn) were extracted using the dry ashing method (Husni *et al*., 1990). The element composition was done by weighing 1g of samples and combusted in a muffle furnace at a high temperature (500 °C) for 6 h and let cooled before 2-3 drops of deionized water were added. After that, 2 mL of HCL was mixed and left to dry before 10 mL of 20% HNO_3 is added. The samples were placed in a water bath at 90 °C for one hr. After 1 h, the samples were made up into 100 mL with deionized water. Next, the elemental compositions were analyzed by using Inductively Coupled Plasma Mass Spectrometry (ICP-MS) (Optima 8300, Perkin Elmer, USA).

Total phenolic compound (fresh & dried powder)

The total phenolic compound was determined by the following modified method of Kim *et al*. (2003). Approximately, 1 g of fresh samples was extracted with 50 mL pure methanol by agitating it using an orbital shaker (TECH-LAB MFG Sdn. Bhd.) for 1 h at room temperature. The extraction samples were then filtered by using Whatman No.2 filter paper known as stock solution. Then, 200 µL of diluted sample extract was micropipette into a 2 mL cuvette followed by 1000 µL Folin-Ciuocalteu reagent diluted with water (1:5, v/v), and 800 µL

of 7% sodium carbonate ($NaCO_3$). The solutions were stored in dark for 1 h before the absorbance reading was recorded at 765 nm by using the UV Spectrophotometer (UV-1800, Shimadzu, Japan).

Meanwhile, 3 g of dried powder form samples were extracted with 25 mL pure methanol and then agitated by using an orbital shaker (TECH-LAB MFG Sdn. Bhd.) for 2 h at room temperature. After that, 2 mL of the solution was taken out to make up 100 mL using pure methanol. The homogenate was centrifuged (Sigma 3-18K5, Sartorius, Germany) at 10,000 r.p.m. for 15 min at 4 °C. Then, 200 µL of supernatant was mixed with 1000 µL Folin-Ciuocalteu reagent followed by 800 µL of 7% sodium carbonate ($NaCO_3$). The solutions were stored in dark for 1 hr before the reading was recorded at 765 nm by using UV Spectrophotometer (UV-1800, Shimadzu, Japan). Gallic acid was used as a standard for the calibration curve. The total amount of phenolic compared was calculated and expressed as GAE (mg/g FW or mg/g DW based on the extracted sample).

Total antioxidant

Total antioxidants were determined by using the modified method of Brand-Williams *et al*. (1995). It was measured by using 2,2-diphenyl-1-picrylhydrazyl (DPPH) as a stock solution by dissolving 24 mg DPPH in 100 mL methanol. A diluted stock solution (1:4v/v) was prepared as a working solution. 3 g of fresh samples and 0.5 g of dried powder samples were grounded with mortar and pestle by using clean sand (180 Mic. aperture) into 10 mL extraction buffer (2 mM NaF dissolved in 200 mL distilled water and 800 mL methanol). Later, the samples were centrifuged (Sigma 3-18K5, Sartorius, Germany) at 10000 rpm for 20 min by using a Refrigerated Tabletop Centrifuge. The supernatant (50 µL) was mixed with a 950 µL working solution. The absorbance was recorded using UV Spectrophotometer (UV-1800, Shimadzu, Japan) at 515 nm wavelength. Total antioxidant was calculated by using a standard curve of 6-hydroxy-2,5,7,8-tetramethylchromane-2-carboxylic acid (Trolox) and was expressed as mM TE/g FW/DW.

Water activity

The water activity (a_w) of dried black ginger rhizomes was measured using a Dew Point Water Activity Meter (Aqua Lab Series 4TE, UK). The dried rhizomes of black ginger slices were placed on a specific plate before the reading was taken. Measurement was done after 15-30 min for each sample. The data were directly recorded as indicated on the screen of the water activity meter.

Statistical analysis

Data were analyzed based on two-way analysis of variance (ANOVA) by using GLM (General Linear Models) procedures using the SAS 9.1 software package, SAS Institute Inc, Cary, NC, USA. Treatment means were further separated by the Tukey test for the least significant value at $p \leq 0.05$ (SAS Institute Inc., 1999).

RESULTS

The postharvest quality of black ginger parameters; TPC, TA, a_w, and mineral nutrients (P, K, Ca, Mg, Cu, Zn, Mn, Fe, & B) were not significantly affected by the interaction between growing media and drying temperatures applied on black ginger slices (Table 1 & 2). However, the TPC, a_w, and Ca were significantly affected when different temperatures were applied. From the results, 75

Table 1. Effects of different growing media and temperatures on total phenolic content, total antioxidant, and water activity of black ginger rhizome

Factor	Total phenolic compound (mg GAE/g)	Total antioxidant (mM TE/g DW)	Water activity (a_w)
Growth media (GM)			
CP	26.45[a]	12.78[a]	0.38[a]
CPRH	65.47[a]	13.26[a]	0.39[a]
CPPKS	35.58[a]	14.33[a]	0.39[a]
CPSB	33.52[a]	14.21[a]	0.39[a]
CPCS	29.13[a]	14.73[a]	0.36[a]
Pr > F	ns	ns	ns
Temperature (T)			
50	25.01[b]	13.72[a]	0.45[a]
75	43.95[a]	14.01[a]	0.33[b]
Pr > F	**	ns	***
Interaction (GM x T)	ns	ns	ns

Means with different letters are significantly different at the 5% level according to the Tukey test. ns = non-significant ($p \geq 0.05$), * is significant at $p \leq 0.05$, ** is very significant at $p \leq 0.001$ and *** is highly significant at $p \leq 0.0001$. CP = cocopeat, CPRH = cocopeat+rice husk biochar, CPPKS = cocopeat+palm kernel shell biochar, CPSB = cocopeat+sugarcane bagasse biochar, and CPCS = cocopeat+coconut shell biochar.

Table 2. Effects of growing media and temperatures on the mineral nutrient of black ginger rhizomes slices

Factor	Mineral nutrient (ppm)								
	P	K	Mg	Ca	Cu	Zn	Mn	Fe	B
Growth media (GM)									
CP	51.87a	243.93a	18.13a	18.92a	0.04a	1.58a	1.50b	1.16a	0.11a
CPRH	57.53a	195.52a	20.19a	17.03a	0.07a	0.99a	6.18a	1.09a	0.10a
CPPKS	56.06a	179.06a	19.02a	21.66a	0.27a	0.93a	1.64b	1.14a	0.09a
CPSB	68.72a	268.37a	19.15a	20.37a	0.19a	0.97a	2.38b	1.42a	0.12a
CPCS	49.40a	334.94a	21.58a	16.84a	0.42a	1.04a	2.65b	1.53a	0.16a
Pr > F	ns	ns	ns	ns	ns	ns	***	ns	ns
Temperature (T)									
50	56.28a	236.00a	20.47a	21.39a	0.04a	1.11a	2.56a	1.28a	0.11a
75	56.53a	254.81a	19.11a	16.60b	0.04a	1.08a	3.38a	1.26a	0.12a
Pr > F	ns	ns	ns	***	ns	ns	ns	ns	ns
Interaction (GM x T)	ns	ns	ns	ns	ns	ns	ns	ns	ns

Means with different letters are significantly different at the 5% level according to the Tukey test. ns = non-significant ($p \geq 0.05$), * is significant at $Pp \leq 0.05$, ** is very significant at $p \leq 0.001$ and *** is highly significant at $p \leq 0.0001$. CP = cocopeat, CPRH = cocopeat+rice husk biochar, CPPKS = cocopeat+palm kernel shell biochar, CPSB = cocopeat+sugarcane bagasse biochar, and CPCS = cocopeat+coconut shell biochar

°C drying temperature gave a higher value of TPC (43.95 mg GAE/g) of black ginger rhizome slices. Meanwhile, the a_w and Ca concentrations of black ginger rhizomes slices were recorded greater at 50 °C drying temperature ($0.45a_w$ & 21.39 ppm).

Although the interaction between the two factors was not significant, there was a significant difference among growing media on Mn concentration of black ginger rhizome slices irrespective of the drying temperature applied. The combination of CPRH significantly affected Mn concentration in black ginger rhizomes (6.18 ppm) as compared to CP (1.50 ppm), CPPKS (1.64 ppm), CPSB (2.38 ppm), and CPCS (2.65 ppm). Although the interaction between the two factors was not significant, there was a significant difference among growing media on Mn concentration of black ginger rhizome slices irrespective of the drying temperature applied. The combination of CPRH significantly affected Mn concentration in black ginger rhizomes (6.18 ppm) as compared to CP (1.50 ppm), CPPKS (1.64 ppm), CPSB (2.38 ppm), and CPCS (2.65 ppm). On the other hand, although no significant effect was recorded on TA content on both factor, TA of black ginger rhizomes slices tends to exhibit high values in a combination of CPCS at drying temperatures of 75 °C.

As previously mentioned, the mineral nutrient content of P, K, Mg, Cu, Zn, Fe, and B was not significantly affected by both factors. Similarly, to the single factor, no apparent effect was noticed. For that reason, a comparison cannot be made between the treatments. However, the results can be elaborated based on the values within the parameters of the same treatment. Regardless of drying temperatures, the K concentration tends to show high values in black ginger rhizomes grown in all growing media applied. The concentration recorded ranged from 179.06 ppm to 334.94 ppm. Meanwhile, the Cu concentration tends to show low values in all growing media applied ranging from 0.04 ppm to 0.42 ppm. Concerning different drying temperatures, 50 °C tends to exhibit a high concentration of Mg, Ca, Zn, and Fe on black ginger rhizomes. Meanwhile, 75 °C of drying temperature tends to demonstrate a high concentration of P, K, Mn, and B, respectively.

DISCUSSION

Drying is one of the oldest processing of preservation for foods. The primary objective of drying is to remove water from foods, which microorganisms require for growth, resulting in a more shelf-stable, smaller, and lighter food (Ajayi *et al*., 2017). As reported by Eze and Agbo (2011), drying is also essential for crops in developing countries. Generally, drying is also used in herbs and spices to extend the shelf-life of the resulting dried products. Presently, there is no information available on the impact of drying black ginger rhizome slices. Hence, this study purposely determines the impact of different drying temperatures of black ginger slices on different applications of growing media.

Total phenolic compound (TPC) was not significantly interacted between the two factors. However, irrespective of biochar substrates, different drying temperatures applied on black ginger rhizome slices were in line with those studied by Thuwapanichayanan *et al*. (2014). The result agreed obtained the TPC markedly increased with increasing temperatures from 60 °C to 80 °C. In the present study, a higher TPC value at a drying

temperature of 75 °C as compared to 50°C has been attributed to the liberation of bound phenolic compounds by the breakdown of cellular tissues and due to the formation of a new compound in rhizomes (Ali *et al*., 2008; & Wu *et al*., 2010). Other than that, the TPC of black ginger rhizomes also can be said in the acceptance range (25.01-43.95 mg GAE/g). This was based on the results of Rahman *et al*. (2018) who claimed that the TPC extracted ranged from 45 to 210 mg GAE/g DW for various time/temperature combinations.

The total antioxidant (TA) of black ginger rhizomes slices did not affect by the different drying temperatures of the application of growing media. Previously reported by Manzocco *et al*. (2000) several factors might influence antioxidant activity at 75 °C drying temperatures which were due to an increase in reducing sugar and Maillard Reaction Product (MRPs) which often exerted in a chain-breaking and DPPH types of mechanism. Besides, TA was also highly dependent on the extract and concentration of solvent used (Turkmen *et al*., 2006). TA in black ginger rhizome slices showed no significant effects on drying temperature. However, 75 °C dried ginger rhizomes tend to show high value than 50 °C. In addition, Maizura *et al*. (2011) revealed a positive correlation between TPC and DPPH assay of ginger extracts, which means that higher TPC showed higher total antioxidants (Maizura *et al*., 2011). This indicated that TPC might also contribute to having higher TA in black ginger rhizomes.

Noor Aziah and Komathi (2009) claimed that water plays an important role in food product quality and characteristics of moisture content. Moisture content and water activity have a potent effect on the food products in terms of storage stability, microbial activity, non-enzymatic browning, lipid oxidation, and enzymatic reaction during storage (Prachayawarakorn *et al*., 2008). As shown in Table 1, the water activity (a_w) of black ginger rhizomes slices was significantly higher in drying temperature at 50 °C (0.45a_w). Meanwhile, no significant effects were recorded on a_w the application of different growing media. Increasing temperatures showed lower a_w. This means that at any relative humidity ginger slices become less hygroscopic with an increase in temperature. For a considerably safe standard level of A_w, the amount of water absorbed at a_w=0.0805 was generally low for a relatively large increase in water activity (Alakali *et al*., 2009).

In the present study, all mineral nutrients of black ginger rhizomes showed comparable value among the treatments except for Mn and Ca which significantly affects by different growing media and drying temperatures, respectively (Table 2). Wagesho and Chandravanshi (2015) claimed that the higher amount of Ca in ginger might be due to higher mobility in the plant tissue and translocation from older plant tissue to new plant tissue. Meanwhile, Mn might be the most accumulated trace metal in ginger samples. Furthermore, Majkowska-Gadomska *et al*., (2018) claimed that the mineral content of ginger roots was significantly influenced by the types of growing substrates (100% of coco peat) and highly affected in P, K, Mg, and Ca concentration.

CONCLUSION

In conclusion, Cocopeat+600 g of biochar substrates such as sugarcane bagasse, rice husk, palm kernel shell, and coconut shell can serve as newly developed growing media for black ginger under the fertigation system. Interestingly, black ginger can be further dried at a temperature between 50 °C and 75 °C without adversely affecting its hidden quality particularly total phenolic compounds that prime importance in combating various diseases.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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