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Effects of Drying and Blanching on the Retention of Bioactive Compounds in Ginger and Turmeric

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Abstract: Ginger and turmeric, members of the *Zingiberaceae* family, are widely used for their pungent and aromatic flavour in foods and also for their medicinal properties. Both crops are often grown by smallholders in mountain areas on rich former forest soils with no need for fertilizers and pesticides, fulfilling de facto the conditions of organic agriculture. They are consumed fresh or dried. Drying is often performed without taking into account the content of bioactive compounds in the dried product. Various bioactive compounds have been identified in their rhizomes, and their content affects the price of the dried product. Hence, this study focused on the effects of drying treatments and blanching on the retention of bioactive compounds in the dried products. The bioactive compounds in ginger rhizome (*Zingiber officinale* Roscoe) are gingerols (particularly 6-gingerol). The drying treatments that were applied to fresh ginger included constant and also changing temperature conditions. Due to the short drying time, 60 °C was the optimal drying temperature to retain 6-gingerol. However, the changing temperature conditions significantly improved the retention of 6-gingerol. As for blanching, it had a significant negative effect on 6-gingerol retention. Turmeric (*Curcuma longa*) is known for its bright yellow colour and pharmacological properties due to curcumin, a phenolic compound. Drying was performed under constant conditions at 38 °C, 48 °C, 57 °C and 64 °C and a relative humidity of 20% and 40%. Drying at 57 °C with a lower relative humidity was the best drying treatment, yielding the highest amount of curcumin among non-blanched samples. Blanching for 15 min exhibited the highest curcumin yield while blanching for 5 min and 30 min did not have much effect. The findings of this study will benefit the industry in terms of improved quality control and cost reduction.

Keywords: ginger rhizome (*Zingiber officinale* Roscoe); air drying; changing conditions; 6-gingerol; turmeric rhizome (*Curcuma longa*); blanching; curcumin

1. Introduction

Ginger (*Zingiber officinale* Roscoe) and turmeric (*Curcuma longa*) belong to the *Zingiberaceae* family. Both species are spices that are cultivated and consumed in subtropical and tropical regions all around the world. They are erect perennial herbs that are grown for their rhizomes. A rhizome is an underground plant stem that is capable of producing shoots and roots of a new plant. Rhizomes of both plants are consumed in many subtropical and tropical countries such as China, India, Jamaica and Australia. They are consumed fresh or dried. Ginger is often consumed as a condiment and served with food or in beverages as flavoured tea or soft drink, whereas turmeric is often used in dried form in curries. Both are highly regarded in culinary preparations due to their characteristic smell and

flavour produced by volatile components and pungent components. Other important applications are in pharmacology, and their medicinal properties have been known for centuries. The moisture content (MC) of fresh ginger is between 83%–94% on a wet basis [1,2]. Polyphenol compounds including 10-gingerol, 8-gingerol, 6-gingerol, and their derivatives, are detected in the roots of ginger, and extracts have been proven to have high antioxidant activity [3,4] and anti-inflammatory effect [5].

The MC of fresh turmeric is about 83%–87% [6]. According to Parthasarathy et al. [7] turmeric contains 6.3% protein, 5.1% fat, 3.5% minerals, and 69.4% carbohydrates. The essential oil has 1% α-phellandrene, 0.6% sabinene, 1% cineol, 0.5% borneol, 25% zingiberene and 53% sesquiterpenes. The components of turmeric can vary amongst cultivars. In addition, the content of curcumin depends on location of growth. Curcumin is the component of turmeric responsible for its colour and all its medicinal properties. It has a molecular formula of C21H20O6 and its structure has been identified as diferuloylmethane. It is insoluble in water and soluble in ethanol and acetone. It makes up 2.5%–6% of the rhizome. Curcumin and its two related demethoxy compounds, demethoxycurcumin and bisdemethoxycurcumin, are known as curcuminoids. These components have been identified as antioxidants. Cyclocurcumin is a newly identified curcuminoid isolated from the fraction of turmeric found to be active as a nematicide. New phenolics have been identified as well, which are antioxidants and anti-inflammatory.

Among the bioactive compounds of interest in the rhizomes of these two plants are gingerols in ginger and curcumin in turmeric. The content of these compounds in the dried product generally determines the price of the commodity. Drying is an important processing step in the postharvest handling of ginger and turmeric as it reduces their MC and water activity, hence reducing microbial activity and chemical reactions which decrease deterioration and increase shelf life. It also reduces the size of products, which decreases storage and transportation costs. Yet, some adverse effects on product quality caused by drying cannot be ignored which include the loss of volatile aromatic compounds, decrease of antioxidant activity, and degradation of valuable nutrient content [8]. Also, the formation of some new components can take place as a result of thermal reactions [9].

Blanching in hot water after harvesting is a traditional process that removes the raw odour and improves drying time. There are conflicting views on the effect of blanching on bioactive compounds in ginger and turmeric. Thuwapanichayanan et al. [10] found that blanched ginger powder had lower total phenolic content and antioxidant activity compared to the untreated sample due to the loss of phenolics into the hot water during blanching. Some studies reported that high temperatures, such as experienced in blanching, cause thermal degradation of curcumin [11], while other studies have shown that blanching protects the bioactive ingredients from the effects of drying [12]. Therefore, this study investigated the effects of blanching time and drying conditions on the concentration of the key bioactive compounds, 6-gingerol in dried ginger, and curcumin in dried turmeric.

2. Materials and Methods

2.1. Ginger and Turmeric Samples

Mature, fresh ginger samples of Australian origin were obtained from the Buderim Ginger Pty Ltd in Yandina, Queensland, Australia. Fresh turmeric was procured as rhizomes from Earthcare Enterprises, Maleny, Queensland, Australia.

2.2. Sample Preparation

Ginger and turmeric samples were stored at −18 °C in a refrigerator after procurement. Frozen samples were defrosted at 4 °C for 24 h, and placed at ambient temperature for 12 h before use. Defrosted rhizomes were peeled and sliced to 4 mm thickness. In all drying treatments, in addition to untreated sliced samples, three batches of samples were blanched in a 70 °C water bath for 5, 15, or 30 min, respectively.

2.3. Drying Treatments

2.3.1. Dryer

Air drying of rhizome slices was conducted in a cabinet dryer (developed by the University of New South Wales Food Engineering Research Group) (Figure 1). The dryer consisted of a temperature and relative humidity (RH) controller, a steam injection unit, a fan, and a drying chamber. The weight of samples was about 200 g for each batch. The samples were spread in a single layer on a stainless steel tray placed in the drying chamber. A load cell connected to a computer was placed below the tray for automatic recording of weight. The drying air flow was parallel to the tray surface with a constant air velocity of 0.75 ± 0.03 m·s^{-1}. The temperature and RH were monitored online using a data logger (Datataker DT50).

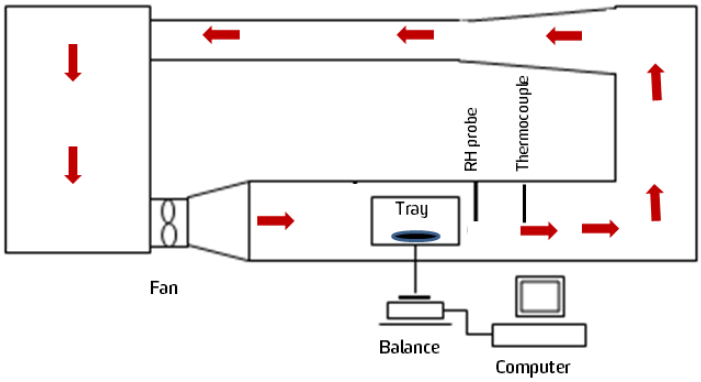

Figure 1. Schematic of the laboratory-scale cabinet dryer used in the experiments.

2.3.2. Drying Conditions

Ginger

Under constant conditions the drying run was stopped after a constant sample weight was reached. Under changing conditions, the change to the next condition took place when the sample weight fell to 60 g. Then, the samples were dried until they reached a constant weight. The weights of samples were recorded online at 15 min intervals. Initial and final MCs of the ginger slices were determined in a vacuum oven according to AOAC standards [13], i.e., at 70 ± 1 °C under 13.3 kPa pressure for 24 h. MC determination was the average of triplicate samples. The results were expressed as means with standard deviation. Comparison of means was done with ANOVA using EXCEL™ (Microsoft Corp., Redmond, WA, USA). The ginger samples drying treatments are in Table 1.

Table 1. Drying conditions of ginger [2].

S/N	Strategy	Temperature (°C)	Relative Humidity (%)	Blanching (min)
1	Temperature control only	40	9–12	0
2		40	9–12	5
3		40	9–12	15
4		40	9–12	30
5		50	6–8	0

Table 1. *Cont.*

S/N	Strategy	Temperature (°C)	Relative Humidity (%)	Blanching (min)
		Temperature & RH Control		
6	Constant conditions	30	30	0
7		40	10	0
8		40	30	0
9		50	25	0
10		60	15	0
11	Changing conditions	40 then 60	30 then 15	0
12		60 then 40	15 then 30	0
13		40 then 30	10 then 30	0
14		30 then 40	30 then 10	0
15		50 then 60	25 then 15	0
16		60 then 50	15 then 25	0

Turmeric

The turmeric samples were subjected to drying treatments as shown in Table 2. Turmeric samples were dried under constant conditions only. MC was determined in the same way as in ginger [13].

Table 2. Drying conditions turmeric.

S/N	Temperature (°C)	Relative Humidity (%)	Blanching (min)
1	40	20	0
2	40	40	0
3	50	20	0
4	50	20	5
5	50	20	15
6	50	20	30
7	60	20	0
8	60	40	0
9	70	20	0

2.4. Determination of Bioactive Compounds

2.4.1. Gingerol

Extraction

The 6-gingerol (≫98% purity) standard was obtained from Sigma-Aldrich (St. Louis, MO, USA). Methanol was of HPLC grade. Water for HPLC analysis was purified with a Milli-Q system (Merck, KGaA, Darmstadt, Germany). A stock solution of 6-gingerol in methanol (5.0 mg/mL) was prepared to produce a series of dilutions. The dilutions were prepared from the stock solution by dilution with 10% methanol and 90% water. For establishing standard curves, the solutions were prepared containing 5, 10, 20, 40, 60, 80 and 100 µg/mL, respectively. All solutions were stored in amber glass bottles at 4 °C before use.

Dried and fresh ginger ware pulverized and passed through a 40 mesh (0.42 mm) sieve before extraction. A powder sample (1 g) from each treatment was dissolved in 25 mL methanol and sonicated for 30 min. The mixtures were centrifuged at 10,000 rpm for 10 min and supernatant was filtered through Whatman filter paper (No. 1). Then, it was diluted with water until the final solvent ratio was 10% methanol and 90% water. All the extracts were kept at 4 °C. Extracts of ginger were filtered through a 0.45 µm nylon filter into an Agilent amber vial with cap and a wide opening for HPLC analysis.

Instrumentation and Chromatographic Conditions

A Prominence LC-20AD HPLC system (Shimadzu, Kyoto, Japan) was used in this study. The separation of the extract was conducted using a C18 column, 3.5 µm, 2.1 × 150 mm. Water (A) and methanol (B) constituted the mobile phase which was used for separation. The gradient elution had the following profile: 0–5 min, 50%–60% B; 5–9 min, 60% B; 9–14 min, 60%–95% B; 14–15 min, 95% B; 15–16 min, 95%–50% B; 16–25 min, 50% B. The injection volume was 40 µL and the flow rate was 0.18 mL/min. The UV detector (0~1000 nm) wavelength was set at 281 nm and the column temperature was maintained at 30 °C.

2.4.2. Curcumin

Extraction

Dried samples were ground in a Pulverisette, type 14,202 laboratory mill (Fritsch, Idar-Oberstein, Germany) at 15,000 rpm with a 1 mm mesh screen and stored in glass flasks. The powdered samples (10 g) were extracted with dichloromethane using a Soxhlet extractor in a water bath at 70 °C for 1.5 h. The extract was concentrated in a rotary evaporator, then diluted in ethanol. The curcumin standard (Sigma-Aldrich) was used for identification and quantitation. A calibration curve was produced using the following concentrations of the standard: 30, 100, 300, 700 and 1000 ng/mL.

Instrumentation and Chromatographic Conditions

The same HPLC as for 6-gingerol was used for curcumin detection. The separation of the extract was performed using a C18 column, 2 µm, 2.1 × 150 mm. Formic acid (0.1%) (A) and acetonitrile (B) constituted the mobile phase which was used for separation. The gradient elution profile is shown in Table 3. The injection volume was 5 µL. The detector wavelength was set at 360 nm.

Table 3. The gradient elution profile.

Step	Time (min)	A%	B%	Flow Rate (mL/min)
0	0.00	99.5	0.5	6.0
1	0.34	99.5	0.5	6.0
2	1.40	45.0	55.0	6.0
3	4.50	40.0	60.0	6.0
4	4.80	0.5	99.5	7.5
5	6.60	0.5	99.5	7.5
6	7.00	99.5	0.5	7.5
7	10.00	99.5	0.5	7.5

3. Results

3.1. Drying

3.1.1. Ginger

The MC of fresh rhizomes was between 536%–904% on a dry basis (db) (Table 4). A higher temperature and lower RH of the drying air led to lower a MC (i.e., higher moisture loss) of the final product. Treatments with higher RH in the dryer produced a higher MC in the final product. The results of changing conditions indicated that treatments with mild temperature and humidity conditions at the initial stage led to a higher MC of the dried sample, while initial harsh conditions caused a lower MC. Thus, the initial conditions of air drying are a primary factor determining final MC of the product. The results of blanching as a pre-treatment of ginger slices (Table 4) showed that blanched slices were generally less hygroscopic than non-blanched slices. The MCs of fresh ginger after 15 and 30 min were on average 383% db lower than those of fresh ginger without blanching. This could

be due to gelatinisation of starch molecules which may have blocked sorption sites and reduced water adsorption. A less hygroscopic polymer network may have formed around the blanched surfaces, thus disfavoring moisture adsorption.

3.1.2. Turmeric

The final MCs decreased with an increase in temperature, a decrease in relative humidity and a shorter blanching time (Table 5).

Table 4. Moisture content (MC) of samples subjected to different drying treatments.

Treatment	Fresh MC (% db)	Dried MC (% db)
40 °C/9–12% RH/No blanching	904 ^{b} ± 3	11.9 ^{f} ± 0.2
40 °C/9–12% RH/5 min blanching	922 ^{a} ± 5	10.7 ^{g} ± 0.3
40 °C/9–12% RH/15 min blanching	523 ^{i} ± 2	9.7 ^{g} ± 0.2
40 °C/9–12% RH/30 min blanching	519 ^{i} ± 1	10.3 ^{g} ± 0 .2
50 °C/6%–8% RH	935 ^{a} ± 1	8.5 ^{h} ± 0.3
60 °C/15% RH	536 ^{h} ± 4	7.5 ^{i} ± 0.2
50 °C/25% RH	604 ^{f} ± 2	11.0 ^{f} ± 0.2
40 °C/30% RH	924 ^{a} ± 3	18.4 ^{c} ± 0.2
40 °C/10% RH	666 ^{e} ± 3	10.2 ^{g} ± 0.3
30 °C/30% RH	587 ^{f} ± 5	21.6 ^{a} ± 0.2
60 °C/15% RH to 50 °C/25% RH	761 ^{d} ± 1	13.8 ^{e} ± 0.2
50 °C/25% RH to 60 °C/15% RH	865 ^{c} ± 1	17.8 ^{d} ± 0.2
60 °C/15% RH to 40 °C/30% RH	596 ^{f} ± 4	20.2 ^{b} ± 0.2
40 °C/30% RH to 60 °C/15% RH	566 ^{g} ± 4	20.5 ^{b} ± 0.2
40 °C/10% RH to 30 °C/30% RH	634 ^{e} ± 3	11.8 ^{c} ± 0.2
30 °C/30% RH to 40 °C/10% RH	671 ^{b} ± 3	19.4 ^{f} ± 0.2

Values are mean ± standard deviation of triplicate analyses. In the same column, values followed by the same letter are not significantly different ($p \leq 0.05$).

Table 5. Moisture characteristics of turmeric slices subjected to different drying treatments.

Treatment	Fresh MC (% db)	Dried MC (% db)
40 °C/20% RH	190 ^{g} ± 3	7.4 ^{b} ± 0.2
40 °C/40% RH	335 ^{e} ± 3	10.5 ^{a} ± 0.3
50 °C/20% RH	377 ^{d} ± 3	7.0 ^{c} ± 0.1
50 °C/20% RH/5 min blanching	530 ^{a} ± 3	5.7 ^{d} ± 0.2
50 °C/20% RH/15 min blanching	420 ^{c} ± 3	7.0 ^{c} ± 0.3
50 °C/20% RH/30 min blanching	490 ^{b} ± 2	7.9 ^{b} ± 0.3
60 °C/20% RH	274 ^{f} ± 3	5.2 ^{e} ± 0.2
60 °C/40% RH	256 ^{f} ± 2	7.6 ^{b} ± 0.3
70 °C/ 20% RH	325 ^{e} ± 4	6.1 ^{d} ± 0.1

Values are mean ± standard deviation of triplicate analyses. In the same column, values followed by the same letter are not significantly different ($p \leq 0.05$).

3.1.3. Retention of 6-Gingerol in Ginger

The peak of 6-gingerol is shown in Figure 2a. A linear regression between retention area and standard concentration was calculated and a coefficient of determination (R2) of 0.9788 was obtained showing a good linear relationship. Under constant drying conditions, the content of 6-gingerol decreased with increasing temperature and RH. Under changing conditions, it appeared that with specific combinations of drying conditions, the concentration of 6-gingerol significantly increased when compared with constant conditions (Table 6).

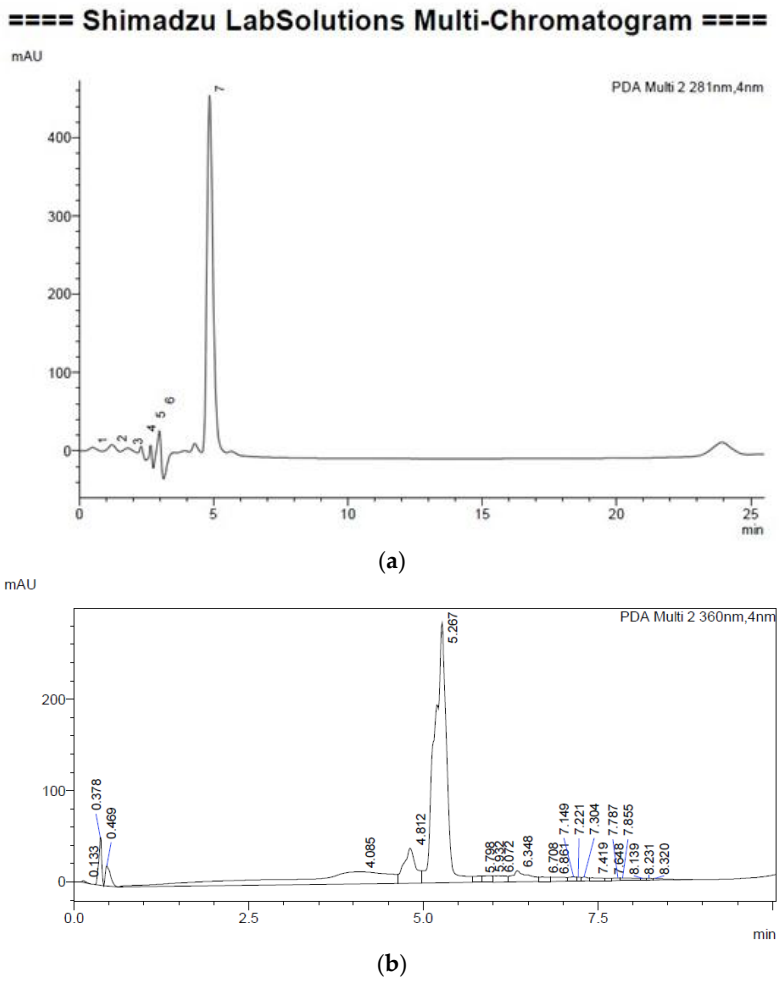

Figure 2. (**a**) Peak of 6-gingerol (peak #7); (**b**) Peak of curcumin from a drying treatment of 60 °C 20% RH.

Table 6. Effects of different drying treatments on 6-gingerol concentration in dried samples.

Treatment	Retention Area	6-Gingerol Concentration (%)	Drying Time (min)
40 °C/9%–12% RH	3572383	1.273 ^{e} ± 0.063	343 ^{d} ± 3
40 °C/9%–12% RH/5 min blanching	2289876	0.773 ^{i} ± 0.005	353 ^{d} ± 3
40 °C/9%–12% RH/15 min blanching	1196832	0.348 ^{j} ± 0.012	353 ^{d} ± 3
40 °C/9%–12% RH/30 min blanching	1059796	0.294 ^{j} ± 0.005	831 ^{a} ± 4
50 °C/6%–9% RH	3037359	1.064 ^{h} ± 0.010	289 ^{e} ± 3
60 °C/15% RH	2991478	1.047 ^{h} ± 0.015	177 ^{h} ± 3
50 °C/25% RH	3306548	1.169 ^{g} ± 0.011	233 ^{g} ± 4
40 °C/30% RH	3659751	1.307 ^{d} ± 0.067	297 ^{e} ± 3
40 °C/10% RH	3702015	1.323 ^{d} ± 0.005	257 ^{f} ± 2
30 °C/30% RH	3512811	1.250 ^{f} ± 0.050	489 ^{b} ± 3
60 °C/15% RH to 50 °C/25% RH	4155793	1.500 ^{b} ± 0.036	185 ^{h} ± 4
50 °C/25% RH to 60 °C/15% RH	4007405	1.442 ^{c} ± 0.050	203 ^{h} ± 3
60 °C/15% RH to 40 °C/30% RH	3532484	1.257 ^{e} ± 0.005	193 ^{h} ± 3
40 °C/30% RH to 60 °C/15% RH	3675330	1.313 ^{d} ± 0.054	257 ^{f} ± 2
30 °C/30% RH to 40 °C/10% RH	4470837	1.623 ^{a} ± 0.025	425 ^{c} ± 2
40 °C/10% RH to 30 °C/30% RH	4458393	1.618 ^{a} ± 0.025	305 ^{e} ± 3

Values are mean ± standard deviation of triplicate analyses. In the same column, values followed by the same letter are not significantly different ($p \leq 0.05$).

The combined treatments of 60 °C 15% RH and 50 °C 25% RH resulted in 0.35% more 6-gingerol retention vs. either of the constant conditions. Mild conditions as initial treatment led to higher 6-gingerol concentration. Blanching treatment reduced 6-gingerol retention. After 5 min of blanching, almost half of the 6-gingerol was lost vs. samples without blanching, and it decreased further with 15 and 30 min of blanching, possibly due to the high temperature of blanching.

3.1.4. Retention of Curcumin in Turmeric

The chromatogram indicated a curcumin peak at 5.267 min (Figure 2b). The greatest curcumin content (area under the curve) with samples dried at 50 °C 20% RH and blanched for 15 min. The greatest content for the non-blanched samples was at 60 °C 20% RH which had 82.2% of the content of the highest samples (Table 7).

Table 7. Effects of different drying treatments on curcumin concentration in dried samples.

Treatment	Area under the Curve	Normalised Concentration (%)
40 °C/20% RH	3308511	73.7
40 °C/40% RH	2646929	58.9
50 °C/20% RH	3447014	76.8
50 °C/20% RH/5 min blanching	3506873	78.1
50 °C/20% RH/15 min blanching	4490862	100.0
50 °C/20% RH/30 min blanching	3375932	75.2
60 °C/20% RH	3691512	82.2
60 °C/40% RH	2953344	65.8
70 °C/20% RH	3327375	74.1

4. Conclusions

The following conclusions were drawn from the study:

- Increasing drying temperature decreased 6-gingerol content in the dried product.
- Changing drying conditions significantly increased the concentration of 6-gingerol.
- Blanching treatment had a significant negative effect on 6-gingerol retention.
- Increasing drying temperature at low RH tended to increase curcumin retention.
- Blanching for 15 min favoured curcumin retention in the dried product.

Author Contributions: Haozhe Gan conducted the research on drying of ginger, conceived and designed the experiments, performed the experiments and analysed the data. Erin Charters conducted the research on drying of turmeric, conceived and designed the experiments, performed the experiments and analysed the data. George Srzednicki and Robert Driscoll wrote the paper.

Conflicts of Interest: The authors declare no conflict of interest.

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