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Effect of different drying methods and drying time on the sliced ginger rhizomes (*Zingiber officinale* Rosc.)

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Abstract
Under the present investigation, ginger was produced at the instruction cum research plots of the Department of Plantation Crops and Processing, Faculty of Horticulture, Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal. The farm is situated at 26o 19'86''N latitude and 89o 23'53" E longitude, at an elevation of 43 meters above mean sea level. It is situated in the terai agro-climatic zone of West Bengal. Experiments were conducted by factorial CRD experimental design with four ginger varieties (Gorubathan, Suprabha, Suruchi and Suravi) and five drying methods (Sun drying, Hot air drying at 50°C, 60°C and 70°C and Microwave drying). Among different drying methods, sun drying took upto 40 h (about 5 days) whereas, microwave drying took only 3- 5 min to reduce moisture content upto 8 - 10%. Among the drying methods, maximum dry recovery was found in microwave drying of Suravi variety (25.77%). Microwave drying (2.080%) was best followed by sun drying (2.055%) and microwave dried samples of Gorubathan variety has the highest essential oil content (2.243%) and oleoresin content (14.840%) among the four varieties in this study, followed by Suravi variety. Highest crude fiber content (5.253%) was observed in Suprabha and highest dry recovery (25.77%) was obtained from Suravi variety. In hot air drying, with increase in temperature dry recovery reduced. With high dry recovery (25.77%), essential oil (2.037%) and oleoresin content (13.510%) and moderately low crude fiber content (4.637%), it can be concluded that Suravi variety is best suitable for producing dry ginger. Apart from microwave drying, sun drying can be recommended as better practice, when hygienically conducted, based on essential oil and oleoresin content.

Keywords: Drying, methods, drying, ginger, rhizomes, *Zingiber officinale* Rosc.

Introduction
India is the largest producer, consumer and exporter of the spices in the World. Ginger (*Zingiber officinale* Rosc.) is a perennial herb with thick tuberous rhizome belonging to the family Zingiberaceae. It is known for its characteristic flavour and pungency and it is used throughout the world as a spice in culinary dishes, bakery products, meat products, flavouring agent in beverages, cosmetics. It also has wide range of application as herbal remedy. It has been used in Indian Ayurvedic as well as in Chinese medicine since ancient time (Bag, 2018). Ginger contains 1.5–3.0% of essential oil (Zingiberene) (Bellik *et al.* 2014) and 5 ─ 10% oleoresin, which are responsible for the aroma and pungency of the spice, respectively. Fresh ginger contains moisture (80.9%), protein (2.3%), minerals (1.2%), fiber (2.4%) and carbohydrates (12.3%). Iron, calcium, and phosphorous are important minerals present in ginger, followed by vitamins such as thiamine, riboflavin, niacin, vitamin A and vitamin C (Langner *et al.* 1998; Shukla *et al.* 2007) [2, 3].

After harvesting, ginger rhizomes are washed to remove the soil and roots. Due to improper post-harvest processing most of the ginger is consumed as a fresh vegetable in India. Fresh ginger contains about 80– 85% moisture and it is susceptible to microbial growth and deterioration (Mishra *et al.* 2004). Drying of ginger can prevent microbial spoilage and quality degradation and also it adds convenience in use for culinary purpose, storage and transportation. The yield of dry gingers 16-25 percent of the fresh ginger (Sasikumar *et al.* 2008) [5]. The quality of dried product and yield of essential oil depends on many factors including the quality of raw material as well as processing parameters. The variety of ginger and maturity at the time of harvest are the two main factors related to the raw material used for producing dried ginger. Drying method, temperature and duration of drying are important factors affecting quality of the product (Famurewa *et al.* 2012). Production of good quality dried ginger would help to make the crop available in the market for longer and farmers will also be able to get better value for their harvest by processing.

Materials and Methods

Under the present investigation, ginger was produced at the instruction cum research plots of the Department of Plantation Crops and Processing, Faculty of Horticulture, Uttar Banga Krishi Vishwavidyalaya, Pundibari, Cooch Behar, West Bengal. The farm is situated at 26o 19'86''N latitude and 89o 23'53" E longitude, at an elevation of 43 meters above mean sea level. The experimental design followed was Factorial Completely Randomized Design (FCRD) with four ginger varieties Gorubathan, Suprabha, Suruchi and Suravi and five drying methods (Sun drying, Hot air drying at 50 °C, 60°C and 70°C and Microwave drying).

Drying of ginger: The rhizomes were peeled carefully with a stainless steel knife to remove a very thin layer and sliced with 0.5 cm thickness. Sliced rhizomes were dried by different drying methods upto 8-10% moisture content. Different drying methods are- Sun drying, Hot air oven drying (50°C, 60°C, 70°C) and Microwave drying.

Sun drying (D1): Washed, peeled and sliced rhizomes were taken in a single layer in a stainless steel tray and dried in the sun from 9:00 am to 4:00 pm every day. The tray was kept on a laboratory table without any lid during the night.

Hot air drying at 50°C (D2): Washed, peeled and sliced rhizomes were taken in a single layer in a stainless steel tray and dried in a tray dryer at 50°C.

Hot air drying at 60°C (D3): Washed, peeled and sliced rhizomes were taken in a single layer in a stainless steel tray and dried in a tray dryer at 60°C.

Hot air drying at 70°C (D4): Washed, peeled and sliced rhizomes were taken in a single layer in a stainless steel tray and dried in a tray dryer at 70°C.

Microwave drying (D5): Washed, peeled and sliced rhizomes were taken in a single layer in a borosilicate glass plate. During drying of the ginger slices, weight was recorded at regular interval. For sun drying, weight was recorded at 2 h interval, for hot air drying at 1 h interval and at 0.5 min interval for microwave drying.

Estimation of moisture content and drying time

Moisture loss from the ginger rhizomes in each drying method was estimated from the weight loss and measurement of initial moisture content. Ginger rhizomes from each treatment were thinly sliced and dried in petri plates in hot air oven at 100oC for 24h (until constant weight). Moisture content (wet basis) was calculated from the weight of ginger rhizome before and after drying, recorded using weight measurements of the samples were taken using weighing balance(METTLER TOLEDO, Model no: PB153-L).

Weight of moisture = Weight of fresh sample – Weight of dried sample

Moisture Content (%) = Weight of moisture/Weight of fresh sample × 100 Drying time for each sample to reach 8 – 10% moisture content was recorded.

Calculation of dry recovery: Dry recovery for drying of ginger rhizomes by different methods were calculated from the weight of unpeeled ginger rhizomes and weight of dried ginger. Dry recovery was expressed in percentage.

Dry recovery (%) = Weight of dried sample (g)/ Weight of fresh sample (g) × 100

Statistical analysis: The observations recorded in laboratory from different treatments were subjected to statistical analysis as well as DMRT were carried out by using the statistical package adopting SPSS 14. Treatment variations were tested for significance under different parameters performed using critical difference test at 5% level of significance ($p \leq 0.05$) adopted by Fisher and Yates table (Gomez and Gomez, 1984) [7].

Results and Discussion

Moisture content of different varieties of fresh ginger

The data for moisture content of ginger rhizomes of different varieties used in this study is presented in Table 1. Variation in moisture content of the ginger rhizomes of different varieties was found to be not significant. Moisture content (w.b.) of ginger rhizomes varied in the range of 79.10% to 81.11% with variety Suprabha (81.11%) having highest moisture content and Suravi (79.10%) is having lowest moisture content.

Table 1: Effect of drying on moisture content (%) on slices of different varieties of Ginger

	Average moisture content (% w.b.)
Gorubathan (V1)	80.69
Suprabha (V2)	81.11
Suruchi (V3)	79.77
Suravi (V4)	79.10
SEm (±)	0.88

Effect of drying methods on drying time of ginger slices of different varieties: The drying time taken to dry peeled, sliced ginger rhizomes of varieties Gorubathan, Suprabha, Suruchi and Suravi upto a moisture content of 8 – 10% were recorded from the weight loss during drying and initial moisture content. The effect of drying methods on the drying time taken to dry upto 8 – 10% moisture content is presented in Table 4.3. In this table drying method significantly affects the drying time of ginger slices. A wide range of mean drying time, from 37.137 h in sun drying to 0.065 h (3.9 min) in microwave drying was observed. Sun drying took about 6 days to complete the drying process with approximately 7 h drying time per day. In hot air drying, the mean drying time varied between 10.341 h to 20.324 h, depending on air temperature. Microwave drying took only 3.9 min (mean) to complete drying of ginger slices.

Table 2: Effect of drying methods on drying time (h) on slices of different varieties of ginger

Variety	Drying time (h)					Mean
	Sun drying (D1)	Hot air drying, 50oC (D2)	Hot air drying, 60oC (D3)	Hot air drying, 70oC (D4)	Microwave drying (D5)	
Gorubathan(V1)	35.833	24.722	16.084	14.833	0.078(4.68 min)	18.310a
Suprabha (V2)	39.927	21.556	11.973	9.723	0.069(4.14 min)	16.650b
Suruchi (V3)	36.287	15.600	13.250	8.417	0.061 (3.66 min)	14.723d

Suravi (V4)	36.500	19.418	14.723	8.389	0.053 (3.18 min)	15.817c
Mean	37.137a	20.324b	14.008c	10.341d	0.065e (3.9 min)	
	Drying method		Variety		Drying method × Variety	
SEm(±)	0.189		0.169		0.378	
C. D. (P≤0.05)	0.542				1.084	

In respect to mean drying time, the variety Suruchi (14.723 h) differed significantly with all other varieties due to low drying time. Microwave drying (3.9 min) is best for fast drying followed by hot air drying at 70OC (10.341 h). Maximum mean drying time was observed in Gorubathan variety (18.310 h) whereas minimum drying time was observed in Suruchi (14.723 h). The interaction effect of drying method and variety of ginger on the drying time required was also found to be significant at 5% probability level. Among the different drying methods, sun drying of Suprabha variety took maximum time (39.927 h) and the minimum drying time was observed for microwave drying of Suravi variety (0.053 h or 3.18 min).

Effect of drying methods on dry recovery of ginger of different varieties

The dry recovery percentage of ginger of different varieties as affected by drying methods are presented in Table 3 and Fig. 1 shows the graphical representation of the dry recovery of ginger of different varieties. Dry recovery varied significantly with variety of ginger. It can be observed from Table 3 that mean dry recovery of ginger of different varieties varied between 21.01% in Suprabha and 24.98% in Suravi variety. The drying methods also showed significant variation in dry recovery of ginger. Among the drying methods, microwave drying resulted in maximum mean dry recovery (24.23%) followed by hot air drying at 50oC (22.99%) and hot air drying at 70oC resulted in minimum mean dry recovery (21.75%). Among the temperature variation in hot air drying, the mean dry recovery reduced as the temperature increased from 50oC to 70oC. Among all the dried ginger rhizomes of different varieties obtained by different drying methods, maximum dry recovery was found in microwave drying of Suravi variety (25.77%), which was statistically at par with Suruchi variety (25.57%) and minimum in sun drying of Suprabha variety (20.17%).

In respect to mean dry recovery, the variety Suravi (24.98%) differed significantly with all other varieties due to high dry recovery. Variety Suravi (24.98%) had best dry recovery followed by Suruchi (23.52%). Microwave drying (24.23%) is best followed by hot air drying at 500C among different drying methods. The variation in dry recovery among the varieties may be due to differences in their composition and textural properties. Moisture movement through the material during falling rate period is influenced by the internal structure of the material. Also during drying the volatile components may evaporate due to high temperature, which can influence the dry recovery. Variation in dry recovery among different varieties of ginger has also been reported in literature (Sanwal *et al.*, 2012; Sheo Govind *et al*. 1998) [8, 9].

Table 3: Effect of drying methods on dry recovery (%) of different varieties of ginger

Variety	Dry recovery (%) of ginger					Mean
	Sun drying (D1)	Hot air drying, 50oC (D2)	Hot air drying, 60oC (D3)	Hot air drying, 70oC (D4)	Microwave drying, (D5)	
Gorubathan (V1)	20.58	22.60	22.83	20.80	22.87	21.94a
Suprabha (V2)	20.17	21.17	20.77	20.23	22.70	21.01d
Suruchi (V3)	25.33	23.27	21.47	21.97	25.57	23.52c
Suravi (V4)	25.47	24.93	24.73	24.00	25.77	24.98b
Mean	22.89a	22.99b	22.45c	21.75d	24.23a	
	Drying method		Variety		Drying method × Variety	
SEm(±)	0.22		0.19		0.43	
C. D(P≤0.05)	0.62		0.55		1.23	

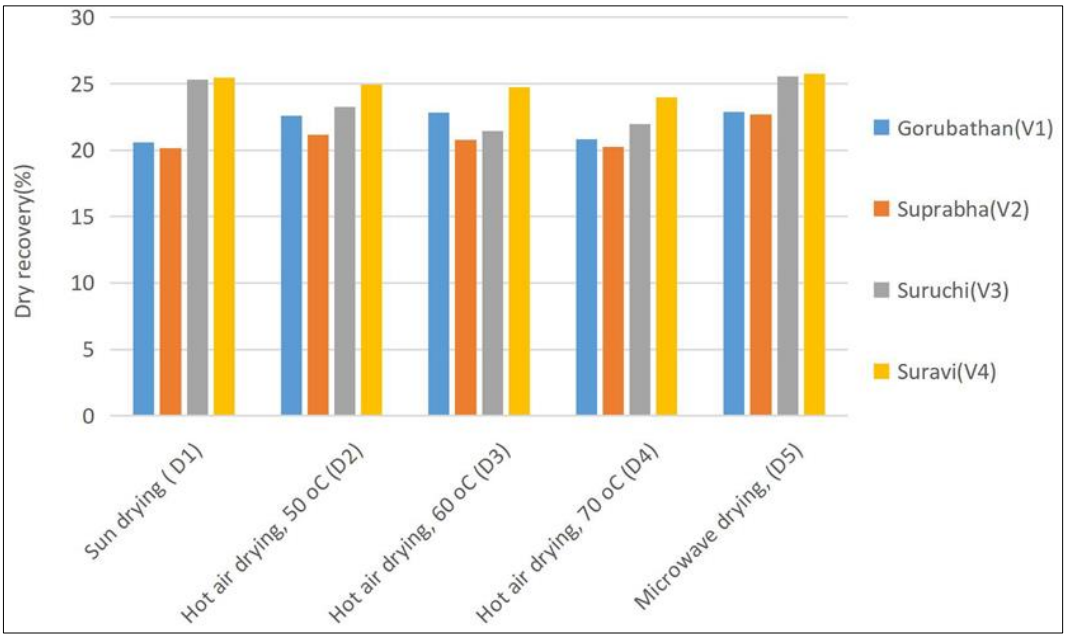

Fig 1: Dry recovery (%) of different varieties of ginger produced by S different drying methods

Conclusions

From the present study it can be concluded that, among different drying methods, microwave drying resulted in highest dry recovery (24.23%) and maximum dry recovery was found in microwave drying of Suravi variety (25.77%), it can be concluded that Suravi variety is best suitable for producing dry ginger.

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