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Influence of pre-treatments on the dehydration behavior of various ginger (*Zingiber officinale*) cultivars

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Abstract
The present investigation on the "Influence of Pre-treatments on the Dehydration Behavior of Various Ginger (*Zingiber officinale*) Cultivars" was carried out at the fruit science laboratory and central instrumentation laboratory, at the Post Graduate Institute for Horticultural Sciences (PGIHS), SKLTGHU, Mulugu, Siddipet, Telangana. The experiment was laid out in a Factorial Completely Randomized Design (FCRD) with two factors, each consisting of 4 levels. Factor one comprises different ginger varieties *viz.*, V1: Maran; V2: Mahim; V3: Kohir and V4: Regodi. The second factor consists of Pre-treatments such as P1: Potassium meta- bisulfite (KMS) @ 0.4%; P2: Citric acid @ 2g/l; P3: Ascorbic acid @ 0.1% and P4: Control (No pre- treatments) replicated thrice. The results on drying characteristics were influenced by the different ginger varieties and pre-treatments. Among the varieties, V2- Mahim recorded lowest moisture content (9.50%) with corresponding maximum values for drying ratio (9.20%), drying rate (3, 6, 9, 12, 15 and 18 hrs) (29.15 g/hr,12.74 g/hr, 6.39 g/hr, 3.31 g/hr, 1.64 g/hr and 0.37 g/hr, respectively) and drying recovery (11.32%). Among the various pre-treatments, P1: Potassium Metabisulfite (KMS) @ 0.4% recorded the maximum drying ratio (9.38%), drying rates at successive intervals (35.23 g/hr, 15.66 g/hr, 17.08 g/hr, 3.91 g/hr, 2.05 g/hr and 0.61 g/hr respectively), and drying recovery (12.50%), with the minimum moisture content (9.71%). Among the interaction effects, V2P1: (Mahim + Potassium metabisulfite (KMS) @ 0.4%) recorded the maximum drying ratio (9.84%), drying rates at successive intervals (37.64%, 19.73%, 8.31%, 4.12%, 2.79% and 0.85%, respectively) and drying recovery (12.91%), with minimum moisture content (8.46%).

Keywords: Drying characteristics, moisture content, drying rate, drying ratio and drying recovery

Introduction
Ginger (*Zingiber officinale*) is a rhizomatous perennial herb belongs to the Zingiberaceae family and native to Southeast Asia. It has been used as a spice in India for centuries, both in fresh and dried forms. The plant typically grows up to 3-4 feet tall, with a thick spreading rhizome. In 2023, global ginger production reached approximately 4.88 million tonnes. India led the world with 2.2 million tonnes, accounting for the largest share. Madhya Pradesh is a major contributor, yielding 692,110 tonnes. Nigeria followed with 781,641 tonnes, and China produced 672,914 tonnes. Other major producers included Nepal (309,533 tonnes), Indonesia (198,873 tonnes) and Thailand (174,103 tonnes). (FAOSTAT- Food and Agriculture Organization Corporate Statistical Database). The economic importance of ginger is primarily due to its modified stem, known as a rhizome, which is compact and grows horizontally. The compound responsible for its characteristic aroma is zingiberene, found abundantly in the rhizome (Bellik, 2014) [3]. Ginger contains about 1.5 to 3.0% essential oils and 5 to 10% oleoresin, both of which contribute to its strong flavor and fragrance. Oleoresin includes non-volatile phenolic compounds such as gingerols, shogaols and zingerone (Huang *et al*., 2012) [5]. In the state of Telangana, India, the Maran, Mahim, Khoir and Regodi varieties of ginger are cultivated primarily for the production of dry ginger. However, limited information is available on the drying characteristics of these varieties, particularly with respect to the retention of quality parameters. The present study aims to investigate the effect of different combinations of pretreatments and ginger varieties on the drying characteristics of ginger.

Preservatives like citric acid, lime, potassium metabisulfite and ascorbic acid are widely used for pretreating ginger before drying. Citric acid, one of the most commonly used food additives, helps retain color, texture and taste by increasing acidity and inhibiting microbial growth (Zhang *et al.*, 2023) [9]. Ascorbic acid prevents the oxidation of lipids and pigments, thereby extending shelf life and preserving the color, flavor and nutritional value of various foods. It also improves the overall quality and technological properties of food products (Cvetkovic and Jokanovic, 2009) [4]. Potassium metabisulfite (KMS) is effective in preserving vegetables and meats by preventing microbial spoilage. Additionally, KMS functions as an antioxidant, helping to maintain the natural color and flavor of food items.

Materials and Methods

The present experiments were conducted at Fruit Science Laboratory and Central Instrumentation Laboratory at Post Graduate Institute for Horticultural Sciences, SKLTGHU, Mulugu, Siddipet during the year, 2024-25. The ginger (*Zingiber officinale*) rhizomes of 4 varieties namely Maran Mahim, Kohir and Regodi utilized in the present study were procured from multiple locations across Telangana. Among them, (The Mahim and Kohir varieties were collected from the farm of Mr. Padawal Dinesh Kumar of Keshampet village, Rangareddy district, Hyderabad, with the rhizomes harvested at full maturity stage, approximately 9-10 months after planting, in the month of December) The Maran variety was obtained from a local farm situated in Mohammed Yadul village, Karchal, Raikole mandal, Sangareddy district. Wheres, the Regodi variety was procured from the Osman Gunj ginger market in Hyderabad.

Experimental details

The design adopted in the experiment was Factorial Completely Randomized Design (FCRD) with three replications.

Treatment details

Factor 1: Varieties (V) 4 Levels V1: Maran
V2: Mahim **V3:** Kohir **V4:** Regodi
Factor 2: Pre - Treatments (P)4 Levels P1: Potassium meta bisulfite (KMS) 0.4%
P2: Citric acid 2 g/l
P3: Ascorbic acid 0.4%
P4: Control (No pre-treatments)

Treatment combinations

1	V1P1	:	Maran + Potassium meta bisulfite (KMS) 0.4%
2	V1P2	:	Maran + Citric acid 2g/l
3	V1P3	:	Maran + Ascorbic acid 0.2%
4	V1P4	:	Maran + Control (No pretreatments)
5	V2P1	:	Mahim + Potassium meta bisulfite (KMS) 0.4%
6	V2P2	:	Mahim + Citric acid 2g/l
7	V2P3	:	Mahim + Ascorbic acid 0.2%
8	V2P4	:	Mahim + Control (No pretreatments)
9	V3P1	:	Kohir + Potassium meta bisulfite (KMS) 0.4%
10	V3P2	:	Kohir + Citric acid 2g/l
11	V3P3	:	Kohir + Ascorbic acid 0.2%
12	V3P4	:	Kohir + Control (No pretreatments)
13	V4P1	:	Regodi + Potassium meta bisulfite (KMS) 0.4%
14	V4P2	:	Regodi+ Citric acid 2g/l
15	V4P3	:	Regodi + Ascorbic acid 0.2%
16	V4P4	:	Regodi + Control (No pretreatments)

Fresh ginger (*Zingiber officinale*) was selected as the raw material for the experiment. The rhizomes were initially cleaned under running water to eliminate adhering soil and other surface contaminants. Damaged and undesirable portions were carefully removed, followed by a second thorough wash to ensure complete cleanliness. The cleaned rhizomes were then manually peeled using a sharp knife in preparation for further processing. For each experimental replication, approximately 500 g of peeled ginger rhizomes were used. To control microbial contamination, the samples were first immersed in a calcium oxide (CaO) solution at a concentration of 2 g/l for 10 minutes.

Application of pretreatments

After this initial treatment, the rhizomes were subjected to three different chemical pre-treatments: potassium meta bisulphite (KMS) at 0.4% (w/v), ascorbic acid at 0.2% (w/v) and citric acid at 2 g/l, for a duration of 5 minutes. Control samples were prepared without the application of any chemical pre- treatment. These pre-treatment processes were aimed at enhancing the overall quality, microbial safety and stability of the ginger rhizomes prior to experimental analysis.

Results and Discussion

Moisture content (%)

The moisture content was estimated using standard air oven method as described AOAC (1995) [2]. Pre-weighed samples were placed in a hot air oven maintained at 60 °C until a constant weight was achieved (usually 18 hours). The dish with dried sample was transferred to a desecrator and cooled to room temperature. The loss in weight during drying was used to calculate the moisture content of the sample. The moisture content (wet basis) was calculated using the following formula:

$$\text{Moisture content} = \frac{M_f - M_i}{M_i} \times 100$$

M.C (w. b.) = Moisture content%
Mf = Final mass of the dried sample (g) Mi= Initial mass of sample (g)

The results regarding the final moisture content of ginger rhizomes, influenced by pre-treatments and different ginger varieties, were presented in table.2 and graphically in fig.1.The experiment demonstrated that significant differences were observed among the ginger varieties with respect to moisture content (%). The minimum moisture content (%) was recorded in the variety V2- Mahim (9.50%) and maximum moisture content was recorded in V4- Regodi (11.14%).Among the various pre-treatments, P1- Potassium metabisulfite (KMS) @ 0.4% recorded minimum moisture content (9.71%). However, P4- Control (No pre-treatments) was recorded maximum moisture content (11.27%). The interaction effect between different ginger varieties and pre-treatments significantly influenced the moisture content of dried ginger rhizomes. The minimum moisture content (8.46%) was recorded in V2P1 Mahim + KMS @ 0.4% treated samples, whereas the maximum moisture content was recorded in V4P4- Regodi+ Control (No pre-treatments) (11.68%).
KMS acts as a sulfiting agent and is commonly used in food processing as an antioxidant and antimicrobial agent. Its ability to disrupt cell membranes and facilitate water expulsion through osmotic effects can contribute to lower moisture content in dried products of ginger. Amoah in ginger and Rani and Tripathy (2019) [8] in pineapple.

Drying ratio

The drying ratio was calculated as the percentage ratio of the final weight of dried ginger rhizomes to the initial weight of ginger rhizomes loaded for drying. It was expressed using the following formula:

$$\text{Drying ratio (Dr)} = \frac{W_1}{W_2} \times 100$$

W1=Initial weight of Ginger before drying (g) W2= final weight of dried product (g) The data regarding drying ratio was significantly influenced by various pre- treatments among different varieties during the experiment presented in table.3 and illustrated in fig.2. Among the different varieties, maximum drying ratio (9.20) was recorded in V2- Mahim, and the minimum drying ratio was observed in V4-Regodi (8.23). Among the various pre-treatments, P1- (KMS) potassium metabisulfite @ 0.4% recorded the maximum drying ratio (9.38) and the lowest drying ratio was observed in P4- Control (No pre-treatments) (7.86). The interaction effects between the different varieties and pre- treatments were also found to significantly influence the drying ratio of ginger rhizomes. V2P1- Mahim + KMS @ 0.4% recorded the maximum drying ratio (9.84). The minimum drying ratio (7.21) was recorded in V4P4- Regodi+ Control (No pre-treatments).

Drying rate (g/hr)

Drying rate was calculated based on the amount of moisture content in sample per unit time per unit dry mass. Measurements were recorded at 3-hour intervals throughout the 18-hour drying period, specifically at 3, 6, 9, 12, 15 and 18 hours and expressed in percentage. It was determined using the following formula:

$$\text{Drying rate (g/h)} = \frac{\text{Weight of water in sample (kg)}}{\text{Time (h) x Weight of dry (kg)}} \times 100$$

The results pertaining to the drying rate (g/hr) of ginger rhizomes as affected by different varieties and pre-treatments and their combinations are depicted in fig. 4.3.The significant differences in drying characteristics were observed due to the influence of ginger varieties,V2- Mahim recorded maximum drying rate at 3, 6, 9, 12, 15 and 18 hrs (29.15 g/hr, 12.74 g/hr, 6.39 g/hr, 3.31 g/hr, 1.64 g/hr and 0.37 g/hr),V4- Regodi recorded Minimum drying rate at 3, 6, 9, 12, 15 and 18 hrs (25.58 g/hr, 10.33 g/hr, 5.21 g/hr, 2.73 g/hr, 1.08 g/hr and 0.20 g/hr). Among the various pre-treatments, P1- Potassium meta bisulfite (KMS) @ 0.4% recorded significant maximum drying rate at 3, 6, 9, 12, 15 and 18 hrs (35.23 g/hr, 15.66 g/hr, 17.08 g/hr, 3.91 g/hr, 2.05 g/hr and 0.61 g/hr respectively). P4- Control (No pre- treatments) recorded minimum drying rate at 3, 6, 9, 12, 15 and 18 hrs (18.57g/hr, 8.40g/hr, 4.27g/hr, 1.94g/hr, 0.65g/hr and 0.06g/hr respectively).Among the interaction effects, V2P1- Mahim + KMS @ 0.4% noted maximum drying rate at 3, 6, 9, 12, 15 and 18 hrs (37.64g/hr, 19.73g/hr, 8.31g/hr, 4.12g/hr, 2.79g/hr and 0.85g/hr respectively). Minimum drying rate at 3, 6, 9, 12, 15 and 18 hrs (16.66g/hr, 7.66g/hr, 3.60g/hr, 1.72g/hr, 0.39g/hr and 0.01g/hr respectively).V4P4- Regodi+ Control (No pre-treatments) recorded minimum drying rate at 3, 6, 9, 12, 15 and 18 hrs (16.66g/hr, 7.66g/hr, 3.60g/hr, 1.72g/hr, 0.39g/hr and 0.01g/hr respectively). The results are in accordance with Amoah in ginger.

Drying recovery (%)

The results concerning the drying recovery percentage of ginger rhizomes as influenced by different varieties, pre-treatments and their combinations were presented in table 1. The maximum dry recovery percentage was recorded by the variety V2- Mahim (11.32%) and minimum dry recovery percentage was observed in V4- Regodi (10.09%). The maximum dry recovery percentage (12.50%) was recorded with P1- KMS @ 0.4%, minimum value for dry recovery percentage was recorded in P4- Control (No pre-treatments) (9.66%). The interaction effects between the different varieties and pre-treatments had significant effect on dry recovery percentage of ginger rhizomes. The maximum dry recovery percentage (12.91%) was recorded in V1P1- Maran + KMS @ 0.4% and the minimum dry recovery percentage (7.51%) was recorded in V3P4- Kohir + Control (No pre-treatments). The results are in accordance with Khurana *et al.* (1997) and Jayashree *et al.* (2014) [7] in ginger and also Anitha *et al.* (2021) [1] in turmeric.

Table 1: Effect of pre-treatments on moisture content (%) of different ginger varieties.

Factors	Pre-treatments				
Varieties	P1	P2	P3	P4	Mean
V1	10.31^{c}	10.80^{d}	10.42^{cd}	11.39^{ef}	10.73^{bc}
V2	8.46^{a}	8.95^{ab}	9.78^{bc}	10.78^{ef}	9.50^{a}
V3	9.50^{b}	10.99^{ab}	10.43^{cd}	11.24^{ef}	10.54^{b}
V4	10.57^{cd}	11.27^{e}	11.05^{de}	11.68^{g}	11.14^{d}
Mean	9.71^{a}	10.50^{bc}	10.42^{b}	11.27^{d}	
	S.Em (±)		CD at (1%)		CV (%)
V	0.11		0.33		4.29
P	0.14		0.41		
V×P	0.28		0.81		

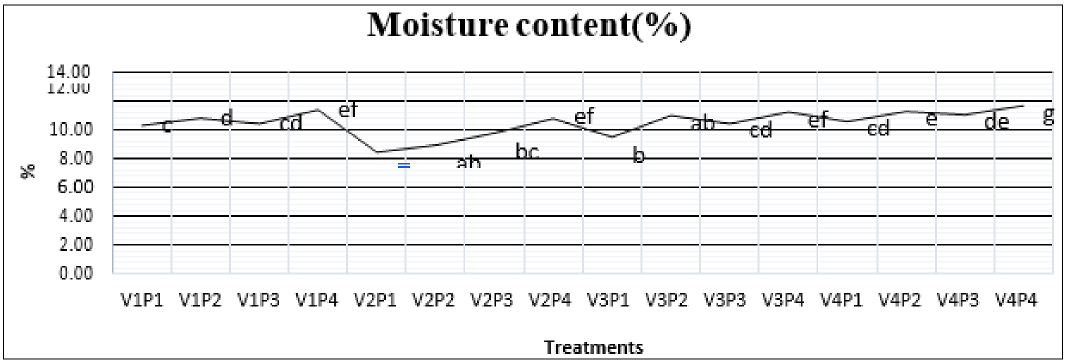

Fig 1: Effect of pre-treatments on moisture content (%) of different ginger varietie

Table 2: Effect of pre-treatments on drying recovery (%) of different ginger varieties.

Factors			Pre-treatments		
Varieties	P1	P2	P3	P4	Mean
V1	12.91a	10.28d	11.19bc	8.98e	10.84b
V2	12.55ab	8.59e	12.48ab	11.66bc	11.32a
V3	12.88ab	11.48bc	12.56ab	7.51f	11.11ab
V4	11.67b	8.37ef	9.83d	10.48cd	10.09c
Mean	12.50a	9.68c	11.51b	9.66c	
	S.Em (±)		CD at (1%)		CV (%)
V	0.09		0.26		3.27
P	0.11		0.32		
V×P	0.22		0.63		

Table 3: Effect of pre-treatments on drying ratio of different ginger varieties Factors Pre-treatments

Factors		Pre-treatments			
Varieties	P1	P2	P3	P4	Mean
V1	9.10bc	8.25de	8.57cde	7.43f	8.34c
V2	9.84a	8.61cde	9.65a	8.71cd	9.20a
V3	9.54ab	8.42de	9.03bc	8.08e	8.77b
V4	9.05bc	8.19de	8.48de	7.21f	8.23c
Mean	9.38a	8.37c	8.93b	7.86d	
	S.Em (±)		CD at (1%)		CV (%)
V	0.06		0.17		
P	0.07		0.21		2.26%
V×P	0.15		0.42		

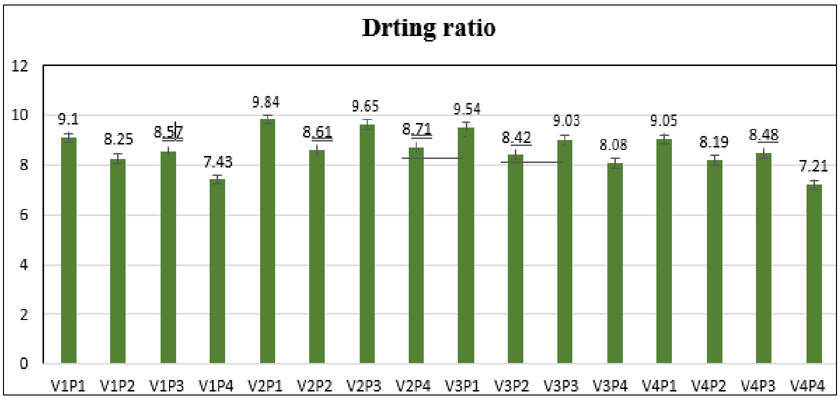

Fig 2: Effect of pre-treatments on drying ratio of different ginger varieties

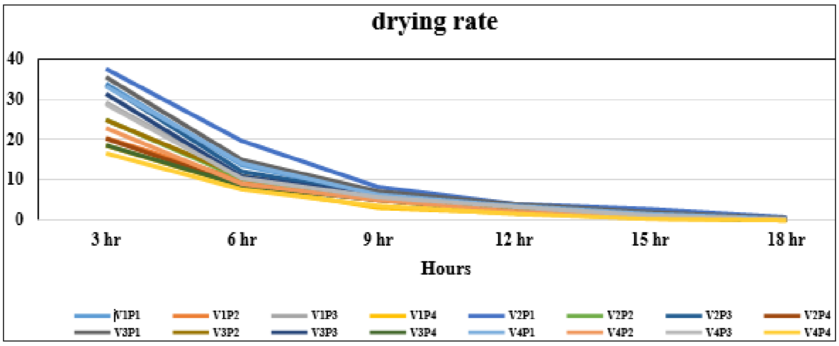

Fig 3: Effect of pre-treatments on drying rate (g/hr) of different ginger varieties

Conclusion

It can be concluded from the present investigation that different pretreatments influenced the Dehydration behavior of different ginger (*Zingiber officinale*) varieties.

Based on a comprehensive evaluation of the different ginger varieties, V2 (Mahim) performed comparably to V1 (Maran) across all drying characteristics. The pretreatment P1 (KMS at 0.4%) resulted in higher moisture loss, enhanced drying rate, and greater drying recovery in ginger rhizomes. Among the varietal and pretreatment interactions, V2P1 (Mahim + KMS at 0.4%) exhibited the most favourable drying characteristics.

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