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INFLUENCE OF PACKAGING MATERIALS ON THE SHELF LIFE AND QUALITY OF DRIED GINGER RHIZOMES

Varshini N.V.[1], Bhoomika H.R.[2*], Kantharaj Y.[3], Ravi C.S.[1] and Akshitha H.J.[4]

[1]Department of PSMAC, College of Horticulture, Mudigere-577132, Karnataka, India

[2]ICAR- Krishi Vigyan Kendra, Brahmavara, Udupi-576213, Karnataka, India

[3]Department of Post- harvest Technology, College of Horticulture, Mudigere (Karnataka)- 577132, India

[4]ICAR-IISR Regional Stion, Appangala, Madikeri, Coorg (D) (Karnataka)- 571201, India

*Corresponding author: bhoomi04@yahoo.co.in.

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ABSTRACT

The present study investigated the impact of different packaging materials on the storability of dry ginger (*Zingiber officinale*). The performance of gunny bags, nylon bags, gunny bag with polyethylene lining and polywoven bags preserving key quality parameters, including essential oil content, oleoresin content, colour retention, moisture content and microbial load, over an extended storage period was evaluated. The findings revealed that polyethylene lined gunny bags were superior in retaining essential oil and oleoresin content which are the two primary indicators of ginger's potency and market value. Additionally, this packaging solution minimized colour degradation, preserved a bright and desirable colour and effectively reduced moisture uptake, thus enhancing storability. The polyethylene lining acted as a barrier against moisture ingress, which is crucial in preventing microbial growth and spoilage. The study concludes that using gunny bags with a polyethylene lining is an efficient method for prolonging the storability and preserving the quality attributes of dry ginger.

Keywords **:** Dry ginger, storage, gunny bag with polyethylene lining, essential oil, oleoresin content.

Introduction

Ginger (*Zingiber officinale* Roscoe) belongs to the Zingiberaceae family and it is indigenous to south-eastern Asia (Purseglove *et al.,* 1981). It is cultivated and consumed in subtropical and tropical regions all around the world. Rhizomes of plant are consumed in many subtropical and tropical countries such as China, India, Jamaica and Australia. It is one of the earliest known treasured spices esteemed for its pungency and aroma, viewed as a healing gift from God by the Indian Ayurveda. Since ages, ginger is known for its medicinal value as a digestive aid, spiritual beverage, aphrodisiac, antiemetic, anticancer, anti-platelet, anti-microbial, anti-parasitic, anti-oxidant, anti-inflammatory, analgesic, hepato-protective, and for immune stimulating properties (Malhotra and Singh, 2003). The moisture content (MC) of fresh ginger is between 83–94 % on wet basis. 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 and anti-inflammatory effect (Gan *et al.*, 2017).

Pretreatment is an essential step before processing of food materials. It has been reported that pretreatments can accelerate drying rate by dissociating the wax and forming fine cracks on the surface of the material for easy moisture removal. It helps retain essential nutrients and flavours while extending the shelf life by reducing microbial growth.

Ginger rhizomes are valued for their bioactive compounds, particularly gingerols, which largely influence the market price of dried ginger. Drying is a crucial postharvest step as it lowers moisture content and water activity, thereby curbing microbial growth and slowing chemical reactions that lead to spoilage.

This process not only extends the shelf life but also reduces the product's size, cutting down on storage and transportation costs. However, drying can negatively impact product quality by causing the loss of volatile aromatic compounds, reducing antioxidant activity, and degrading essential nutrients. Additionally, thermal reactions during drying may lead to the formation of new compounds.

Drying is one of the important processing techniques to process fresh ginger and is vital for its utilization in different products and long-term preservation. Open sun drying may require long time exposure to an uncontrolled environment that may result in microbial and other types of contamination (Wang *et al*., 2019). Conventional industrial procedures mostly involve hot air oven drying; however, the resultant product may be of inferior nutritional quality. Microwave drying may result in better preservation of nutritional quality than conventional methods due to lower process temperature, better process control and precision, operational speed, fast start and quick shutdown and higher efficiency (Lv *et al.,* 2016 and Megahed, 2001).

The freshly harvested ginger rhizomes are perishable and prone to water loss and fungal diseases. Therefore, it is important to dry the rhizomes and to store them in best packaging materials to extend the shelf life and maintain the quality (Taghavi *et al*., 2022). Environmental factors such as temperature, relative humidity and atmospheric composition are not controlled during storage. Hence, new and costeffective methods are adopted for controlling storage conditions and maintaining post-harvest quality of dry ginger.

Materials and Methods

Drying of ginger- Ginger rhizomes treated with lime and KMS were dried in solar tunnel dryer.

Packaging- dried ginger were packed in different packaging materials like gunny bags, nylon bags, gunny bag with polyethylene lining and polywoven bags.

Storage – The dried ginger packed using different packaging materials were stored for 180 days. The analysis carried out at 90- and 180 days after storage (DAS) using completely randomized design.

Moisture content: The moisture content of the fresh and dried samples was estimated by Mettler Tolledo moisture analyzer. Once the analyser was ready, an empty sample pan was placed on the weighing platform, and the scale was tared to zero. The 5g of sample was placed on the sample pan and evenly spread to ensure uniform heating. After the sample was added, the drying parameters were set to 105°C. Once the parameters were configured, the lid was closed, and the measurement was started. The analyser heated the sample, recording the weight loss as moisture evaporated. The process continues until the moisture content stabilizes or the drying time concludes. The moisture content was then displayed as a percentage of the initial sample weight. After the measurement, the sample pan was allowed to cool, the results were recorded.

Calculation

$$\text{Moisture}\,(\%) = \frac{(W_2 - W_3)}{(W_2 - W_1)} \times 100$$

where,

W_1 = weight of container or empty dish (g)

W_2 = weight of container + sample before drying (g)

W_2 - W_1 = weight of sample (g)

W_3 = weight of container + sample after drying (g)

$W_2 - W_3$ = loss of weight (g)

Microbiological analysis (cfu×10^4): The ginger powder was subjected to microbial analysis using the serial dilution method. Potato dextrose agar was prepared, autoclaved at 121°C, cooled, and then poured into sterile petri plates, allowing the media to solidify. One gram of ginger powder was added to 9ml of double-distilled water and shaken for 15-20 minutes. The sample solution was then diluted in a 10-fold series. 1ml of the serially diluted suspension was spread on pre-poured, cooled, and solidified medium. The plates were incubated at 37°C for 24 to 48 hours, allowing isolated colonies to develop on the enriched medium. The number of colonies was expressed as cfu (Colony Forming Units) ×10^4 per sample.

Essential oil content (%): The essential oil content was determined using Clevenger's apparatus as described by Hirko *et al.* (2020). 50 grams of ginger powder was accurately weighed and placed in a 1000 ml round bottom flask, then the volume was adjusted with an adequate amount of water was added. A continuous flow of water was maintained to condense the vapours into oil droplets, with the operating temperature set to 60°C. Distillation was carried out for three hours until completion. The percentage of essential oil content in the sample was calculated using the following formula.

$$\text{Essential oil}\,(\%) = \frac{\text{Volume of essential oil obtained (ml)}}{\text{amount of sample used (g)}} \times 100$$

Oleoresin content (%): The Soxhlet method of extraction was employed to extract oleoresin following the procedure cited by Hirko *et al.* (2020). The dried powdered ginger of 5g wrapped in filter paper, was placed in glass columns with a 500 ml volumetric flask positioned below to collect the extract. For each sample, 125 ml of acetone used. The extraction process continued until the solvent became colourless. The extract was then transferred into a pre-weighed empty glass beaker and subjected to evaporation to obtain a brown-coloured semisolid mass. The oleoresin recovery was expressed as percentage.

Colour measurement: The visual colour measurement of dried ginger powder was conducted using a Lovibond colorimeter. The colorimeter was first calibrated using a white sheet and confirmed to be properly calibrated. Readings obtained in L*, a*, b* system where L* refers to (whiteness/ brightness/ darkness), a* refers to (redness/ greenness) and b* refers to (yellowness/blueness). L*, a*, b* values were determined for respective samples. Three values were taken and average value was calculated for each sample.

Result and Discussion

The moisture content was significantly affected by packaging materials was represented in Table 1. Least moisture content was observed in the treatment T_7- KMS @ 0.2% for 2 min and solar tunnel drying + gunny bag with poly ethylene lining (11.16 to 12.65%) and T_3- lime @ 2% for 6 hours and solar tunnel drying + gunny bag with poly ethylene lining (11.55 to 12.50%). Whereas, maximum moisture was absorbed by ginger rhizomes packed in treatment T_6- KMS @ 0.2% for 2 minutes and solar tunnel drying + nylon bag (13.96 to 16.05%) and T_2- lime @ 2% for 6 hours and solar tunnel drying+ nylon bag (13.75 to 16.75%). The increased moisture content noted in both gunny bags and nylon bags is likely due to moisture penetration through the pores of these packaging materials. The results are in agreement with that of Chandrasekaran *et al.* (2018).

The microbial load increased in rhizomes stored in all packaging materials over time. However, the lowest levels were observed in rhizomes stored in gunny bags with polyethylene liners, specifically in treatment T_7 (KMS @ 0.2% for 2 minutes with solar tunnel drying and storage in a gunny bag with polyethylene lining) and treatment T_3 (lime @ 2% for 6 hours with solar tunnel drying and storage in a gunny bag with polyethylene lining), with microbial counts ranging from 2.45×10^4 to 3.45×10^4 and 2.76×10^4 to 3.55×10^4 at 90 and 180 days after storage (DAS), respectively. In contrast, the highest microbial load was recorded in rhizomes stored in nylon bags, with levels ranging from 3.87×10^4 to 5.15×10^4 in treatment T_6 (KMS @ 0.2% for 2 minutes and solar tunnel drying + nylon bag) and 3.86×10^4 to 5.00×10^4 in T_2 (lime @ 2% for 6 hours and solar tunnel drying+ Nylon bag) over the same period. Additionally, treatment T_1 (lime @ 2% for 6 hours and solar tunnel drying+ gunny bag) also exhibited a relatively high microbial load, ranging from 3.22×10^4 to 4.25×10^4 at 90 and 180 DAS is shown in Table 2.

The oil content in dry ginger at 90 and 180 DAS is presented in Table 3. Treatments T_3 (lime @ 2% for 6 hours with solar tunnel drying and storage in a gunny bag with polyethylene lining) and T_7 (KMS @ 0.2% for 2 minutes with solar tunnel drying and storage in a gunny bag with polyethylene lining) had the highest oil content, recorded at 1.65% and 1.52% for T_3 and 1.4% and 1.35% for T_7 at 90 and 180 DAS, respectively. In contrast, the lowest oil content was found in treatments T_5 (KMS @ 0.2% for 2 minutes with solar tunnel drying and storage in a gunny bag), with 0.75% and 0.3%, and T_1 (lime @ 2% for 6 hours with solar tunnel drying and storage in a gunny bag), with 0.87% and 0.37% after 90 and 180 DAS, respectively. This oil retention may be associated with changes in moisture levels during storage. Moreover, as essential oils are highly volatile, the polyethylene-lined gunny bags reduced the rhizomes exposure to atmospheric air, minimizing oil loss through evaporation. These results align with findings from Chandrasekaran *et al.* (2018) and Anjaneyulu *et al.* (2021).

Retention of oleoresin content at 90 and 180 DAS was interpreted in Table 4. The highest oleoresin retention was observed in rhizomes stored in gunny bags with polyethylene lining. Treatment T_3 (lime @ 2% for 6 hours with solar tunnel drying and storage in a gunny bag with polyethylene lining) retained oleoresin content of 4.05% and 3.55% at 90 and 180 DAS, respectively, while treatment T_7 (KMS @ 0.2% for 2 minutes with solar tunnel drying and storage in a gunny bag with polyethylene lining) showed 3.20% and 2.96% oleoresin in the same timeframe. In contrast, rhizomes stored in plain gunny bags had the lowest oleoresin retention, with treatment T_1 (lime @ 2% for 6 hours with solar tunnel drying and storage in a gunny bag) recording 3.25% and 2.55%, and T_5 (KMS @ 0.2% for 2 minutes with solar tunnel drying and storage in a gunny bag) recording 2.95% and 2.30% at 90 and 180 DAS, respectively is recorded in Table 4. This lower retention may be due to oxidation induced degradation of active compounds in rhizomes. A gradual decline in oleoresin content was observed as storage duration increased, which aligns with findings by Chandrasekaran *et al*. (2018) and Pooja *et al.* (2022). Similarly, Naveen *et al*. (2017) reported that nutmeg stored in gunny bags had lower oleoresin levels compared to other packaging, a conclusion supported by Anjaneyulu and Sharangi (2022) and Fikiru *et al*. (2024).

The colour characteristics of ginger rhizomes was depicted in Table 5 at 90 and 180 DAS. The highest lightness (L^*) values were observed in rhizomes stored in gunny bags with polyethylene lining. This was particularly evident in treatment T_7 (KMS @ 0.2% for 2 minutes with solar tunnel drying and storage in a gunny bag with polyethylene lining), where L^* values ranged from 67.10 to 66.50, and treatment T_3 (lime @ 2% for 6 hours with solar tunnel drying and storage in a gunny bag with polyethylene lining), with L^* values ranging from 65.30 to 65.10 over a storage period of 90 to 180 DAS. In contrast, the lowest L^* values were found in plain gunny bags, particularly in treatment T_5 (KMS @ 0.2% for 2 minutes with solar tunnel drying and storage in a gunny bag), with values from 66.23 to 64.15, and in treatment T_1 (lime @ 2% for 6 hours with solar tunnel drying and storage in a gunny bag), with values 64.17-62.25 at 90 and 180 DAS, respectively. The pretreatments used may also influence oxidative reactions; for example, KMS acts as both a preservative and an antioxidant, helping to reduce colour degradation during storage. These findings align with previous studies by Chandrasekaran *et al*. (2018), Anjaneyulu and Sharangi (2022), Sidhu *et al.* (2011), Garuba *et al.* (2022) and Fikiru *et al.* (2024), supporting the link between storage conditions and the colour stability of ginger rhizomes.

Conclusions

A gunny bag with polyethylene lining has been identified as the most effective packaging option for storing dry ginger. This combination helps maintain the quality of dry ginger over extended storage by effectively controlling moisture levels and shielding the product from external atmospheric conditions.

Table 1 : Effect of packaging materials on moisture content (%) of rhizomes during storage

Treatments	Initial value	90 DAS	180 DAS	Difference (180 DAS-Initial value)
T_1- Lime @ 2% for 6 hours and solar tunnel drying + Gunny bags	9.00	13.50	15.50	+6.50
T_2- Lime @ 2% for 6 hours and solar tunnel drying + Nylon bags	9.00	13.75	16.75	+7.75
T_3- Lime @ 2% for 6 hours and solar tunnel drying + Gunny bags with polyethylene line	9.00	11.55	12.50	+3.5
T_4- Lime @ 2% for 6 hours and solar tunnel drying + Poly woven bags	9.00	12.73	14.35	+5.35
T_5- KMS 0.2% for 2 Min and solar tunnel drying + Gunny bags	9.00	13.85	15.65	+6.65
T_6- KMS 0.2% for 2 Min and solar tunnel drying + Nylon bags	9.00	13.96	16.05	+7.05
T_7- KMS 0.2% for 2 Min and solar tunnel drying + Gunny bags with polyethylene line	9.00	11.16	12.65	+3.65
T_8- KMS 0.2% for 2 Min and solar tunnel drying + Poly woven bags	9.00	12.95	14.55	+5.55
S.Em±	**0.22**	**0.07**	**0.13**	**0.16**
CD @ 1%	**NS**	**0.30**	**0.48**	**0.67**

NOTE: DAS- Days after storage

Table 2 : Effect of packaging materials on microbial load (cfu×10^4) of ginger rhizomes during storage

Treatments	90 DAS	180 DAS	Difference (180-90)
T_1- Lime @ 2% for 6 hours and solar tunnel drying + Gunny bags	3.22×10^4	4.25×10^4	$+1.03\times10^4$
T_2- Lime @ 2% for 6 hours and solar tunnel drying + Nylon bags	3.86×10^4	5.00×10^4	$+1.14\times10^4$
T_3- Lime @ 2% for 6 hours and solar tunnel drying + Gunny bags with polyethylene line	2.76×10^4	3.55×10^4	$+0.79\times10^4$
T_4- Lime @ 2% for 6 hours and solar tunnel drying + Poly woven bags	2.97×10^4	3.85×10^4	$+0.88\times10^4$
T_5- KMS 0.2% for 2 Min and solar tunnel drying + Gunny bags	3.38×10^4	4.95×10^4	$+1.57\times10^4$
T_6- KMS 0.2% for 2 Min and solar tunnel drying + Nylon bags	3.87×10^4	5.15×10^4	1.28×10^4
T_7- KMS 0.2% for 2 Min and solar tunnel drying + Gunny bags with polyethylene line	2.45×10^4	3.45×10^4	1.00×10^4
T_8- KMS 0.2% for 2 Min and solar tunnel drying + Poly woven bags	2.92×10^4	3.95×10^4	1.03×10^4
S.Em±	**0.04**	**0.01**	**0.02**
CD @ 1%	**0.19**	**0.03**	**0.08**

Note: DAS- Days after storage cfu- Colony forming unit

Table 3 : Effect of packaging materials on essential oil (%) content of rhizomes during storage

Treatments	**Initial value**	**90 DAS**	**180 DAS**	**Difference (180 DAS- Initial value)**
T_1- Lime @ 2% for 6 hours and solar tunnel drying + Gunny bags	1.75	0.87	0.37	-1.38
T_2- Lime @ 2% for 6 hours and solar tunnel drying + Nylon bags	1.75	0.83	0.39	-1.39
T_3- Lime @ 2% for 6 hours and solar tunnel drying + Gunny bags with polyethylene line	1.75	1.65	1.52	-0.23
T_4- Lime @ 2% for 6 hours and solar tunnel drying + Poly woven bags	1.75	1.62	1.50	-0.25
T_5- KMS 0.2% for 2 Min and solar tunnel drying + Gunny bags	1.50	0.75	0.30	-1.20
T_6- KMS 0.2% for 2 Min and solar tunnel drying + Nylon bags	1.50	1.00	0.55	-0.95
T_7- KMS 0.2% for 2 Min and solar tunnel drying + Gunny bags with polyethylene line	1.50	1.40	1.35	-0.15
T_8- KMS 0.2% for 2 Min and solar tunnel drying + Poly woven bags	1.50	1.39	0.31	-0.19
S.Em±	**0.01**	**0.01**	**0.02**	**0.06**
CD @ 1%	**0.02**	**0.04**	**0.07**	**0.26**

NOTE: DAS- Days after storage

Table 4 : Effect of packaging materials on oleoresin content (%) of rhizomes during storage

Treatments	**Initial value**	**90 DAS**	**180 DAS**	**Difference (180 DAS- Initial value)**
T_1- Lime @ 2% for 6 hours and solar tunnel drying + Gunny bags	4.53	3.25	2.55	-1.98
T_2- Lime @ 2% for 6 hours and solar tunnel drying + Nylon bags	4.53	3.45	2.75	-1.78
T_3- Lime @ 2% for 6 hours and solar tunnel drying + Gunny bags with polyethylene line	4.53	4.05	3.55	-0.98
T_4- Lime @ 2% for 6 hours and solar tunnel drying + Poly woven bags	4.53	3.99	3.40	-1.13
T_5- KMS 0.2% for 2 Min and solar tunnel drying + Gunny bags	3.40	2.95	2.30	-1.10
T_6- KMS 0.2% for 2 Min and solar tunnel drying + Nylon bags	3.40	2.97	2.33	-1.07
T_7- KMS 0.2% for 2 Min and solar tunnel drying + Gunny bags with polyethylene line	3.40	3.20	2.96	-0.44
T_8- KMS 0.2% for 2 Min and solar tunnel drying + Poly woven bags	3.40	2.98	2.46	-0.94
S.Em±	**0.01**	**0.07**	**0.13**	**0.03**
CD @ 1%	**0.04**	**0.27**	**0.54**	**0.12**

NOTE: DAS- Days after storage

Table 5 : Effect of packaging materials on colour value (L*) of rhizomes during storage

Treatments	**Initial value**	**90 DAS**	**180 DAS**	**Difference (180 DAS -Initial value)**
T_1- Lime @ 2% for 6 hours and solar tunnel drying + Gunny bags	67.10	64.17	62.25	-4.85
T_2- Lime @ 2% for 6 hours and solar tunnel drying + Nylon bags	67.10	64.23	62.35	-4.75
T_3- Lime @ 2% for 6 hours and solar tunnel drying + Gunny bags with polyethylene line	67.10	65.30	65.10	-2.00
T_4- Lime @ 2% for 6 hours and solar tunnel drying + Poly woven bags	67.10	65.87	64.85	-2.25
T_5- KMS 0.2% for 2 Min and solar tunnel drying + Gunny bags	68.10	66.23	64.15	-3.95
T_6- KMS 0.2% for 2 Min and solar tunnel drying + Nylon bags	68.10	66.95	64.93	-3.17
T_7- KMS 0.2% for 2 Min and solar tunnel drying + Gunny bags with polyethylene line	68.10	67.10	66.50	-1.60
T_8- KMS 0.2% for 2 Min and solar tunnel drying + Poly woven bags	68.10	67.43	66.33	-1.77
S.Em±	**0.02**	**0.20**	**0.05**	**0.04**
CD @ 1%	**0.09**	**0.86**	**0.21**	**0.17**

NOTE: DAS- Days after storage

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