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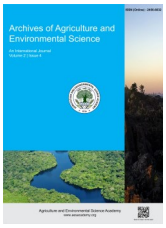

ORIGINAL RESEARCH ARTICLE

A comparative study of the effect of peeling and drying on phytochemical and proximate composition of ginger varieties in Nepal

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ABSTRACT

The handling and processing of ginger are done by farmers in Nepal by following primitive practices that result in poor and unhygienically processed ginger of low quality. Due to little information on the quality and compositional aspects of ginger and its value-added product (essential oil), there is a need to improve traditional methods of processing and drying for a better quality of ginger and its product. This study aimed to assess the effects of peeling and drying conditions on two local ginger varieties in Nepal. A three-factor Completely Randomized Design (CRD) experiment was laid out at Ginger Research Program, Kapurkot, Salyan, Nepal. Three treatment factors were variety (Bose ginger and Nase ginger varieties), peeling (peeled and unpeeled ginger), and drying methods (direct sun drying and oven drying). After drying ginger rhizomes, the dry recovery percentage was calculated and the dried ginger rhizomes were ground to powder and subjected to laboratory analysis, where essential oil content and proximate composition of ginger powder were evaluated. Then, the extracted essential oil was subjected to GC-MS (Gas Chromatography and Mass Spectrometry) analysis to know the chemical composition of essential oil. The result obtained showed that unpeeled oven-dried gingers retained higher essential oil content (2 %). The moisture content of oven-dried peeled ginger was reduced to 10.49 % which is within the standard of 7-12 % acceptable to the international market unlike that of direct-sun drying which could only attain about 17% moisture content in the study area. Likewise higher dry recovery percentage (22.25%) was observed in unpeeled sun-dried gingers. Ether extract (5.05 %) and crude fiber (5.05 %) were higher in the Nase variety whereas nitrogen-free extract (75.51 %) was more efficient in Bose variety. From the GC-MS analysis of ginger oil, α-Zingiberene (16.61-21 %) was found to be a major chemical constituent of ginger essential oil followed by (E, E)-α-farnesene (8.68-10.99 %) and β-Sesquiphellandrene (8.26-10.23 %). The use of an oven to dry unpeeled ginger will improve the retention of essential oil; However, peeling of ginger showed reduced fiber content in the ginger.

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INTRODUCTION

Ginger (*Zingiber officinale* Roscoe) is one of the most valuable spice crops in the world belonging to the family Zingiberaceae (Britannica, 2020). Ginger is monocotyledonous, herbaceous, perennial, underground modified stem believed to be originated from Southeast Asia (Sharma, 2014) and has been cultivated from time immemorial. Ginger is used in raw, dried, and powdered forms for culinary and medicinal purposes throughout the world. It is commercially available in various forms, such as green ginger, dry ginger, ginger powder, ginger oil, ginger oleoresin, and preserved ginger (Fikre and Kifle, 2013). A variety of

products such as pickles, candy, squash, shampoo, soap, etc. can be processed from raw ginger (K.C. *et al.*, 2013). Apart from using ginger as a spice crop and flavoring agent, it can be utilized for its essential oil extracts. Volatile oils and nonvolatile solvent extractable pungent compounds found in ginger contribute to the characteristic organoleptic properties due to the presence of different polyphenolic compounds (Nair, 2019; Mahmudati *et al.*, 2020). Ginger contains two major classes of constituents; essential oils which consist of monoterpenes and sesquiterpenes that contribute to the characteristics flavor of ginger and oleoresins which is responsible for pungent flavor and also the source of anti-oxidants (Bartley and Jacobs, 2000). The major constituents of ginger are: carbohydrates (50-70 %); lipids (3-8 %); terpenes (α-Zingiberene, β-Bisabolene, α-Farnesene, α -Curcumene, etc.); phenolic compounds (6-Gingerol, 6-Paradols, 6-Shagaols, etc.); amino acids; ash; proteins; vitamins, etc. and terpenes are generally responsible for aromatic flavor whereas phenolic compounds are responsible for the pungent flavor of ginger (Ghosh *et al.*, 2011). Among aromatic compounds, α-Zingiberene (sesquiterpene hydrocarbon) is predominant and the pungent taste is predominately caused by gingerols followed by shogaols and zingerone present in ginger (Vasala, 2001).

The quality of ginger is determined not only by its physical form but also by its chemical composition. Though two released varieties of ginger in the Salyan district have been studied and analyzed by Ginger Research Program, Salyan, for their physical and chemical quality, local varieties are yet to be studied. The study of the nutritional and phytochemical composition of ginger is lacking in Nepal which has caused a knowledge gap among the farmers. With the extraction of essential oil, one can get a higher price for it as compared to fresh ginger. The handling and processing of ginger are done by Nepalese farmers following primitive practices, resulting in poor quality and unhygienic processed ginger. Due to the lack of information on quality and composition, there is a need to improve traditional processing and drying methods to improve the quality of ginger and its products. Significant improvement in the quality of ginger products can be made with the identification of better processing techniques for ginger to preserve the nutritional value of ginger and the biochemical properties of different varieties of gingers. Better quality ensures the enhancement of end product value for export in the global market meeting the international standards of quality and demands. The research is an incentive for the use of ginger other than for culinary purposes and the study aimed to determine the appropriate method of peeling and drying ginger for enhancing its quality and biochemical composition.

MATERIALS AND METHODS

Experimental site

The two local varieties of ginger "Bose ginger" and "Nase ginger" were collected from Siddha Kumakha Rural Municipality of Salyan district of Nepal. Processing and laboratory analysis were carried out at Agriculture and Forestry University (AFU), Rampur, Chitwan. Salyan, Khalanga is located at 28° 22' 31.01" N latitude, 82° 09' 42.01" E longitude, and an altitude of 1530 meters above sea level. It lies in the mid-hills of Nepal and the physical and environmental condition of Salyan is favorable for ginger production.

Design of experiment

The experiment was laid out in a three-factor completely randomized design where three factors were ginger variety, peeling method, and drying method. Factor "variety" consisted of Bose ginger and Nase ginger. Similarly, for the factor "peeling": peeled ginger and unpeeled ginger were used, and for the factor "drying", two types of drying: direct sun drying and oven drying were used. Thus, the experiment consisted of eight treatments (Table 1) replicated three times resulting in a total of twenty-four units laid out in a Completely Randomized Design (CRD) factorial design.

Table 1. Treatment details.

Treatments (3 factors)		
Factor 1: Variety V1: Bose ginger V2: Nase ginger	**Factor 2: Peeling** P1: Peeled ginger P2: Unpeeled ginger	**Factor 3: Drying methods** D1: Sun drying D2: Oven drying
Treatments	**Variety X Peeling × Drying**	
T1	Bose ginger (V1) X Peeled ginger (P1) × Sun drying (D1)	
T2	Bose ginger (V1) X Unpeeled ginger (P2) × Sun drying(D1)	
T3	Nase ginger (V2) X Peeled ginger (P1) × Sun drying (D1)	
T4	Nase ginger (V2) X Unpeeled ginger (P2) × Sun drying(D1)	
T5	Bose ginger (V1) X Peeled ginger (P1) × Oven drying (D2)	
T6	Bose ginger (V1) X Unpeeled ginger (P2) × Oven drying (D2)	
T7	Nase ginger(V2) X Peeled ginger (P1) × Oven drying (D2)	
T8	Nase ginger(V2) X Unpeeled ginger (P2) × Oven drying (D2)	

Working procedure

Washing: Local ginger varieties: Bose and Nase ginger were collected and rhizomes were subjected to cleaning for the removal of adhering soil by soaking in water.

Peeling, slicing, and drying: Rhizomes were distinctly divided into eight treatments with three replications consisting of twenty-four units. Rhizomes to be peeled were subjected to manual peeling and others were left unpeeled according to their treatment combination. Then the gingers were sliced to uniform thickness and data were recorded for the fresh batch. The remaining were subjected to oven drying and sun drying according to the treatments such that all the twenty-four units contain an equal amount of ginger rhizomes. Sun-drying was carried out for one week as recommended by Fikre and Kifle (2013) and Ravindran and Babu (2016) or until the dried ginger rhizomes produced a metallic sound while breaking. Similarly, oven drying was carried out at 57°C for 24 hours as stated by Ravindran and Babu (2016). Dried samples were then ground to powder form and were subjected to further analysis and data collection.

Data collection: Data were collected at different steps and lab analyses to assess the following parameters:

Dry recovery percentage: After the drying of the ginger rhizomes as mentioned above, the weight of dried ginger was taken and the dry recovery percentage was calculated by the formula given by Goudar *et al.* (2017).

$$\text{Percentage of dry recovery of ginger} = \frac{\text{Weight of dried ginger}}{\text{Weight of fresh ginger}} \text{x } 100$$

Proximate analysis: The proximate composition of oven-dried ginger powder was analyzed at Animal Nutrition Laboratory, AFU, and determined using standard AOAC methods of analysis as adopted by Garg *et al.* (2013).

Moisture content: Moisture was determined by the loss in weight that occurs when a sample was dried to a constant weight in an oven. One gram of dried ginger powder was weighed and further complete oven drying was carried out to determine moisture in the sun-dried and oven-dried ginger. Moisture content was determined by:

$$\% \text{ Moisture content} = \frac{M1 - M2}{M1} \times 100$$

M_1= mass of the sample before final oven drying
M_2= mass of the sample after final oven drying

Ether extract (%EE): The SoxTRON (SOX 6) was used for the extraction of crude fat by following the procedures mentioned by Garg *et al.* (2013).

Crude fiber (%CF): The organic residue left after sequential extraction of the sample with ether was used to determine the crude fiber content. The procedure mentioned in AOAC, 962.09, 16th edition was followed.

Crude protein (%CP): Crude protein was determined by measuring the nitrogen content of the sample and multiplying it by a factor of 6.25 (IS 14825, 2000). Crude protein was determined by Kjeldahl's method. The method involves Digestion, Distillation, and Titration. From Kjeldahl's method, % nitrogen content was obtained and multiplied by 6.25 to obtain crude protein content (Garg *et al.*, 2013).

Ash content (%Ash): Ash content was determined by following methods given in Thiex *et al.* (2012).

Nitrogen-free extract (%NFE): NFE represents soluble carbohydrates and other digestible and easily utilizable non-nitrogenous substances in the sample. It was obtained by subtracting the sum of percentages of crude fiber, crude protein, ether extract, and total ash from the dry matter as given below.

%NFE = Dry matter- (%CF + %CP + %EE + %Ash)

Essential oil extraction: The essential oil was extracted at the Biotechnology lab, Centre of Biotechnology, AFU using the Clevenger apparatus by hydro distillation method (Figure 1) (Yingngam and Brantner, 2018). 75 grams of ginger powder was mixed with 200-300 ml of water and was subjected to hydro distillation for 3 hours at 60-80°C. The extracted oil was measured and converted into a percentage (V/W basis).

$$\text{Essential oil \%} = \frac{\text{Volume of oil extracted (ml)}}{\text{Weight of dry powder (g)}} \times 100\ \%$$

GC-MS (Gas Chromatography-Mass Spectrometry) analysis: The essential oil extracted by the hydro distillation method from different replication of each treatment were mixed to form a total of eight composite samples. The composite samples were subjected to GCMS analysis to obtain the phytochemical constituents of the volatile oil obtained from different treatments and varieties. Details of the GC-MS profiling test are given below:

Sample: Essential oil of ginger
Quantity: 5 ml
Detector type: MS
Column type: RTX-5 MS
Library used: FFNSC 4.0
Dimension of Column: 60m x 0.32mm x 0.25µm
Test method: DPR/SOP/7.2/01
Packaging of Sample: Glass vial

Figure 1. *Essential oil extraction a) Powder ginger; b) Clevenger apparatus; c) Essential oil in plastic vials.*

Data analysis

The data recorded were arranged and entered in MS Excel and analyzed by using statistical software R version 4.1.0. The inference was drawn at a 5 % level of significance and mean comparisons of the above-mentioned parameters were done using DMRT (Duncan's Multiple Range Test).

RESULTS AND DISCUSSION

Effect of peeling and drying methods on dry recovery percentage, moisture content, and essential oil content of different local ginger varieties of Salyan

The effect of peeling and drying methods on dry recovery percentage, moisture content, and essential oil content of different local ginger varieties are tabulated in Table 2. There was no significant effect of variety on dry recovery percentage, moisture content, and essential oil content at a 5 % level of significance whereas statistically significant results were obtained for peeled and unpeeled gingers and also for sun-dried and oven-dried gingers on all three given parameters. The result of the experiment shows a highly significant interaction ($p<0.001$) between all three factors: variety, peeling, and drying on the dry recovery percentage. The interaction revealed that the highest dry recovery percentage was observed in the sun-dried, unpeeled Nase ginger variety which is statistically similar to the sun-dried unpeeled Bose ginger variety. Likewise, the lowest value

Table 2. Dry recovery (%), moisture content and essential oil content of different ginger varieties as influenced by peeling and drying methods.

Treatment	Dry recovery percentage	Moisture content	Essential oil percentage
Variety			
Bose ginger	20.13	14.41	1.94
Nase ginger	19.94	14.38	1.83
LSD	NS	NS	NS
SE_m (±)	0.135	0.098	0.037
F-probability value	0.33	0.808	0.050
CV (%)	2.32	2.35	6.80
Peeling			
Peeled	18.85^b	13.20^b	1.76^b
Unpeeled	21.23^a	15.20^a	2.009^a
LSD	0.404	0.292	0.11
SE_m (±)	0.135	0.098	0.037
F-probability value	<0.001***	<0.001***	<0.001***
CV (%)	2.32	2.35	6.80
Drying			
Sun drying	21.06^a	17.25^a	1.755^b
Oven drying	19.01^b	11.54^b	2.012^a
LSD	0.404	0.292	0.11
SE_m (±)	0.135	0.098	0.037
F-probability value	<0.001***	<0.001***	<0.001***
CV (%)	2.32	2.35	6.80
Grand mean	20.04	14.39	1.88

*, ** and *** represent significant at 5 %,1 % and 0.1 % level of significance respectively, NS=not significant. Treatment means sharing the same superscript are not significantly different from each other based on DMRT at a 0.05 level of significance.

Figure 2. *Interaction effect of drying methods, peeling and varieties on dry recovery of ginger.*

Figure 3. *Interaction effect of drying methods, peeling and varieties on the moisture content of ginger.*

for the dry recovery percentage was recorded in oven-dried, peeled Bose ginger variety which can be observed in Figure 2. Dry recovery percentage was obtained more in sun-dried and unpeeled ginger samples due to inadequate drying and more moisture content left in them than in oven-dried and peeled ginger samples. The result is supported by Ajayi *et al.* (2017) and Eze and Agbo (2011), as they also observed similar results. From the study, it was observed that dry recovery percentage was positively and significantly correlated with final moisture content with a correlation coefficient of 0.85 (r=0.85) and coefficient of determination of 0.72 (R^2=0.72) at a 5% level of significance which infers that 72% of the variation in dry recovery percentage was due to final moisture content in dried ginger.

Likewise, the effect of interaction between variety, peeling, and drying was found highly significant (p<0.01) on moisture content. The highest moisture content was observed in the sun-dried, unpeeled Nase ginger variety which is statistically at par with the sun-dried unpeeled Bose ginger variety. Similarly, the lowest amount of moisture content was obtained for the oven-dried peeled Bose ginger variety (Figure 3). Lower moisture content (7-10%) in the peeled oven-dried sample was also observed by Kaushal *et al.* (2017). Oven drying is more effective in removing moisture compared to sun drying according to Ajayi *et al.* (2017) and a similar result was observed in the current study, where oven drying required only 24 hours for drying whereas sun-drying required 7 days with continuous 8 hours drying per day for complete drying of the ginger. The heat supplied by the oven is more consistent than the sun which depends on climate and season at the time of drying, the time required for sun drying is more (Bankole *et al.* 2005). With the same duration for drying methods, a large difference is obtained for dry recovery percentage and moisture content in

Table 3. Proximate composition of different ginger varieties as influenced by peeling and drying methods.

Treatment	Ether extract	Crude fiber	Crude protein	Total ash content	Nitrogen free extract
Variety					
Bose ginger	4.5[b]	4.45[b]	7.95	7.57	75.51[a]
Nase ginger	5.05[a]	5.05[a]	7.86	7.33	74.69[b]
LSD	0.179	0.115	NS	NS	0.395
SE_m (±)	0.06	0.039	0.083	0.091	0.132
F-probability value	<0.001***	<0.001***	0.46	0.088	<0.001***
CV (%)	4.34	2.80	3.64	4.245	0.608
Peeling					
Peeled	5.15[a]	4.68[b]	8.17[a]	7.46	74.53[b]
Unpeeled	4.4[b]	4.83[a]	7.63[b]	7.44	75.68[a]
LSD	0.179	0.115	0.249	NS	0.395
SE_m (±)	0.06	0.039	0.083	0.091	0.132
F-probability value	<0.001***	<0.05	<0.001***	0.893	<0.001***
CV (%)	4.34	2.80	3.64	4.245	0.608
Drying					
Sun drying	4.32[b]	4.55[b]	8.28[a]	7.24[b]	75.59[a]
Oven drying	5.22[a]	4.96[a]	7.52[b]	7.66[a]	74.62[b]
LSD	0.179	0.115	0.249	0.387	0.395
SE_m (±)	0.06	0.039	0.083	0.091	0.132
F-probability value	<0.001***	<0.001***	<0.001***	<0.001***	<0.001***
CV (%)	4.34	2.80	3.64	4.245	0.608
Grand Mean	4.77	4.757	7.9	7.453	75.10

*, ** and *** represent significant at 5%,1% and 0.1% level of significance respectively, NS=not significant. Treatment means sharing the same superscript are not significantly different from each other based on DMRT at a 0.05 level of significance.

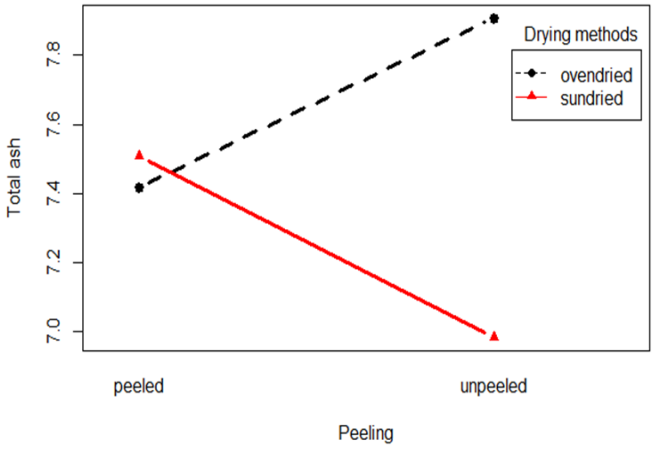

Figure 4. *Interaction effect of peeling and drying methods on total ash of ginger.*

different treatments which may be due to the peeling and different drying methods adopted (Bag, 2018).

On the contrary, the essential oil content was found significantly higher in unpeeled ginger than in peeled ginger. Similarly, oven-dried ginger had a significantly higher essential oil content than the sun-dried ginger samples. This higher essential oil content in oven-dried gingers in our experiment is supported by the findings of Yiljep *et al.* (2005). In sun-dried ginger, volatile oils are lost due to longer exposure to the sun than shorter exposure to heat in oven-dried samples (Yiljep *et al.* 2005). Similarly, the essential oil content was also found higher in unpeeled ginger samples than in peeled ones in the study by Ravindran and Babu (2016), who also explained the cause of the result obtained as most of the constituents of essential oil are found in and underneath the peel which is lost during the peeling of ginger.

Effect of peeling and drying methods on proximate composition of different local ginger varieties of Salyan

The effect of peeling and drying methods on the proximate composition of different local ginger varieties are tabulated in Table 3. Different parameters of proximate composition were significantly affected by the treatment factors. While appraising the variety, the ether extract and crude fiber were recorded significantly higher in the Nase ginger variety than Bose ginger variety whereas nitrogen-free extract was observed significantly higher in Bose ginger variety as compared to the Nase variety. No significant difference was observed in the crude protein and total ash content of ginger due to variety. The crude protein and ether extract were found to be significantly higher in peeled ginger than in unpeeled ones ($p<0.001$) whereas the crude fiber and nitrogen-free extract were found to be significantly higher in unpeeled gingers than in the peeled ginger samples ($p<0.05$). Factor 'peeling' had no significant effect on the total ash content ($p=0.05$). Likewise, the effect of drying methods was highly significant on all the parameters of nutritional composition ($p<0.001$). The results depict that the oven-dried ginger had significantly high ether extract, crude fiber, and total ash content whereas the sun-dried ginger samples had significantly high crude protein and nitrogen-free extract ($p<0.001$). A significant interaction effect was seen between the factors peeling and drying on the parameter total ash content. The results show that the highest amount of total ash was obtained for unpeeled oven-dried ginger samples whereas the lowest amount was obtained for unpeeled sun-dried ginger samples which are illustrated clearly in Figure 4.

In our experiment, ether extract was found to be 5.22% and crude fiber was 4.96% in oven drying which was higher than in sun drying. Also, the crude protein and nitrogen-free extracts were 8.28% and 75.59% in sun-drying which were found greater than in oven drying. Ajayi *et al.* (2017) also obtained similar results for drying methods on the given parameters. Contrary to our results, Ajayi *et al.* (2017) observed high total ash content in open sun-dried ginger than in oven-dried gingers. Ginger can be best preserved in its natural form under open sun drying with a temperature less than 40°C and high temperature denatures protein which explains the low crude protein content in the oven drying in our study (Eze and Agbo, 2011). However, oven drying is the most preferred method of drying to maintain high nutritional content and minimize the processing time (Ajayi *et al.*, 2017). Higher crude protein and ether extract content in peeled ginger makes them superior in nutritional composition. Yiljep *et al.* (2005) also found similar results in their study. The removal of peel and splitting reduces fiber content in ginger. Considering the factor variety, our study shows the local Bose ginger variety is superior to the local Nase ginger variety in terms of nutritional composition. More fiber content in the ginger is considered inferior quality which is found significantly higher in local Nase ginger of the Salyan district. However, ether extract and volatile oils are found higher in the Nase variety.

Phytochemical composition of ginger essential oil through Gas Chromatography-Mass Spectrometry (GC-MS) analysis

After the extraction of essential oil through the hydro-distillation method, to determine the components of essential oil, GC-MS was performed (Table 4). Different peaks were obtained for different treatments with the highest peak number of thirty in the Nase peeled sun-dried ginger sample.

Bose peeled sun-dried ginger (T1): From the GC-MS analysis, twenty-five chemical components were identified for Bose peeled sun-dried ginger. Among the twenty-five phytochemicals, α-Zingiberene was the major constituent with 19.27% area followed by (E, E)-α-farnesene (10.99%), β-Sesquiphellandrene (10.09%), Geranial (9.88%) and Neral (7.75%) being the top five phytochemicals for the given treatment.

Bose unpeeled sun-dried ginger (T2): Similar to above, from the GC-MS analysis, twenty-seven chemical components were identified for Bose unpeeled sun-dried ginger. Among the twenty-seven phytochemicals, α-Zingiberene was the major constituent with 16.61% area followed by (E, E)-α-farnesene (8.68%), β-Sesquiphellandrene (8.26%), β-Phellandrene (8.05%) and Geraniol (7.60%) being the top five phytochemicals for the given treatment.

Nase peeled sun-dried ginger (T3): The GC-MS analysis of essential oil of Nase peeled sun-dried ginger identified thirty chemical components which was the highest peak number among the treatments of the study. Among the thirty phytochemicals, the top five phytochemicals for the given treatment are α-Zingiberene as the major constituent with 17.91% area followed by β-Sesquiphellandrene (9.56%), (E, E)-α-farnesene (9.36%), Geranial (7.00%) and α-Curcumene (6.29%).

Nase unpeeled sun-dried ginger (T4): From the GC-MS profiling of essential oil of Nase unpeeled sun-dried ginger, twenty-six chemical components were identified. Among the twenty-six phytochemicals, α-Zingiberene was the pre-dominant chemical constituent similar to other treatments with 20.04% area. Other dominant phytochemicals were (E, E)-α-farnesene (10.15%), β-Sesquiphellandrene (10.04%), Geranial (9.01%), and Neral (7.24%).

Bose peeled oven-dried ginger (T5): From the GC-MS analysis of essential oil of Bose peeled sun-dried ginger, twenty-five chemical components were identified. Among those twenty-five phytochemicals, α-Zingiberene was found to cover the highest area% with 20.13% area. Other dominant phytochemicals with their area coverage are (E, E)-α-farnesene (10.62%), β-Sesquiphellandrene (9.90%), β-Phellandrene (7.53%), and Geranial (6.95%).

Bose unpeeled oven-dried ginger (T6): According to the GC-MS profiling in the current study, twenty-six different phytochemicals could be identified from Bose unpeeled oven-dried ginger. Among the chemical constituents identified, the pre-dominant chemical was found to be α-Zingiberene with the area% of 20.22% followed by (E, E)-α-farnesene (10.51%), β-Sesquiphellandrene (10.13%), Geranial (7.53%) and β-Phellandrene (7.43%) being the top constituents of the given treatment.

Nase peeled oven-dried ginger (T7): Similarly, from the GC-MS analysis of essential oil of Nase peeled oven-dried ginger, twenty-six chemical components were identified. Among the twenty-six phytochemicals, α-Zingiberene was the pre-dominant chemical constituent similar to other treatments with an 18.97% area. Other dominant phytochemicals were (E, E)-α-farnesene (9.67%), β-Sesquiphellandrene (9.15%), β-Phellandrene (7.56%), and Geraniol (7.21%).

Nase unpeeled oven-dried ginger (T8): Likewise, according to the GC-MS profiling in the current study, twenty-nine different phytochemicals could be identified from Nase unpeeled oven-dried ginger. Among the chemical constituents identified, the pre-dominant chemical was found to be α-Zingiberene with the area% of 21.00% followed by β-Sesquiphellandrene (10.24%), (E, E)-α-farnesene (10.18%), β-Phellandrene (6.94%) and Geranial (6.26%) being the top constituents of the given treatment. From the results obtained from GC-MS analysis, a maximum peak of thirty chemical constituents was observed in Nase peeled sun-dried ginger. α-Zingiberene was found as the pre-dominant chemical composition of the ginger oil in the study. Other important phytochemicals of ginger obtained from the

Table 4. Essential oil composition of Ginger (*Zingiber officinale* Roscoe) of different treatment combinations.

Compound	Percentage composition in different treatments							
	T1	T2	T3	T4	T5	T6	T7	T8
(E)-nerolidol	0.9	0.7	1.26	0.77	0.71	0.74	0.83	0.82
(E)-β-farnesene	-	-	0.77	-	-	2.25	-	0.83
(E, E)-α-farnesene	10.99	8.68	9.36	10.15	10.62	10.51	9.67	10.18
(Z)-Y-atlantone	-	-	3.88	-	0.82	-	-	-
(Z,Z)-geranyl linalool	-	-	1.52	-	-	-	-	-
6-methyl-hept-5-en-2-one	0.77	3.02	0.8	1.12	-	1	-	1.21
ar-tumerone	-	-	1.88	-	-	-	-	-
Borneol	1.69	1.51	1.84	1.51	1.38	1.29	1.41	1.7
Camphene	2.83	5.24	3.05	4.6	4.48	4.76	5.28	5.29
Citronellal	0.91	-	-	-	-	0.61	-	-
Citronellol	1.21	3.05	0.91	0.91	1.32	0.77	1.64	0.79
Dihydrocarvyl acetate	-	0.7	-	-	-	-	-	0.62
Eucalyptol	2.29	2.72	2.43	2.34	2.3	2.22	2.83	2.77
Fokienol	-	-	0.99	-	-	-	-	0.63
Geranial	9.88	4.96	7	9.01	6.95	7.53	5.48	6.26
Geraniol	-	7.6	-	0.65	4.52	-	7.21	-
Germacrene B	-	-	-	-	-	-	-	0.57
Linalool	1.93	1.72	1.88	1.45	1.62	1.43	1.58	1.46
Methyl lavender ketone	0.7	-	0.76	0.61	0.72	0.68	0.73	-
Myrcene	1.19	2.01	1.14	1.36	1.58	1.64	1.61	1.5
Neral	7.75	3.62	5.45	7.24	5.3	5.55	3.98	4.64
Nerol	-	2.6	-	-	1.19	-	2.76	-
Nonylmethyl ketone	0.88	0.6	0.93	0.72	0.72	0.79	0.82	0.61
α Pinene	1.11	2.6	1.28	2.07	2.16	2.37	2.47	2.43
α-(Z)-bergamotol	0.79	0.51	1.12	0.62	-	0.79	0.71	0.8
α-Acorenol	1.08	0.8	0.86	0.9	0.75	0.92	0.87	1.01
α-Copaene	-	-	-	0.64	-	-	0.65	0.73
α-Curcumene	7.02	5.44	6.29	6.14	5.82	6.38	4.6	5.74
α-Phellandrene	-	0.56	-	-	-	-	-	-
α-Selinene	1.59	1.29	1.6	1.55	1.38	1.52	1.37	-
α-Terpineol	0.77	0.7	1.03	0.69	-	-	0.69	0.74
α-Zingiberene	19.27	16.61	17.91	20.04	20.13	20.22	18.97	21
β-Acoradiene	-	-	-	-	-	0.62	-	0.71
β-Bisabolene	5.63	4.53	5.39	5.62	5.33	5.54	4.93	5.75
β-Himachalene	-	-	-	-	0.75	-	-	-
β-Phellandrene	6.44	8.05	5.29	6.8	7.53	7.43	7.56	6.94
β-Selinene	-	-	-	-	-	-	-	1.57
β-Sesquiphellandrene	10.09	8.26	9.56	10.04	9.9	10.13	9.15	10.24
Y-Cadinene	2.27	1.95	2.55	2.44	2.04	2.29	2.2	2.45

study were β-Sesquiphellandrene, (E, E)-α-Farnesene, β-Phellandrene, Geranial, β-Bisabolene, and α-Curcumene. The major five constituents in different treatment combinations are shown in Figure 5.

α-Zingiberene was found maximum in Nase unpeeled oven-dried ginger whereas the minimum was observed in Bose unpeeled sun-dried ginger. From the result, we can also make the inference that α-Zingiberene was found maximum in all the oven-dried ginger samples than in the sun-dried samples with other factors remaining the same. One of the major constituents of ginger oil, β-Sesquiphellandrene was observed to be decreased in the oven drying for peeled gingers considering both the varieties. However, the same chemical constituent was found to increase in sun-drying while the gingers were left unpeeled for both varieties. Poonkuil and Raja (2017) also observed similar chemical composition of ginger oil in support of the current study. Abdullahi *et al.* (2020) and Noori *et al.* (2018) also found α-Zingiberene (18-28%) as the highest component of essential oil of ginger as obtained in our study and α-Zingiberene possesses antioxidant, anticancer, anti-inflammatory, anti-fungal properties. Similar composition in oven-dried ginger was reported by Huang *et al.* (2011) as α-Zingiberene (27.8%), α-Curcumene (6.0%), and β-Sesquiphellandrene (10.2%). The drying method had shown high effects on essential oil yield and the chemical composition of ginger rhizomes according to Mahboubi, (2019) who also confirmed the antibacterial, anti-fungal, analgesic, anti-inflammatory, and anti-ulcer, immunomodulatory, relaxant, and warming effects of ginger oil in experimental and preclinical studies. The α-Zingiberene proportion in essential oil is directly related to the essential oil content in ginger rhizomes.

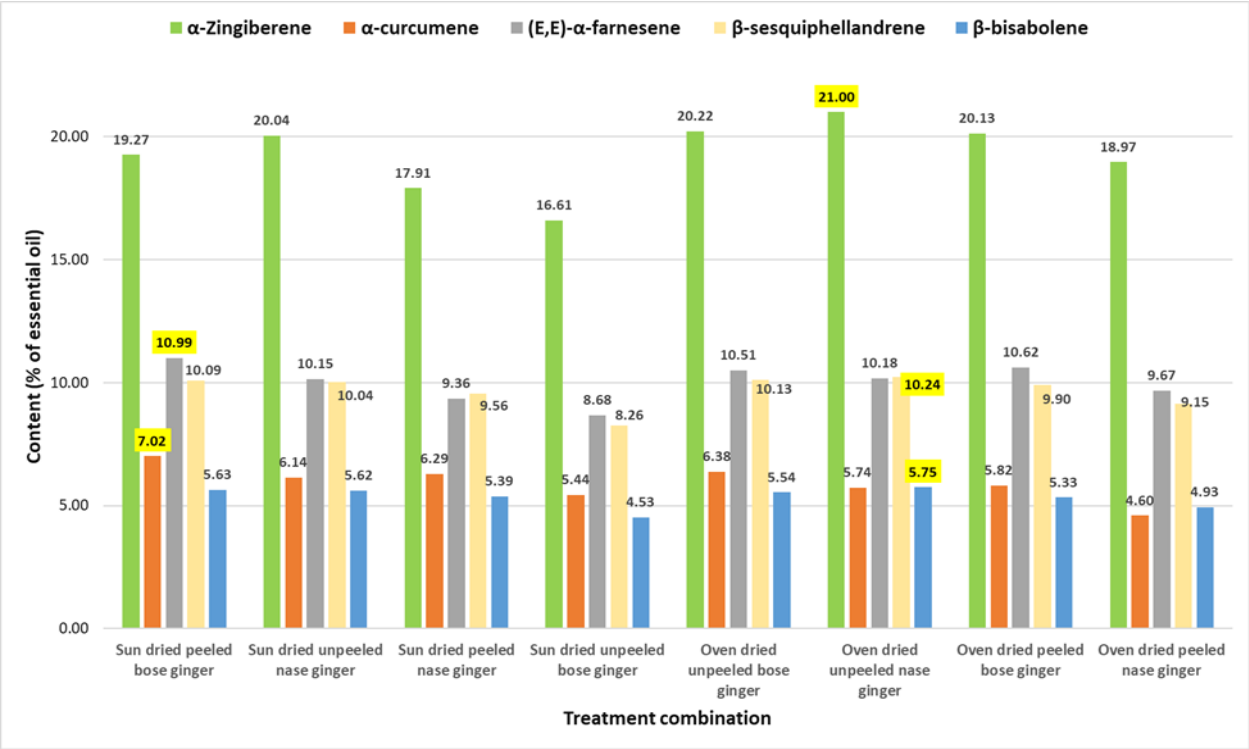

Figure 5. *Composition of major chemical constituents in essential oil obtained from different treatment combinations.*

Conclusion

Results obtained from this research showed that to maintain the moisture content of dried ginger in the acceptable range (7-12%), peeling of ginger rhizomes followed by drying in an oven should be done. The practice of not peeling ginger rhizomes before drying has the advantage of higher retention of essential oil in dried ginger and higher α-Zingiberene content. Sun drying of ginger should be avoided for the maximum retention of volatile oils. Drying ginger rhizomes in an oven (higher temperature) appears to denature its protein and reduce protein content. Bose ginger is superior to Nase ginger on lower fiber content which is the most desired quality parameter of the ginger, and a decrease in fiber content with peeling in ginger indicates peel of ginger accounts for the fiber content in the ginger rhizome.

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Conflict of interest

The authors indicate no conflict of interest for this work.

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