



Research Article

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Effect of Rhizome Types, Drying Thickness and Drying Materials on the Quality of Turmeric (*Curcuma longa L.*) in Tepi, South Western Ethiopia



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Abstract

Turmeric (*Curcuma longa L.*) is used mainly as natural food-coloring agent and coloring material in the textile industry. The experiment consisted of three rhizome types (mother, finger and mixed rhizomes), three drying materials (cement, ground and wire mesh) and three drying thicknesses (4, 6 and 8cm) laid out in 3*3*3 factorial Design with three replications. Data were subjected to analysis of variance using SAS version 9.2 and significant means were separated using Least Significant Difference (LSD). Accordingly, the interaction among rhizome types, drying materials and drying thicknesses revealed significant effect ($P < 0.05$) on curcumin, essential oil, oleoresin, total viable count, total dry matter and moisture content of turmeric, but did not affect weight loss, color value, color of whole dried rhizome and color of powdered turmeric ($P > 0.05$).

The highest curcumin content of turmeric (14.08) was recorded from finger rhizomes dried on wire mesh with drying thickness 6cm followed by finger rhizomes dried on cement with 6cm (13.69). Maximum total viable counts (1.86×10^6 , 1.85×10^6 and 1.87×10^6) were obtained from mixed rhizomes dried on ground with 4, 8 and 6cm drying thickness, respectively which were statistically similar with mixed rhizomes dried on cement with 8cm (1.82×10^6) and mother rhizomes dried on ground with 8cm (1.8×10^6). Oleoresin content (17.65) was recorded from finger rhizomes dried on wire mesh with drying thickness 6cm followed by finger rhizomes dried on cement with 4cm (16.32) and finger rhizomes dried cement with 8cm (14.02). In this regard, Finger rhizomes dried on wire mesh and cement with 6 and 4cm respectively are better in higher Curcumin and oleoresin content. However, it is worth nothing that the experiment was conducted only in one location and for a single season and hence sound recommendations could be drawn if the same study could be repeated for multiple locations and seasons.

Introduction

Turmeric (*Curcuma longa L.*) is a perennial herb which belongs to the family Zingiberaceae. Purselove believed that the genus *Curcuma* originated in the Indo-Malayan region. Turmeric is cultivated extensively in South and South East Tropical Asia. It is one of the most ancient medicinal spices of the world [1]. India is the largest producer of turmeric supplying over 90% of the world's demand Olojede et al. [2] with more than 60% share in turmeric trade. Turmeric production in Ethiopia is from SNNPRS and Oromiya 3,946 ton and 16 ton respectively Roukens [3].

Turmeric is an underground storage organ that is rich in secondary metabolites Govindarajan, 1980 and minerals like phosphorus, calcium, iron and vitamin A Kamal & Yousuf [4].

The main active constituents of turmeric are coloring matters and volatile oil. The coloring matters are composed mainly of Curcumin, Demethoxy curcumin and Bis demethoxy curcumin and the volatile oil contains mainly aromatic principles, i.e. Turmerone, Arturmerone and Zingiberene Martins et al. 2001.

The delightful flavor and pungency of spices make them indispensable in the preparation of edible dishes. The major use of spice in Ethiopia is for the preparation of a highly spiced stew known as 'Wot' which together with 'Injera' is consumed by a large proportion of the population everyday as their main food. In addition, spices are also used by the numerous ethnic groups in the country to flavor bread, meat, soups, different vegetables, and a medicines and perfumes Nigist & Sebsebe [5].

Turmeric had been known for its coloring and flavoring properties and widely used in food industries. It had also been used for Centuries as traditional remedies such as stimulant, stomachic, carminative, diuretic, ant diarrhea, antiemetic, anti-inflammatory, antipyretic, antimicrobial and antioxidant agents and can be used to treat and cure ulcers, wounds and other kinds of skin disorders, and as anti carcinogenic agents. The quality of any agricultural product is a function of the inherent quality of the material and the management (both cultural, harvesting and postharvest handling and processing) practices it is subjected to. Likewise, the quality of turmeric is also determined by both cultural, harvesting and postharvest handling and processing practices.

Since the qualities of turmeric rhizomes for food and medicinal uses are based directly on the content of the curcuminoids and volatile oils, it is important that rhizomes are handled, boiled dried and stored properly to maintain the levels of active principles in the harvested raw material. The rhizomes are exposed to a variety of conditions during processing, packaging, storage and some of which have detrimental effect on the stability of the active constituents and consequently on their quality Pfeiffer et al., 2003. Ethiopia is the land of diverse climate and soil type that enables the growth of several indigenous and exogenous spices, herbs, medicinal plants and other essential oil bearing plants. Despite the availability of the diverse agro ecologies of the country to produce these huge plant species and import substitution, the research conducted on them is very limited due to various reasons

The Government is aware that presently the bulk of Ethiopian spices are not of export quality due to lack of good agricultural practices, adequate post-harvest handling, primary processing facilities and skills, mishandling and unhygienic method of drying (ITC, 2010). Farmers in Ethiopia dry their turmeric by spreading on the ground, or even along the roadsides. Considerable losses occur during such drying processes because of influences such as dusts, odents, birds, insects, rain and microorganisms. This causes loss in turmeric quality and made not to be marketable in both domestic and international market IOSTA, 2008. Hence, this research is initiated and designed to dry turmeric using different drying materials, rhizome types and drying thicknesses to optimize the drying of finger and mother rhizomes of turmeric (*Curcuma longa L.*). Under Tepi condition in view of reducing loss and maintain quality.

Materials and Methods

Description of the study area

The experiment was conducted in Tepi National Spice Research Center (TNSRC) in the year 2012, Ethiopia.

Experimental materials

Dame variety of turmeric was taken from Tepi National Spice Research center seed multiplication plot. It was planted in June 2011 using mother rhizomes planting materials and harvested

in February 2012 which is the optimum time for harvesting of turmeric.

Experimental design and treatments

The experiments were laid out in 3*3*3 factorial designs with 3 replications. Three rhizome types (Mother, Finger and Mixed), three drying materials (Cement, Ground and Wire Mesh) and three drying thicknesses (4, 6 and 8 cm) (FAO, 2004) with a total of 81 experimental units were used.

Experimental procedures

For each experimental plot, 3 kg of turmeric was dried with respective drying thickness of 4, 6, and 8 cm on different drying materials (Cement, Ground and Wire mesh). 243 kg turmeric was harvested in the 9th month after planting in February, 2012. Then the samples were carefully distributed to the experimental unit and dried accordingly. Then, the rhizomes were heaped separately and covered with leaves for a day to enhance sweating and washed so that soil particles, surface microbial load, spray residues and unnecessary particle attached were removed, at the time of washing mother and finger rhizomes were separated. Then, the rhizomes were boiled to arrest growing buds, remove the raw odor, reduce the drying time, gelatinize the starch and produce a more uniformly colored product and kill microorganisms. The recommended boiling time of turmeric is 45 min and 60 min for finger and mother rhizomes respectively, until froth appears at the surface and the typical turmeric aroma is released FAO [6] Sasikumar, 2001. It was stopped when froth comes out and white fumes appear jiggling out a typical odor. Then it was taken out of the pan by lifting the trough and draining the water into pan itself.

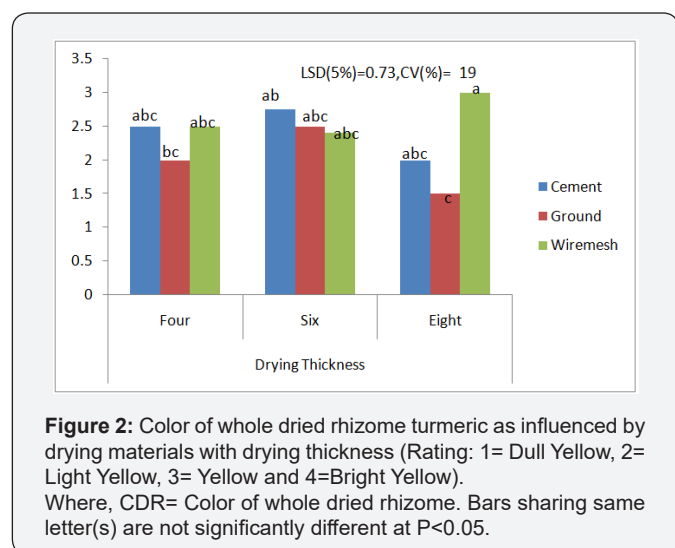
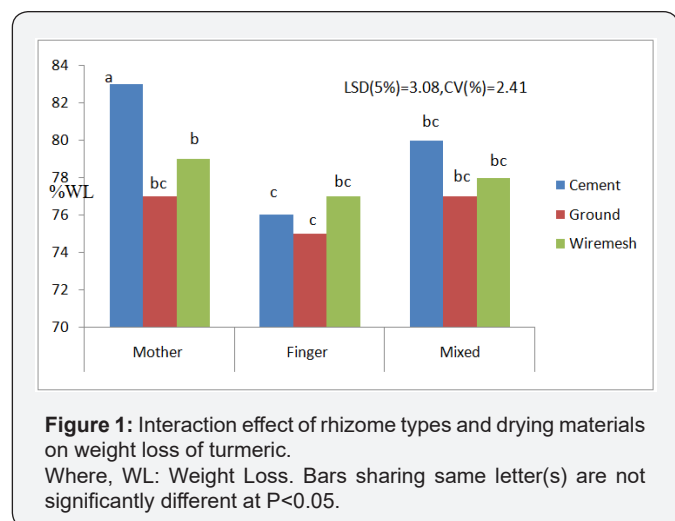
Boiled turmeric was dried on the three drying materials (Ground, Cement and Wire mesh) with 0.4m x 0.4m size plots and 0.25m apart each other and the wire mesh drying materials was constructed at a height of 1m above ground and on the three drying thicknesses (4, 6 and 8cm with 3kg for sample on each [6] with a total of 243kg. Drying lasted when the rhizomes were snap cleanly with a metallic sound as described by the Indian Ministry of Agriculture standards, Agmark) when broken. Drying activity was performed during the sunny day starting from 9:00AM to 5:00 PM. After the drying processes were completed, the dried turmeric rhizomes were taken to the laboratory of Jimma University chemistry department for extraction of Oleoresin (%W/W) and Volatile Oil (%V/W) whereas, Total Dry Matter content (%), Curcumin (%), Color Value (%), Total Viable Count (CFU/ml) were evaluated at Jimma University College of Agriculture and Veterinary Medicine Post Harvest Management and Micro Laboratory Veterinary Department and other supplementary parameters were carried out.

Results and Discussion

Physical quality parameters of turmeric

Weight loss: According to the result of this experiment,

the three way interaction effect among rhizome types, drying materials and drying thicknesses had no significant ($P > 0.05$) effect on weight loss of turmeric. However, the interaction of rhizome types with drying materials on weight loss of turmeric had shown highly significant ($P < 0.05$) (Figure 1). The maximum weight loss (83.33%) was recorded from mother rhizomes dried on cement. This result was in line with the work of Fisiha [7] who concluded, cement drying structure to have high solar heat absorbing nature, contributing to over drying of capsules, resulting to high loss of volatiles and non-volatiles of *A. corrarima*. While, the lowest (75.92%) was obtained from finger rhizomes dried on ground which had statistically similar value with mother rhizomes dried on ground (76.67%), mixed rhizomes dried on ground (78%), finger rhizomes dried on wire mesh (78%), finger rhizomes dried on cement (78%), mother rhizomes dried on wire mesh (78%) and mixed rhizomes dried on wire mesh (78%). Weight loss was strongly and negatively correlated with essential oil content ($r = -0.57^{***}$).

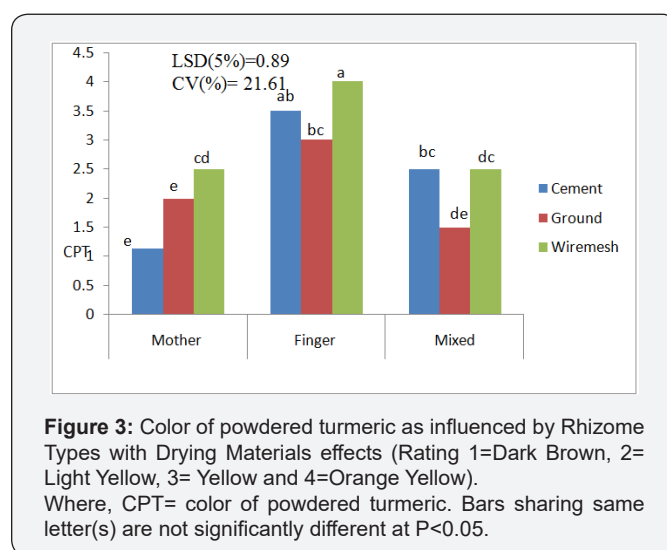


Color of Whole Rhizomes: There was no significant ($P > 0.05$) difference among rhizome types, drying materials and drying

thicknesses on whole dried rhizome. However, the interaction of drying materials and drying thicknesses influenced color of whole dried rhizomes turmeric significantly ($P < 0.05$) (Figure 2). High and similar whole rhizome color values rating yellow color were observed dried on wire mesh with 8 cm (2.77), cement with 6cm (2.67), wire mesh with 4cm (2.44), cement with 4 cm (2.44), wire mesh with 6 cm (2.33), ground with 6 cm (2.33) and cement with 8 cm (2.22). Shibru (2012) who recorded maximum color of whole rhizome was at 100 C for 45 min boiling (1.97) and 60min boiling (2) represented orange yellow color, 0.8% lower whole rhizome color values than this study [8-10].

Whereas small rating values, with light yellow color of whole rhizome (1.77 and 2) were recorded from rhizomes dried on the ground with 8 and 4 cm drying thickness, respectively. This may be due to contamination with ground drying materials. Color of whole dried rhizomes was strongly and negatively correlated with total viable count ($r = -0.273^*$)

Color of powdered turmeric: The combined effects of rhizome types, drying materials and drying thicknesses on color of powdered turmeric was not significant ($P > 0.05$). However, the interaction between rhizome types and drying materials was highly significant ($P < 0.01$) (Figure 3).



High powder color value ratings, representing orange yellow color, were observed (3.89) from finger rhizomes dried with wire mesh followed by finger rhizomes dried on cement (3.67) orange yellow color this may be due to aeration in the wire mesh. Shibru (2012) who recorded orange yellow color from which is 0.92% lower than this study. Whereas the lowest rating value, dark brown color(1.33, 1.44 and 1.67) were obtained from mother rhizomes dried on both cement and ground and mixed rhizomes dried on ground respectively. This result was similar with the result of Beza (2011) who reported, all raised bed drying materials bamboo, mesh wire, palm leaves mat, and jute jut mesh had great aromatic quality, flavor, over all standard and body. Color of powdered turmeric was strongly and negatively

correlated with total viable count and weight loss ($r = -0.367^{***}$ and -0.284^*) respectively. 3.2. Chemical Quality Parameters of turmeric [11-13].

Color value: Turmeric color value results from spectro photometric measurements indicated that the three way interaction effect had no significant ($P > 0.05$) effect. However, the interaction effect between rhizome types and drying materials was very highly significant ($P < 0.01$) (Table 1). The maximum color value ($2.78 E4$) was recorded from finger rhizomes dried on wire mesh which was statistically similar with finger rhizomes dried on cement ($2.63E4$). This may be due to aeration in wire mesh and clean cement floor than ground, whereas the lowest ($1.49 E4$) was obtained from mixed rhizomes dried on the ground. This result is in line with Shibru (2012) who reported that, higher color values were [14-16].

Table 1: Interaction effect of Rhizome Types with Drying Materials, Rhizome Types with Drying Thickness and Drying Materials with Drying Thickness on color value of turmeric.

Rhizome Types	Drying Materials		
	Cement	Ground	Wire Mesh
Mother	2.074c	2.18c	2.17c
Finger	2.63ab	2.28bc	2.78a
Mixed	2.29bc	1.4d	2.26bc
Rhizome types	Drying thickness/cm/		
	4	6	8
Mother	2.087bc	2.087bc	2.087bc
Finger	2.64a	2.64a	2.64a
Mixed	2.05bc	2.05bc	2.05bc
Drying materials	Drying thickness/cm/		
	4	6	8
Cement	2.02cd	2.02cd	2.02cd
Ground	2.43abc	2.43abc	2.43abc
wiremesh	2.32bcd	2.32bcd	2.32bcd
LSD(5%)	0417		
CV%	11.39		

*Means sharing the same letter(s) are not significantly different at 5%.

The interaction effect of rhizome types with drying thicknesses on color value of turmeric was significant ($P < 0.05$) (Table 2). The maximum color value ($2.89 E4$ and $2.64 E4$) were recorded from finger rhizomes dried with 6 and 4 cm drying thickness, respectively, whereas the lowest ($1.77 E4$) was obtained from mixed rhizomes dried with 8 cm drying thicknesses which was statistically similar with mixed rhizomes dried with 4cm ($2.05E4$), finger rhizomes dried with 8 cm ($2.17 E4$) and mother rhizomes dried with 8cm ($2.09E4$) this may be due to the more densely spread turmeric [16-18].

Table 2: Total dry matter content of turmeric as influenced by interaction effect of drying materials, drying thicknesses and rhizome types.

Rhizome Types	Drying Materials	Drying Thickness (cm)		
		4	6	8
Mother	Cement	84.47d-i	89.23abcd f	88.23a-
	Ground	83ghi	82.07hij	84.53 d-h
	Wire mesh	89.4abcd	83.27e-i	80.80 ij
Finger	Cement	87.33b-g	91.53ab	88.2a-f
	Ground	88a-g	88.8a-e	92.53a
	Wire mesh	87.2 b-h	83.87e-i	89.13abcd
Mixed	Cement	86.33b-h	89.80 abc	87 b-h
	Ground	87b-h	83.87e-i	77.13 j
	Wire mesh	87.2 b-h	86.6 b-h	86.6 b-h
LSD (5%)	5.19			
CV (%)	3.67			

*Means sharing the same letter (s) are not significantly different at 5%.

The interaction effect of drying materials and drying thicknesses on the color value of turmeric was highly significant ($P < 0.01$) (Table 1). The maximum color value ($2.77 E4$) was recorded from wire mesh dried with 6 cm drying thickness which was statistically similar value with those dried on cement with 6cm drying thickness ($2.55E4$), wire mesh with 4cm ($2.43E4$), this may be due to the aeration present in wire mesh and medium drying thickness, whereas the lowest result ($1.92 E4$) was obtained from rhizome sets dried on ground dried with 8cm drying thickness. This result agreed with the work of Beza, (2011) who concluded the potential problems associated with drying of coffee on soil (ground) and its negative image. There were a strong and positive correlation between color value and oleoresin content ($r = 0.89^{***}$). On the other hand, a strong but negative association was observed between color value and total dry matter content ($r = -0.81^{***}$). Whereas, weak positive correlation was observed with curcumin content ($r = 0.075ns$) [17-20].

Total dry matter: A combined effect of rhizome types, drying materials and drying thicknesses on total dry mater had shown significant ($P < 0.05$) (Table 1). The highest mean value of total dry matter content (92.53%) was recorded from finger rhizomes dried on ground with drying thickness of 8cm, followed by finger rhizomes dried on cement with 6cm (91.53%) which had statistically similar value with mixed rhizomes dried on cement with 6cm (89.80%), mother rhizomes dried on cement with 6cm (89.23%), finger rhizomes dried on wire mesh with 4cm (89.13%) and mother rhizomes dried on wire mesh with 4cm (89.4%), whereas the lowest mean value (77.13%) was obtained from mixed rhizomes dried on ground with 8cm. However, it

was not significantly different from those recorded by mother rhizomes dried on wire mesh with 8cm (80.80%) and mother rhizomes dried on ground with 6cm drying thickness (82.07%). Shibiru (2012) reported that higher dry matter content was 89.04% recorded from boiling of rhizomes at 100.

The maximum mean value of moisture content (22.86%) was recorded from mixed rhizomes dried on ground with drying thickness of 8cm. However, it was not significantly different from mother rhizomes dried on wire mesh with 8cm (19.2%) and mother rhizomes dried on the ground with 6cm (17.93%). This may be due to mixed rhizome which is not recommended to be dried on ground which released moisture slowly due to and the drying thickness, whereas the lowest mean value (7.42%) was obtained from finger rhizomes dried on the ground with 8cm, which was statistically similar with values of finger rhizomes dried on cement with 6cm and 8cm drying thicknesses (8.46% and 11.8%) respectively, finger rhizome dried on wire mesh with 8cm drying thicknesses (10.87%) and mother rhizomes dried on cement with 6cm and 8cm drying thickness (10.73% and 11.73%) respectively, mother rhizomes dried on wire mesh with 4cm(10.6%) and mixed rhizomes dried on cement with 6cm drying thickness (10.2%).

Peter [8] reported that the moisture content of large cardamom and small cardamom were 8.49% and 8.3%, respectively, which are lower than those observed in this study. Accordingly the author concluded that, a key issue in storage is maintaining the right level of moisture of capsules and/or seeds of Korarrima and reported that the moisture content has to be brought down to 12% to 14% to achieve a longer shelf life. There were strong and positive correlation between moisture content and total viable count ($r = 0.35^{***}$). But, strong and negative correlation with Curcumin ($r = -0.24^{***}$) [21-24].

Table 3: Moisture content of turmeric as influenced by interaction effect of drying materials, drying thicknesses and rhizome types.

Rhizome Types	Drying Materials	Drying Thickness (cm)		
		4	6	8
Mother	Cement	15.53b-g	10.73h-j	11.73e-j
	Ground	17bcd	17.93abc	15.46b-g
	Wire mesh	10.6h-j	16.73b-e	19.2ab
Finger	Cement	12.67d-i	8.46ij	11.8e-j
	Ground	12d-j	11.2f-j	7.42j
	Wire mesh	12c-i	16.13b-f	10.87f-j
Mixed	Cement	13.67c-h	10.2hij	13c-l
	Ground	13.c-i	16.13b-f	22.86a
	Wire mesh	12.8c-i	13.40c-i	12.67d-i
LSD 5%		5.19		
CV (%)		23.39		

*Means sharing the same letter(s) are not significantly different at 5%.

Moisture content: Significant ($P < 0.05$) differences were observed in moisture content of turmeric as a result of the interaction effects among rhizome types, drying materials and drying thicknesses (Table 3).The maximum mean value of moisture content (22.86%) was recorded from mixed rhizomes dried on ground with drying thickness of 8cm. However, it was not significantly different from mother rhizomes dried on wire mesh with 8cm (19.2%) and mother rhizomes dried on the ground with 6cm (17.93%). This may be due to mixed rhizome which is not recommended to be dried on ground which released moisture slowly due to and the drying thickness, whereas the lowest mean value (7.42%) was obtained from finger rhizomes dried on the ground with 8cm, which was statistically similar with values of finger rhizomes dried on cement with 6cm and 8cm drying thicknesses (8.46% and 11.8%) respectively, finger rhizome dried on wire mesh with 8 cm drying thicknesses (10.87%) and mother rhizomes dried on cement with 6cm and 8cm drying thickness (10.73% and 11.73%) respectively, mother rhizomes dried on wire mesh with 4cm(10.6%) and mixed rhizomes dried on cement with 6cm drying thickness (10.2%).

Peter [8] reported that the moisture content of large cardamom and small cardamom were 8.49% and 8.3%, respectively, which are lower than those observed in this study. Accordingly the author concluded that, a key issue in storage is maintaining the right level of moisture of capsules and/or seeds of Korarrima and reported that the moisture content has to be brought down to 12% to 14% to achieve a longer shelf life. There were strong and positive correlation between moisture content and total viable count ($r = 0.35^{***}$). But, strong and negative Correlation with Curcumin ($r = -0.24^{***}$).

Table 4: Curcumin content as influenced by interaction effect of drying materials, drying thicknesses and rhizome types.

Rhizome Types	Drying Materials	Drying Thickness (cm)		
		4	6	8
Mother	Cement	4.62ef	6.32efg	5.73ghi
	Ground	5.07 i-j	5.68g-j	4.57klm
	Wire mesh	5.05jkl	5.51hij	2.53n
Finger	Cement	13.69a	11.61b	7.18d
	Ground	7.27d	9.16hij	4.41m
	Wire mesh	9.38c	14.08a	6.81de
Mixed	Cement	5.46hij	5.86fgh	6.83de
	Ground	2.61n	3.97m	2.66n
	Wire mesh	4.54klm	6.18efg	5.14ijk
LSD (5%)		0.66		
CV (%)		6.31		

*Means sharing the same letter(s) are not significantly different at 5%.

Curcumin: Interaction among, rhizome types, drying materials and drying thicknesses had shown very highly significantly ($P < 0.01$) influenced Curcumin content (Table 4). The highest mean value (14.08%) was recorded from finger rhizomes dried on wire mesh with drying thickness of 6cm followed by finger rhizomes dried on cement with 6cm (13.69%), whereas the lowest mean value (2.53%) was recorded from mother rhizomes dried on wire mesh with 8cm which was statistically similar with values obtained from mixed rhizomes dried on ground with 4cm and 8cm drying thickness (2.61% and 2.66%), respectively. This may be due to mixed rhizomes and ground which leads to minimum curcumin content. About 18.89 % difference was recorded between the maximum and minimum curcumin content. The Curcumin content of turmeric is an important component consisting of all composition which affects the value of turmeric (Table 5).

Table 5: Interaction effect among rhizome types, drying materials and drying thickness on oleoresin content.

Rhizome Types	Drying Materials Drying Thickness (cm)		
	4	6	8
Mother	Cement 13.62def	13.32e-j	12.74klm
	Ground 13.08klj	13.11h-l	12.55m
	Wire mesh 13.38e-j	13.58d-g	13.64def
Finger	Cement 13.75de	13.09i-l	14.02cd
	Ground 12.76klm	12.67lm	14.39c
	Wire mesh 16.32b	17.65a	13.17g-k
Mixed	Cement 13.63def	13.54e-h	13.31f-j
	Ground 12.48m	12.35m	12.78kl
	Wire mesh 13.47e-j	13.49e-j	13.53e-i
LSD (5%)		0.44	
CV (%)		1.97	

*Means sharing the same letter(s) are not significantly different at 5%.

Essential oil: The interaction effect among rhizome types, drying materials and drying thicknesses had significant effect ($P < 0.01$) on essential oil content (Table 6). The highest mean value (3.42%) was obtained from the finger rhizome dried on ground with 6 cm drying thickness. The lowest mean values (2.15%, 2.29% and 2.17%) were recorded from mother rhizome dried on cement with 4, 6 and 8cm drying thickness respectively. However, these values were not significantly different from those recorded from finger rhizome dried on cement with 4,6 and 8 cm drying thickness (2.23%, 2.21% and 2.5%) respectively, and mixed rhizome dried on cement with 4,6 and 8cm drying thickness (2.12%, 2.18% and 2.12%) respectively. But, Fissiha (2011) who reported that, maximum value for essential oil content of dried seeds of *Korrorma* was recorded from mature green capsules harvested and dried on wire mesh for 10 days. The high essential

oil content recorded from drying of finger rhizomes of turmeric on ground is most probably related with the slow heating of the ground floor which had less impact on the volatile components of the rhizomes. It is very pertinent to mention that though significantly high essential oil was recorded from finger rhizomes dried on ground, it is a practice which should be discouraged due to the serious contamination observed in the finished product.

Table 6: Interaction effects of the rhizome types, drying materials and drying thickness on essential oil content of turmeric.

Rhizome Types	Drying Materials	Drying Thickness (cm)		
		4	6	8
Mother	Cement	2.15i	2.29i	2.17i
	Ground	2.97bc	2.98bc	2.28ghi
	Wire Mesh	2.98bc	2.24hi	2.14i
Finger	Cement	2.23hi	2.21i	2.5e-h
	Ground	3bc	3.42a	3.19ab
	Wire Mesh	2.95bc	2.75cde	2.36f-i
Mixed	Cement	2.12i	2.18i	2.12i
	Ground	2.99bc	2.85cd	2.63def
	Wire Mesh	2.53efg	2.52efg	2.24hi
LSD (5%)		0.28		
CV (%)		6.77		

*Means sharing the same letter(s) are not significantly different at 5%.

On the other hand, Shibru (2012) who reported that superior essential oil content (4%) was obtained from rhizomes boiled at 100 °C for 30min. About 62% difference was recorded between the maximum and minimum results of essential oil content. This may be due to turmeric dried on ground had lose moisture slowly and essential oils are volatiles so it had advantage to lose slowly of essential oil. A strong and positive correlation was observed between essential oil and oleoresin ($r = 0.45^{***}$).

Total Viable Count: Results presented in Table 7 revealed that interaction effect among rhizome types, drying materials and drying thicknesses significantly ($P < 0.01$) affected total viable count. The highest mean value of microbial load (1.87×10^6) was recorded from mixed rhizome with 6cm drying thickness dried on ground and which was statistically similar mean value with 4cm and 8cm drying thickness dried on ground (1.86×10^6) respectively which had similar value with mixed rhizome dried on cement with 8cm (1.82×10^6) and mother rhizome dried on ground with 8cm (1.8×10^6). The microbial load of mixed rhizome was expectedly higher apparently because of exposure to attacks by micro organisms and contaminations from different sources.

Table 7: Interaction effects of the rhizome types, drying materials and Drying thicknesses on total viable count.

Rhizome Types	Drying Materials	Drying Thickness (cm)		
		4	6	8
Mother	Cement	1.61x10 ⁶ fg	1.64x10 ⁶ eg	1.66x10 ⁶ def
	Ground	1.71x10 ⁶ cde	1.67x10 ⁶ edf	1.8x10 ⁶ abc
	Wire mesh	1.61x10 ⁶ fg	1.65x10 ⁶ def	1.66x10 ⁶ def
Finger	Cement	1.59x10 ⁶ fg	1.65x10 ⁶ def	1.63x10 ⁶ ef
	Ground	1.59x10 ⁶ fg	1.63x10 ⁶ ef	1.6x10 ⁶ g
	Wire mesh	1.62x10 ⁶ efg	1.64x10 ⁶ ef	1.67x10 ⁶ def
Mixed	Cement	1.58x10 ⁶ fg	1.52x10 ⁶ g	1.82x10 ⁶ ab
	Ground	1.86x10 ⁶ a	1.87x10 ⁶ a	1.85x10 ⁶ a
	Wire mesh	1.58x10 ⁶ fg	1.68x10 ⁶ def	1.75x10 ⁶ bcd
LSD (5%)		0.1		
CV (%)		3.66		

*Means sharing the same letter (s) are not significantly different at 5%.

But, the lowest mean value (1.52 X 10⁶) was obtained from mixed rhizome dried on cement with 6cm drying thickness and statistically similar value with finger rhizome dried on cement with 4cm (1.59 X 10⁶). The minimum microbial load from cement and wire mesh showed a highly reduced level of microbial load as depicted in Table 7. While the Total viable count difference between the highest and the lowest mean value was recorded to 81%. This may be due to the highest solar radiation on cement and aeration in wire mesh which makes re-absorption of moisture extremely difficult and defends against microbial invasion.

The high bacterial load in spices is an indication of unhygienic practices during their preparation. Price and Schweigert (1971) reported that unless spices are treated to reduce their microbial content, they may add high numbers and undesirable kind of organisms to food in which they are used. The microbial flora on many spices and related materials is generally dominated by aerobic spore-forming bacteria. It was found that Celery seed, paprika, black and white pepper and Ginger usually show total plate counts in millions per gram. There were negative but significant correlation between total viable count with total dry matter (r = - 0.29*) and curcumin (r = -0.33**).

Summary and Conclusion

The interaction of rhizome types, drying materials and drying thicknesses revealed significant effect on Curcumin, essential oil, oleoresin, total viable count and total dry matter content of turmeric, but did not affect weight loss, color value, color of whole dried rhizome and color of powdered turmeric.

The highest Curcumin content of turmeric (14.08) was recorded from finger rhizome dried on wire mesh with drying thickness 6cm followed by finger rhizome dried on cement with 6cm (13.69), Total viable count (1.86 X10⁶, 1.85 X10⁶) were obtained from mixed rhizome dried on ground with 4,8 and 6cm drying thickness which was statistically similar with mixed rhizome dried on cement with 8cm (1.82 X10⁶) and mother rhizome dried on ground with 8cm(1.8 X10⁶), Oleoresin content (17.65) was recorded from finger rhizome dried on wire mesh with drying thickness 6cm followed by finger rhizome dried on cement with 4cm (16.32) and finger dried cement with 8cm (14.02).

Drying of turmeric rhizomes (finger) on ground with all drying thickness gives higher essential oil content, essential oil (3.42) was obtained from the finger rhizome dried on ground with (6cm) drying thickness followed by finger rhizome dried on ground with 8cm (3.19). Though the essential oil content of finger rhizomes dried on ground floor was appreciable due to the slow heating of earth material especially with thick layer of rhizomes, one should not recommend this method for the very good reason that microbial contamination of the finished product is very serious and health threatening. Therefore, it would be better to go for a slightly less essential oil content but with no health treat. In this regard, Finger rhizomes dried on wire mesh and cement with 6 and 4cm respectively are better in higher Curcumin and oleoresin content. However, it is worth nothing that the experiment was conducted only in one location and for a single season and hence sound recommendations could be drawn if the same study could be repeated for multiple locations and seasons.

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