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INFLUENCE OF BOILING TEMPERATURE LEVELS AND DURATIONS ON THE PHYSICAL QUALITY OF DIFFERENT RHIZOME SET TYPES OFTURMERIC (CURCUMA LONGA L.)

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ABSTRACT

In Southern Asia, turmeric (Curcuma longa L.), family Zingiberaceae, is a tropical herb that is indigenous Primary processing is still being done with traditional means leading to many post harvest quality losses, hence studies were necessary to investigate the role of different boiling durations and temperature levels on the quality of turmeric. Accordingly, the result of this study revealed that almost all of the parameters on physical quality considered were significantly affected by the treatments or their interaction effects. The interaction effect among temperature levels, boiling durations and rhizome set types manifested significant variations in respect of corkish layer and length shrinkage.The interaction effect between boiling temperature levels and durations significantly affected the duration of drying, rhizome color and powder color; and that of between temperature levels and rhizome set types were affected by drying duration and curing percentage. Rhizome set types presented significant effect on color of whole rhizome and powder. Curing percent significant differed according to boiling durations.

Key words: Curcuma Longa, Essential Oil, Oleoresin; Rhizome, Temperature, Boiling.

INTRODUCTION

Growth of Turmeric is popular in India, Pakistan, Malaysia, Myanmar, Vietnam, Thailand, Philippines, Japan, China, Korea, Sri Lanka, Nepal, South Pacific Islands, East and West Africa, Malagasy, Caribbean islands, and the Central America (Sasikumar, 2001). It is being found that about 80% of turmeric produced around the world is from India and it is also the largest domestic consumer, nearly 93%-94% of its total production (Chempakam and Parthasarathy, 2008; NMCE, 2007). Ethiopia is said to be the origin of various spices and herbs such as *Aframomum corrorima*, coriander, and long pepper, etc due to the presence of diverse agro ecologic settings and appropriate soil factors. Most of the spices cultivated are cardamoms, ginger, hot pepper, fenugreek, turmeric, cummins, corianders and black pepper. Turmeric belongs to the family *Zingiberaceae* and contains 49 genera and 1400 species (Sasikumar, 2001). It belongs to the class *Liliopsida* (Monocotyledons) (Adams,1972). According to a statement by Chempakam and Parthasarathy (2008**)** *C. longa* is a triploid with a somatic chromosome number of 63 (2n=3×63). Turmeric is a sterile triploid and has been propagated vegetatively for thousands of years (Yu, 2006). In addition to*Curcuma longa*, the other economically important species of the genus are *C. aromatica*, used in medicine and in toiletry articles; *C. kwangsiensis, C. ochrorhiza, C. pierreana, C. zedoaria, C. caesia*etc. used in folk medicines of the South-East Asian nations; *C. alismatifolia, C. roscoeana* etc. with floricultural importance; *Curcuma amada* used as medicine, and in a variety of culinary preparations, pickles and salads and*C. zedoaria, C. malabarica, C. pseudomontana, C.montana, C. decipiens, C. angustifolia, C. rubescens, C. haritha, C. caulina* etc. all used in manufacturing arrowroot powder (Sasikumar, 2005). The other important species are *C. purpurescens, C. mangga, C. heyneana, C. xanthorrhiza, C. aeruginosa, C. phaeocaulis* and *C. petiolata* (Peter *et al*., 2007). Limited information is available on the extent of destruction of bioactive principles of spices during food processing. Since the healthy, beneficial physiological effects of spices are attributable to their active principles, there is a need to evaluate the availability of the spice active principles in their original form when spices are heat processed as in domestic boiling. (Srinivasan, 2005). In Ethiopia cultivation of spices for centuries has predominantly stayed traditional by small farmers (MOARD, 2009). Efforts to generate improved technologies were limited to agronomic practices with little effort to improve product quality, which is highly influenced through its value chain from pre-harvest to postharvest managementpractices including processing of final products. Moreover, little effort has been made to assess farmer's pre and post-harvest management practices that could be used as a benchmark for improvement works targeting product quality and sustainable supply (Endrias and Asfaw, 2011). Therefore, studies were necessary to investigate the role of different boiling temperature levels and boiling durations on the quality of turmeric rhizome sets.

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Hence thisstudy was conducted with the objective determining the appropriate boiling temperature and duration of different rhizome set types of turmeric (*Curcuma longa* L.) for its quality improvement.

MATERIALS AND METHODS

Description of the Study Area

The experiment was conducted at the Southern Nations and Nationalities' Peoples Regional State, Sheka zone, Yeki Woreda at the Tepi Soil Analysis Laboratory and on the drying structures at Tepi National Spices Research Center in 2010/11 both of which are located in the Tepi town that is about 611 Km from Addis Ababa. It is located at approximate geographic coordinates of $7^{o}30'$N, and $35^{o}00$E and altitude of 1200 meters above sea level. The experimental site receives a long term mean annual rainfall of 1688mm and has a mean maximum and minimum temperature of 29.5 ^{o} C and 15.3^{o} C, respectively (Edossa, 1998). The relative humidity of the site reaches 80 to 90%, and the soil is classified as Dystric Nitisol and it is dominated by a loam texture (Girma and Kindie, 2008).

Experimental Materials

For this experiment matured (9 months old) rhizomes of turmeric variety Dame was taken from Tepi National Spices Research Center seed multiplication plot. Nine month old rhizomes were preferred because harvesting after nine or ten months after planting the biochemical and dried yield recovery contents were reported higher (Girma *et al*., 2008). Totally 400 kilogram of fresh turmeric was dedicated for the experiment.

Methods

Experimental Design and Arrangement

The treatments were arranged in three factors factorial combination of three boiling temperature levels (80^{o}C, 90^{o}C and 100^{o}C) X four boiling durations (30, 45, 60 and 75 min) X three rhizome set types (Mother, finger and mother-finger) in completely randomized design with three replications. The above treatment levels were set based on the fact that most of turmeric producing farmers in Ethiopia boil mother and finger mixture rhizomes together and give little care to boiling duration though 45-60 minutes were believed to be in practice.

Preparations and boiling method of the rhizomes

Mature rhizomes of turmeric variety (Dame) were harvested from the seed multiplication site of Tepi National Spices Research Center in February, washed thoroughly, and mother rhizomes separated from finger rhizomes. Rhizomes were left heaped for 24 hours for sweating for better development of aroma and flavor. Next, three and half kilograms from each rhizome types (mother, finger and mother-finger mix) was taken separately for each treatment. Then, rhizomes were boiled using electrically operated boiling heater. Boiling was performed in laboratory using stainless steel of 10 liter capacity dishes on three hot plates having capacity of 230V and 2850W(SD8,HarryGestingkeit GmbH, Angermunderstr.12, D-40489, Düsseldorf). During the course of boiling 5 liters of water filled in boiling dish was initially allowed to boil, mean-while each rhizome type put in the boiled water and left for a while until it attained the temperature level required and then heater temperature level was set. While boiling was commenced temperature fluctuations were monitored on interval check using thermometer. And when the specified duration boiling for each treatment was reached then the rhizomes were taken out to a bath of twenty kilogram holding capacity to stop further boiling of rhizomes.Rhizomes were delivered to drying beds as soon as cooled.

The boiled fingers were dried in open sun spread with uniform thickness of 5-7cm until they attained optimum moisture where the fingers will snap cleanly with a metallic sound. Closer supervision was followed by stirring the samples in the day time for uniform drying and covering in the night. After drying the rhizomes were polished on stretched wire mesh by hand to remove the rough surface and improve its inherent color.Finally, weight of dried rhizomes and removed corkish layer were separately recorded.

Data Collected

Relevant data both for analysis and comparison purposes were recorded at different stages of processing steps. Data on drying durations (hrs.) of rhizomes was recorded as soon as boiled rhizomes were brought to bed. Before and after drying data on dry weight recovery (Curing %), diameter and length shrinkage magnitude (%), weight of corkish layer removed (%) and color of polished whole rhizomes (rating) were recorded.

Curing percentage (%DW)

Curing percentage (%DW) is the percent of dry yield recovery of turmeric after undergoing boiling and drying processes. Its quantification was made in such a way that percentages were calculated by taking sample fresh weight (W1) and the sun dried and polished (W2) on weighing balance.

$$\% \text{ DW} = \frac{W1-W2}{W1} \times 100$$

Removed corkish layer (%CL)

Corkish layer (%CL) is a byproduct remained during the course of turmeric polishing. Percent of corkish layer removed pertaining to the treatment combination effect was determined in such a way that weighing of dried turmeric recorded before polishing (W1), thereafter samples were polished and reweighted (W2). Finally difference in weight was rationed against unpolished weight of sample.

$$\% \text{ CL} = \frac{W1-W2}{W1} \times 100$$

Percent shrinkage of length and diameter (%LN and DIA)

Shrinkage of diameter (%DIA) and length percentage (%LN) were considered as the degree of reduction in length and diameter of rhizome set types due to the effect of treatments or their combinations applied during boiling operation. A Vernier Caliper (FOWLER0531187, US) was used to determine the length and diameter shrinkage which was obtained by taking average of repeated measurements of fresh (W1) and then dried and polished (W2) rhizomes and convert into percent of reduction.

$$\% \text{ LN or DIA} = \frac{W1-W2}{W1} \times 100$$

Drying duration (Hrs)

Drying duration is the time required to dry turmeric rhizome set types boiled at different temperature levels and boiling durations. Drying duration recording was made each day, starting from the time rhizome set types were boiled and delivered to bed till optimum drying duration attained.

Color of dried whole rhizomes and powders (Rating)

Color characters of whole rhizomes and powder are among vital quality determining elements of turmeric end products. Color of powder from the rhizome set types boiled by different temperature levels and boiling durations were determined subjectively by rating method under categories of yellowish orange (rating=4), yellow (rating=3), light yellow (rating=2) and dull yellow (rating=1). Color of whole rhizome sets was judged into yellow orange (rating=4), yellow (rating=3), yellowish brown (rating=2) and dull brown (rating=1). The rating and categorizing the rhizomes into their nearest color was done based on the method of Fantahun and Teklu (1995) cited in Girma *et al.* (2008).

Data Analysis (common for all 3 papers)

The collected data on different response parameters were subjected to the Analysis of Variance (ANOVA) by using SAS version 9.2 computer software (SAS Institute Inc., 2008). Pearson's correlation analysis was carried out to estimate the association among response variables. Least Significance Differences (LSD) was used for mean separation whenever the treatments have significant different effects. Quantitative data which were not normally distributed (Whole rhizome and powder color characteristics) were subjected to square root transformation before data analysis.

The fixed effects type model and the ANOVA table lay out have the following form:

Model

$Yijkl = \mu + Ti + \beta j + \gamma k + (T\beta)ij + (T\gamma)ik + (\beta\gamma)jk + (T\beta\gamma)ijk + \varepsilon\ ijkl$

Where *i*= mother, finger and mother-finger rhizome sets

j=Tempereture levels=80°C, 90 °C, 100 °C
k =boiling= 30min, 45min, 60min, 75min
l = 1, 2, 3, …, 108

RESULTS AND DISCUSSION

Curing percentage

The result from the experiment data indicated that the interaction effect among the three factors was not significant (p=0.6007) for dry yield recovery (Appendix Table 2). Again two way interaction effect between rhizome set types and levels of boiling (p=0.3240) and levels of boiling temperature and boiling durations (p=0.1346) were not significant too. But regardless of the boiling durations there was a highly significant variation (p=0.0056) due to interaction effect between rhizome set types and boiling temperature levels applied (Fig 1). Also irrespective of rhizome set types and temperature levels, boiling durations brought about a highly significant difference (p=0.0034) on dry weight recovered (Fig 2). Generally speaking, boiling at low temperature level resulted in greater mean weight percentage of dried turmeric rhizomes as compared to elevated temperature gradients in the three rhizome sets. The highest (32.57%) and the lowest (21.71%) mean curing percentage values were obtained from mother and mother-finger rhizome set types boiled at temperature level of 80°C and 100°C respectively.

Treatment combinations in which mother rhizome sets boiled with 80°C temperature level provided high mean curing percentage (32.57%) over mother rhizome sets boiled at the 90°C (30.33%) and 100°C (29.52%) temperature levels but which were not significantly different each other. Mother-finger mix rhizome sets combined with boiling at 80°C recovered upper mean percentage of dried rhizomes having 25.19% whereas low percent mean values which are at par with each other were recorded from mother-finger rhizome sets boiled at the 90°C (23.38%) and 100°C (22.88%) boiling temperature levels. Unlike the two rhizome set types, finger rhizome sets resulted nearly the same and at par curing percentage mean values when boiled at 80°C (22.88%), 90°C (22.33%) but small yield at 100°C (21.71%). The superiority of the treatment combination that gave the highest yield (32.57%) can be explained by its effect that allowed more curing percentage value (21.31%), whereas the rhizome set type by temperature level treatment combination that gave least value (21.71%) provide about 18.06% less value when compared against the grand mean value (25.63%).

Figure 1 Interaction effect of boiling temperature levels with rhizome set types on curing percentage of turmeric rhizomes The mean values confirmed that, as one goes from the 30min to 75min percent of dry yield recovery tends to decline (Fig 2); i.e., 0.28%, 0.68% and 0.93% was the magnitude of reduction in curing percentage. Boiling for 30min (26.07%) duration gave the highest mean percent value followed by boiling for 45min that recorded 25.87%. Rhizomes boiled for 45min duration recorded statistically at par curing percentage value with 60min (25.42%) duration but significantly higher mean value than the 75min (25.22%) recording the lowest value among the four boiling durations. Sorts of assumptions could be forwarded standing from the above experiment result. First, order of formation of rhizomes could be quoted in this regard. Particularly, as the mother rhizomes are the earlier organs formed and able to prepare their food requirements with their true roots, have suffice time to accumulate higher amount of dry matter composition as compared to the fingers which are developed from the mother having their nutritional need supplied. This phenomenon was explained by Purseglove *et al*. (1981) that in most of the spices as the harvesting stage extends to longer period, there is high accumulation of photosynthate/carbohydrate and other essential components and of course the product's quality decreases, Girma *et al*. (2009a) and Girma *et al*. (2009b) also reported the same results for ginger (*Zingebere officinale*) and black pepper (*Piper nigrum*) cultivars, respectively.

Once more, relatively low temperature for short duration of boiling had resulted in less removal of the outer skin (corkish layer) during polishing that could have otherwise brought weight loss. But finger rhizomes are delicate and covered by thin coat of skin which is easily burnt on exposure to boiling heat; consequently could bring loss of weight as are simple to eliminate at the course of drying and polishing. For the most part of the experiment results high mean values of dry weight was recorded at low temperature with short duration of boiling possibly because at relatively low temperature level the peel can resist heating effect; particularly peel on mother rhizome sets which is likely resistant enough to withstand the boiling heat.

Table 1. Analyses of variance for Curing percentage, Corkish layer removal, Drying duration, Diameter shrinkage, Length shrinkage, rhizome color and powder color

SV	DF	Mean Square Values						
		DW (%)	CL (%)	DD (hrs)	DIA (%)	LN (%)	RC (rating)	PC (rating)
TP	2	42.92***	57.16***	207394.23***	148.46 ***	128.00***	3.316***	2.040***
RM	2	747.19***	564.81***	31625.15***	798.48***	193.35***	0.148**	0.110*
DR	3	4.63**	120.92***	6573.47***	82.35***	21.79**	0.968***	0.534***
TP*RM	4	3.94**	5.58**	1646.86***	3.02 ^{ns}	29.62***	0.020^{ns}	0.039^{ns}
TP*DR	6	0.73 ^{ns}	8.96***	734.15***	9.17 ^{ns}	21.32**	0.143***	0.324***
RM*DR	6	1.26 ^{ns}	6.31***	149.32 ^{ns}	11.38 ^{ns}	13.90*	0.005^{ns}	0.018^{ns}
TP*RM*DR	12	0.35 ^{ns}	3.00*	89.29 ^{ns}	8.07 ^{ns}	14.90**	0.010^{ns}	0.008^{ns}
ERROR	72	0.84	1.35	111.62	6.99	5.18	0.025	0.026

*NS, *, ** and *** = Non-significant, significant, highly significant and very highly significant differences at 5% levels of probability level respectively. DW=Curing percentage, CL=Corkish layer, DD=Drying duration, DIA=Diameter shrinkage,LN=Length shrinkage, RC=Rhizome color and PC= Powder color.*

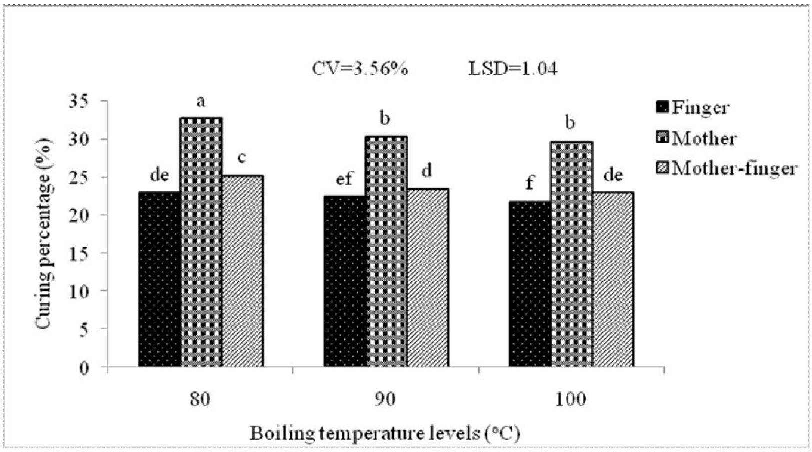

Figure 1. Interaction effect between boiling temperature levels and rhizome set types on curing percentage of turmeric

Table 2 . Interaction effect of boiling temperature levels, durations and rhizome set typeson amount of corkish layer removed (%)

Trts.	Finger Rhizomes			Mother Rhizomes			Mother-Finger Rhizomes		
	T1	T2	T3	T1	T2	T3	T1	T2	T3
D1	4.75^{s}	5.09^{rs}	6.21^{pqrs}	11.38^{fghi}	10.53^{hijk}	12.74^{defg}	6.10^{pqrs}	5.522^{qrs}	6.49^{opqrs}
D2	5.67^{qrs}	6.19^{pqrs}	6.72^{lmno}	12.57^{defg}	14.29^{cd}	15.02^{c}	8.16^{lmno}	9.940^{ijkl}	10.82^{ghij}
D3	5.93^{pqrs}	8.34^{opqr}	9.47^{jklm}	13.34^{cde}	16.98^{b}	17.34^{b}	8.80^{klmn}	12.114^{efgh}	7.73^{mnop}
D4	7.08^{nopq}	8.34^{lmno}	9.82^{ijkl}	13.39^{cde}	18.84^{ab}	20.00^{a}	9.81^{ijkl}	13.451^{cde}	13.25^{cdef}
CV (%) = 11.21		LSD = 1.887		Mean =10.03					

T1=80^{o}C, T2=90^{o}C and T3=100^{o}C boiling temperature; D1= 30min, D2=45min, D3=60min and D4=75 min boiling durations. Means in the same column with the same letter are not significantly different (P≤0.05).

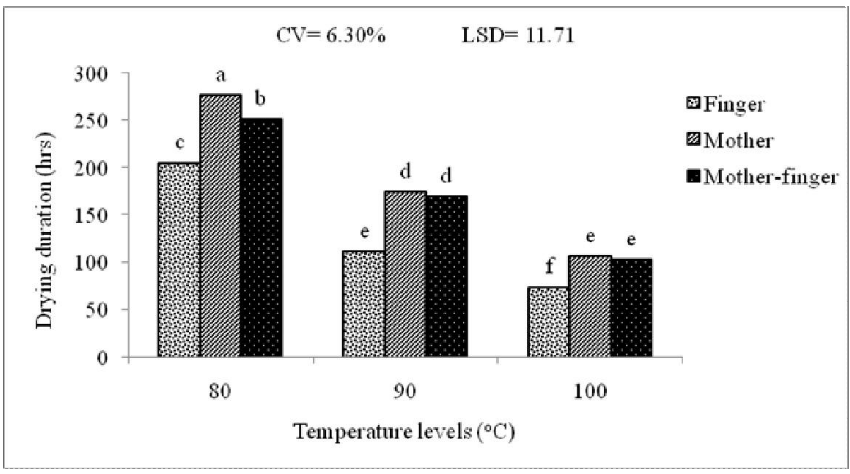

Figure 2. Interaction effect of boiling temperature levels and rhizome set types on drying duration of turmeric

These can be further explained by very highly significant and positive correlation between amount of corkish layer removed and dried yield recovered (r=0.62***) was observed indicating the largest corkish layer removal figures were also recorded from those high dried yield recovering treatment combinations (Appendix Table 5). Related results were found by Maria Lucia *et al*. (2002), who reported that the loss of mass by the rhizome without peel was significantly higher (9.84 g/100g) than for turmeric with peel (14.51 g/100g), indicating that the peel protected the rhizome, reducing weight loss during retort process. On the contrary, high boiling temperature is strong enough to adequately cook the peel. When this coincides concomitantly with longer duration of boiling, is not difficult to imagine what the consequence would be at the end. In confirmation, significant reduction in length and diameter of rhizomes in high temperature and stretched duration of boiling sounds as if contributed to the loss of dried yield. Correlation values were observed to be negatively and highly significant (Appendix Table 5) between dry weight with length (r= -0.55***) and diameter shrinkage (r= -0.56***) showing that dried yield recovery was high from treatment combinations recording less length reductions.

Corkish layer percentage

Polishing is a critical step in turmeric processing, which has the advantage of developing inherent deep yellow orange color and getting cured products deprived of bitter constituents. The mean square values from the experiment result indicated that the three way interaction effect among boiling temperature levels, durations and rhizome set types showed highly significant variation (p<0.0001) for weight of removed corkish layer percentage (Table 5 and Appendix Table 2). Boiling duration and temperature gradient variations have had impact on the extent of percent of corkish layer removed in all rhizome sets tested. Mother rhizomes boiled at 100^{o}C for 75min gave the highest (20%) removal of corkish layer followed by boiling at 90^{o}C temperature level for 75min duration (18.84%) from mother rhizomes. The least removal of corkish layer value was recorded from finger rhizomes boiled at 80^{o}C and 90^{o}C for 30 that resulted removal of 10.53% and 11.38% values, respectively. The effect high temperature, long boiling duration and inherent character of mother rhizomes of their possession of huge peel contributed to the highest removal as evidenced by percent of the highest (20%) corkish layer value was 48.3% and 76.25% more than the overall mean (10.34%) and the smallest value (4.75%) shown on table 2, respectively. And the lowest mean value from the result due to the three way interaction effect of the independent variables showed deviation of about 54.06% when plotted against the grand mean value.

Mother rhizomes boiled at 100^{o}C for 75min, and 90^{o}C for 75min resulted in massive and at peak removal of percent corkish layer which were 20% and 18.84% respectively, whereas boiling at 80^{o}C for 30min and 90^{o}C for 30min led to 10.53% and 11.38% of mean corkish layer percent disposal in mother rhizomes which were low percentage values. The highest value for mother rhizomes due to the temperature and duration combination effect had 48.30% and 47.35% high value over the grand mean and the least value for mother rhizomes, respectively.

Partly parallel to the pattern of variations among mother rhizomes, elevated mean corkish layer percentage value was recorded when mother-finger mix rhizomes boiled at 90^{o}C for 75min (13.45%) and at par value was obtained from boiling at 100^{o}C for 75min (13.35%). In turn, minimum percentage of corkish layer removal values were recorded when rhizomes were boiled for duration of 30min coupled with 80^{o}C, 90^{o}C and 100^{o}C that gave values of 6.10%, 5.52% and 6.49%,respectively. About 23.12% and 58.96% more percent of corkish layer removal were achieved as compared to the overall mean and the least value for the same rhizome set type, respectively. On the other hand, concerning finger rhizomes, those boiled at 100^{o}C for 75min resulted in higher elimination of mean corkish layer (9.82%) followed by treatment combinations 100^{o}C/60min (9.49%), 90^{o}C/60min (8.34%) and 90^{o}C/75min (8.34%).

The least percentage mean values were recorded from finger rhizomes boiled at combinations of 80^{o}C/30min (4.75%), 90^{o}C/30mim (5.09%) boiling. As peel from finger rhizomes expected to be less than their respective mother rhizomes and even that of the mix rhizomes is expressed by the values obtained from the treatments applied. All treatment combinations on finger rhizomes end up with fewer values than the grand mean. The maximum value recorded 5.30% less removal than the grand mean value, while the least value placed about 117.68% less than the grandmean value. High temperature assumed to have role in elimination of peel during polishing because it tends to burn the corkish layer fast and deep. This condition is aggravated when the duration of heating is quite long particularly on finger rhizome. But, there exists difficulty in polishing the mixed rhizome boiled rhizomes. Though easy and effective removal can be achieved at higher heating range, could likely to result in over boiling of the rhizomes leading to quality loss both physically and intrinsically.

Though the corkish layer removed by polishing depend on variety, growing environment and agronomic practices, knowing the quantity likely help in calculating the final product ahead of curing given that the temperature and duration of boiling conditions are redeter mined, according to this experiment result. Similar results were reported by Shinde *et al*. (2011) that claim the extent of corkish layer (peel) removal and the color of the final product is dependent on duration of boiling of the rhizomes; rhizomes boiled for 15 minutes were difficult to remove their peel, hard to stick pierce and developed no uniform color with visible core, while those boiled for 20 minutes allowed less skin removal, less stick pierce and showed uniform yellow color with slightly visible core, and those boiled for 25 minutes permitted easy removal of peel and stick pierce and develop uniform color while turmeric rhizomes boiled for 30 minutes were more easy to peel and stick pierce and develop uniform yellow with very soft rhizomes.

Drying duration

Results obtained from this experiment revealed that regardless of rhizome set types, very highly significant variations (p<0.0001) due to the interaction effect existed between boiling temperature levels with boiling durations (Fig 3 and Appendix Table 2).

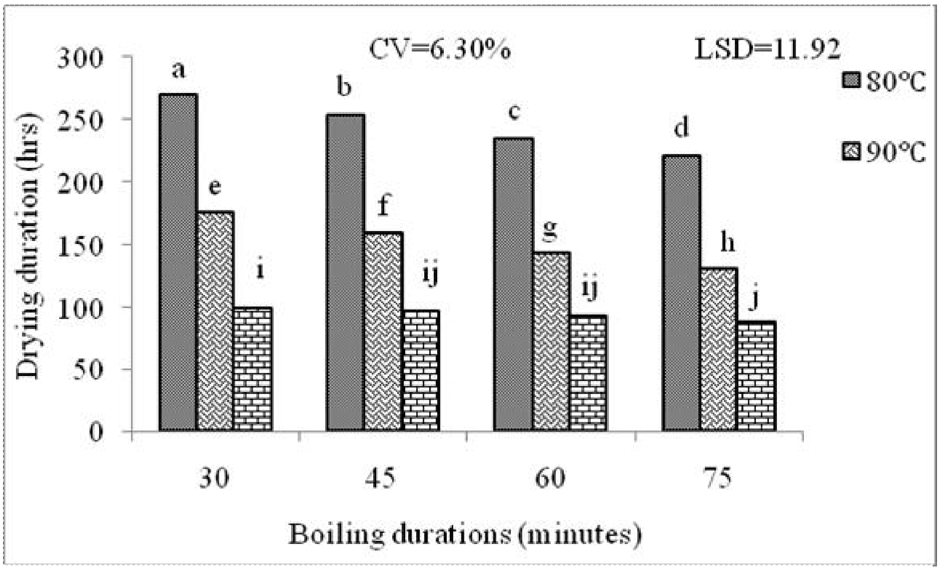

Figure 3. Interaction effect of boiling durations and temperature levels on dying duration of turmeric

Table 3. Effect of boiling temperature levels, durations and rhizome set types on diameter shrinkage of turmeric

Treatments	Diameter shrinkage (%)
Boiling Durations	
30	38.30c
45	40.75b
60	41.36ab
75	42.42a
LSD	1.435
Temperature Levels	
80	38.63c
90	40.81b
100	42.69a
LSD	1.243
Rhizome Types	
Finger	39.62^{b}
Mother	36.64^{c}
Mother-finger	45.87^{a}
CV (%)	6.495
LSD	1.243

Means with the same letter in each column are not significantly different at (p≤0.05).

Table 4. Interaction effect of boiling temperature levels, durations and rhizome set types on length shrinkage (%)

Trts.	Finger Rhizomes			Mother Rhizomes			Mother-Finger Rhizomes		
	T1	T2	T3	T1	T2	T3	T1	T2	T3
D1	$32.62^{defghij}$	$32.62^{efghijk}$	33.70^{defgh}	26.70^{m}	28.70^{klm}	29.36^{jklm}	34.70^{defg}	34.63^{defg}	34.34^{defgh}
D2	28.67^{klm}	36.33^{bcd}	34.70^{defg}	28.27^{lm}	29.57^{ijklm}	31.11^{ghijkl}	28.66^{klm}	36.12^{cd}	32.86^{defghi}
D3	31.23^{ghijkl}	35.98^{cd}	39.95^{ab}	29.31^{jklm}	30.87^{hijkl}	$32.74^{defghij}$	31.47^{ghijk}	33.79^{defgh}	35.75^{cde}
D4	31.36^{ghijkl}	39.05^{abc}	41.31^{a}	30.91^{hijlk}	33.16^{defghi}	$31.78^{fghijkl}$	35.34^{def}	35.96^{cd}	35.98^{cd}
CV (%) = 6.89			LSD = 3.705		Mean = 33.03				

T1=80ºC, T2=90ºC and T3=100ºC boiling temperature; D1= 30min, D2=45min, D3=60min and D4=75 min boiling durations. Means in the same column with the same letter are not significantly different (P≤0.05).

In another two way interaction effects, irrespective of the boiling duration, boiling temperature levels and rhizome set types brought about a very highly significant variation (p<0.0001) on drying duration (Fig 4). It was observed that as the combinations of boiling temperature levels and boiling durations were raised, the duration required to dry rhizomes kept on declining, but it was the boiling duration that more importantly exhibited its effect than the level of temperature and sooner it reached the 100°C combined with the four boiling durations exhibited its positive effect in allowing faster drying, i.e., few sunny hours were required. Accordingly when turmeric rhizomes were boiled at 80°C for 30min duration, rhizomes predisposed to stay for 269.556hrs which was the highest mean drying duration than the mean value from 80°C combined with 45min (254.22hrs), 60min (235.11hrs) and 75min (221.11hrs) boiling durations. Added to this drying duration continued to be reduced in treatment combinations of boiling at 90°C for 30min (175.78hrs), 45min (159.44hrs),

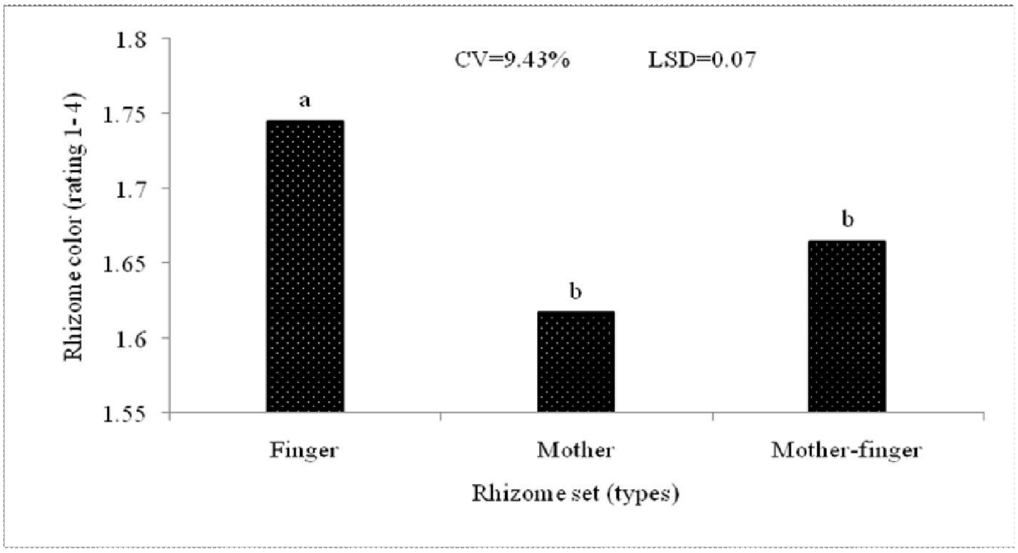

Figure 4. Variation of rhizome color of finger, mother and mother-finger mix rhizomes (Rating: 1=Dull brown, 2=Yellowish brown, 3=Yellow and 4=Orange yellow)

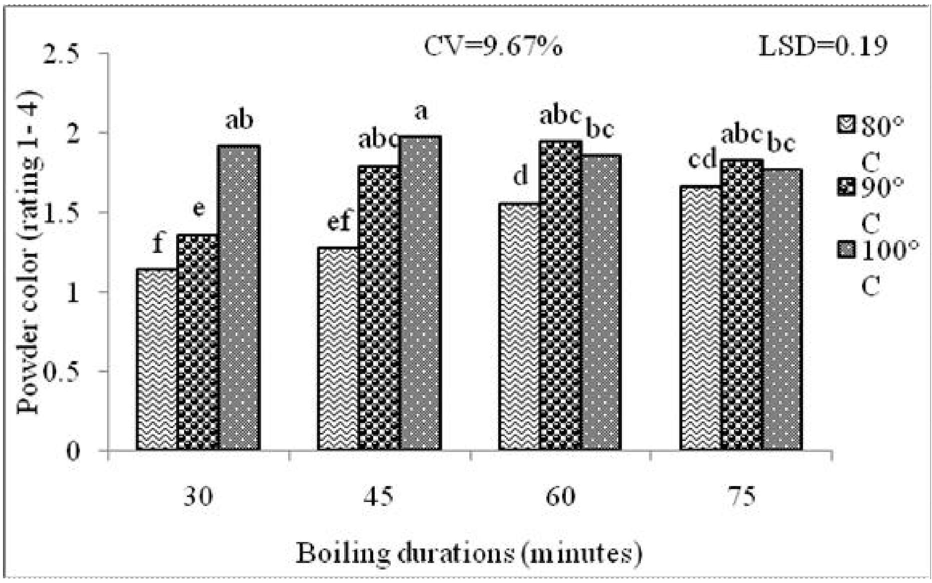

Figure 5. Interaction effect of boiling temperature levels and durations on powder color characteristics (Rating: 1=Brownish yellow, 2=Light yellow, 3=Yellow and 4= Yellowish orange)

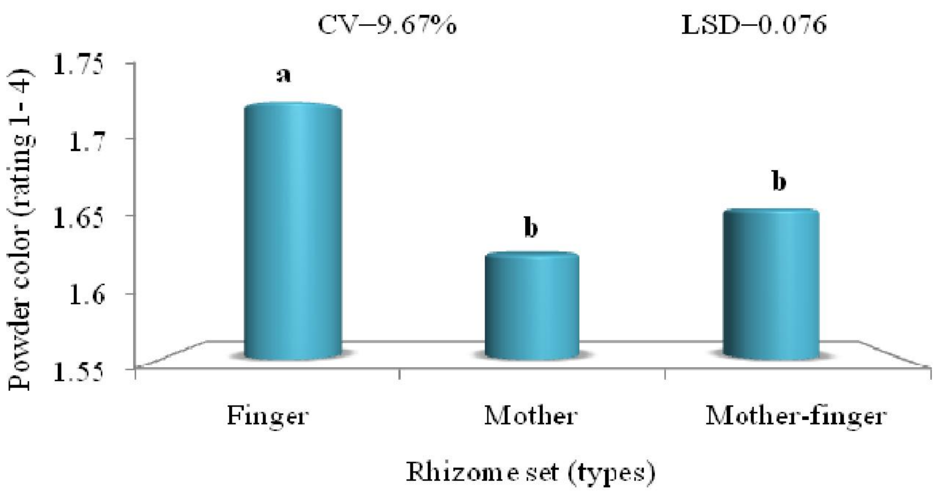

Figure 6. Variation of powder color of finger, mother and mother-finger mix rhizomes (Rating: 1=Brownish yellow, 2=Light yellow, 3=Yellow and 4= Yellowish orange)

60min (143.00hrs) and 75min (130.78hrs). Whereas when boiling was commenced at 100°C for 30, 45, 60 and 75min durations the shortest drying durations having respective mean values of 100.33, 96.89, 93.33 and 88.00 hours were required respectively. The variation between the longest and shortest mean drying hours constituted the largest (181.56hrs) magnitude of difference indicating impact of the treatment combinations on drying durations. Considering the overall mean as a bench mark, the longest duration requiring treatment took about 105.76 more and the shortest 75.80 less hours of drying duration when rated against the grand mean value (163.8hrs).

Concerning combined effect of boiling durations and rhizome sets the highest drying duration (277.417hrs) was observed when mother rhizomes boiled at 80°C, and the short mean drying duration (74.417hrs) was recorded from boiling finger rhizomes at 100°C. Mother-finger rhizomes boiled at 80°C gave high (252hrs) but low mean drying duration than the highest for mother rhizomes. The longest mean drying duration value for finger rhizomes was recorded from 80°C boiling but was shortest mean drying duration than the highest value for mother- finger rhizomes boiled at similar temperature level. Taking in domain the rhizome set types less mean drying durations: 74.42hrs for finger rhizomes, 102.83hrs for mother rhizomes and 106.67hrs were recorded when all boiled at 100°C. On the basis of the projected result due to the interaction effect of the independent variables for the highest drying duration required (277.42hrs), more (113.62hrs) drying hours are required when compared with the overall mean (163.8hrs). Contrary to this the treatment combination that recorded the shortest drying duration (74.42hrs) saved more hours (89.38hrs) with reference to the grand mean and 203 less hours when compared to the longest drying duration value. It is obvious that one of the advantages of boiling of turmeric is shortening of the dying duration. The high temperature and long duration, as resulted in fastest drying, has probably produced changes in cell walls of the rhizomes facilitating their permeability and reducing resistance to mass transfer, which leads to an increase in the drying rate. Besides as boiling aids in gelatinization of starch which in turn facilitates rapid drying, the high temperature and long duration treatment combination may play role in this regard. Parallel to this, taking boiling duration and rhizome set types in domain, comparatively faster drying duration was achieved in finger rhizomes because of enumerable reasons. First, they are thin (less thickness) and slender morphologically, a phenomenon which would likely allow them easily to receive the sun heat along their body length. Second, they are lined with thin and delicate outer layer from where removal of moisture is found to be easy and fast particularly when the rhizomes are being boiled for long duration that paved the way by destroying the peel during boiling. Unlike fingers individual mother rhizomes are thick in size and covered with thick coat of peel. The thick layer has more strength to resist heat during boiling than the fingers, and enable to reduce the degree of moisture loss during drying; likewise their shape aid them not to face the sun fully rather form thick drying layer that make difficult the bottom portion to be reached by the drying heat. In support of the above findings Maria Lucia *et al* (2002) explained, with respect to the duration required for dehydration, the control sample (unblanched) took longer to dry (7 days) compared to the ones that had undergone blanching (6 days). George (1995) reported that boiling reduces drying duration from 30–35 days to 10–15 days. Delayed drying inconventional method may be due to unscientific boiling, layer thickness of drying and relatively low drying temperature and high relative humidity. Added to this, Gonzalo-Vázquez *et al*. (2003) stated that the peridermis of the rhizomes, existing as a consequence of their secondary growth, presents cell layers that protect the plant during periods of drought. Therefore, the water loss is diminished by the peridermis. Likewise, the peridermis could reduce the mass transfer during the drying process; this effect could be addressed as an additional resistance to mass transfer. Investigation results by Singh *et al*. (2010) supported the result from this experiment in that the finger rhizomes took less duration to dry as compared to mother rhizomes.

Diameter reduction of rhizomes

The analysis of variance table revealed that neither the three nor the two way interactions were significant on the diameter of turmeric rhizomes (Appendix Table 2). Rather main effects brought about very highly significant variations ($p<0.0001$) in mean diameter shrinkage values (Table 8). Independent increments in boiling temperature levels and boiling durations from the bottom to the upper level resulted in reduction of diameter. The highest reduction in diameter was observed in mother-finger rhizomes (45.87%), while minimum mean shrinkage values were obtained from finger rhizomes (39.62%) and mother rhizomes (36.64%), in which values from mother rhizomes were the least indicating minimum diameter shrinkage. Reduction was also elevated (42.69%) when turmeric rhizomes were boiled at 100°C over treatments with 90°C (40.81%) and 80°C (38.63%) temperature ranges. The smallest magnitude of reduction in diameter was observed from the 80°C boiling (38.63%). The degree of circumference reduction was the highest in the case of 75min boiling duration (42.42%) followed by 60min (41.36%) boiling duration. The least reduction in diameter was seen when boiling continued for 30 (38.30%) minutes. The reduction in diameter pertaining to the effect of boiling durations, temperature levels and nature of each rhizome set type could be best explained by quantifying the difference of means against the overall mean, and between the highest and lowest. The maximum shrinkage values (42.42%, 42.69% and 45.87%) recorded 4.03%, 4.64% and 11.25% more shrinkage over the grand mean values, respectively. The least reduction values were registered from boiling for 30min (38.3%), at 80°C (38.63%) and mother rhizomes (36.64%) which showed 6.29%, 5.38% and 2.75% less reduction values than the overall mean respectively. The range between the highest and lowest values recorded 9.71%, 9.51% and 20.12% values for boiling duration, temperature levels and rhizome set types, respectively. From the above result inferences can be made in different ways. The first assumption could be stated in such a way that, mass loss in diameter from mother-finger rhizomes pertaining to the treatments applied is because of the mixed boiling effect. Mixed boiling probably played role in non uniform boiling among the mixes and therefore may be due to inferior resistance capacity of the finger rhizomes to high temperature levels which could have brought high dehydration effect during boiling and drying processes. As finger rhizomes require lower drying duration as compared to the mother rhizomes, and being in mother finger mix the finger rhizomes might had lost much of their circumference until both were dried. However, minimum loss in mother boiling is probably because they are composed of less moisture content as compared to fingers and also made of thick and tough peel that have aided in lowering of the impact of high temperature.

Length reduction of rhizomes

Results of the average mean length showed highly significance difference (p=0.0027) because of the interaction effect among rhizome set types, temperature levels and durations (Table 5and Appendix Table 2). In general, as the results from this experiment confirmed, finger rhizomes followed by mother-finger rhizomes were more vulnerable to size reduction compared to mother rhizomes pertaining to the interaction effect. Considering the mean values from all treatment combination, effect of high temperature (100^{o}C) with long boiling duration (75min) on finger rhizomes resulted in maximum shrinkage of length (41.31%) but the least percentage reduction (26.70%) was recorded from mother rhizomes boiled at 80oCfor 30 minutes. The treatment combination that resulted in maximum length reduction constituted about 20.04% more shrinkage value when weighed against the overall mean. On the contrary, the least value ended up with about 23.71% less shrinkage when compared with the overall mean. But the difference between the highest and lowest was 35.37%. On the other hand, boiling at 80oC coupled with 45min duration gave the lowest length shrinkage value (28.67%) compared among finger rhizomes. The lowest mean value showed about 15.21%less removal value than the overall mean.

Boiling of mother rhizomes at 90^{o}C for 75min followed by 100^{o}C for 60 and 75 minutes led to high shrinkage of length that recorded 33.16%, 32.74% and 31.78% respectively; in reverse little reduction in length (26.70%) from mother rhizomes was observed when boiled at 80^{o}Cfor 30min. Referring to the domain of treatment impacts on length shrinkage of mother-finger rhizomes, at peak mean values were penned from boiling temperature and duration combinations of 90^{o}C with 45min, 100^{o}C with 75min and 90oC with 75min having mean values of 36.12%, 35.96% and 35.98% respectively, whereas little shrinkage (28.66%) was obtained from 80^{o}C with 45min treatment combination. The highest value for mother rhizomes gave 0.39% and 23.71% above and below the grand mean shrinkage value, respectively. The results of the present investigation showed that unlike reduction in diameter shrinkage which was high from mixed rhizomes, length reduction was high from finger rhizomes. This is probably because of effect over boiling of finger rhizomes in the mix which are comparatively small and forced to loss more contents due to boiling and when drying. In support of this Balakrishnan (2007) reported that it is important to boil batches of rhizome that are equal in size since different size materials would require different boiling durations.

Rhizome and powder color characteristics

Whole rhizome color

The values recorded on the analysis of variance table (Fig 5 and Appendix Table 2) indicated that whole rhizome color rating values, irrespective of rhizome set types, showed very highly significant difference (p<0.0001) due to the interaction effect of boiling temperature levels and durations. Also, rhizome set types showed significant variations (p=0.004) of their whole rhizome color appearance (Fig 6). High and similar whole rhizome color value ratings, representing yellow orange color, were observed when boiling was run at 100^{o}C for 45min (1.97), 60min (2), 75min (2) and boiling at90^{o}C for 75min (1.94) followed by boiling at 100^{o}C for 30min (1.85) and 90^{o}C for 60minduration (1.85). Whereas small rating values, with dull brown color of whole rhizome, was recorded from boiling at 80^{o}C for 30min (1.09) followed by boiling at 80^{o}C for 45min (1.18).On the other hand, boiling at 80^{o}C for 60min and 90^{o}C for 30min yielded rating values 1.47and 1.34 respectively that is assigned to be brown yellow colored whole rhizomes. And boiling at 80^{o}C for 75min and 90^{o}C for 45min gave rating values of 1.66 and 1.73, respectively representing yellow color of whole rhizomes. With regard to the color of rhizome set types finger rhizomes recorded the highest whole rhizome color rating value (1.75) than mother-finger mix (1.67) and mother rhizome (1.62) set types.

Rhizomes which were boiled at the highest temperature level with duration of boiling increasing from the 30min mark to 75min, there appeared to be development of wrinkled form of products particularly in the case of finger rhizomes. This situation is similar for boiling at90oC for 75min duration. Moreover, finger rhizomes in mother-finger mix rhizomes appeared more wrinkled in texture than finger rhizomes boiled separately. There observed significant and positive correlations between whole rhizome color and powder color (r=0.76***) whereas significant and negative correlation between rhizome color and drying duration (r=-0.83***),curing percentage (r=-0.34***). The negative correlation between rhizome color and drying duration is explained, though longer drying duration led to color destruction (fading), because the highest rhizome color was represented by the largest rating number (5) and the least value by smallest number (1). Regarding negative correlation value between color and curing percentage is because highest rhizome color was observed from treatments on finger rhizome sets boiled at high temperature while the highest curing percentage was from mother rhizomes boiled at low temperature. In agreement with the findings of the present study Kamble and Soni (2009) reported that the colour of rhizomes boiled for 25, 35 and 45 minutes was not uniform, uniform yellow and faint yellow respectively. Turmeric boiled for 25 minutes was under boiled hence the colour remained concentrated in the center of the dried rhizome without spreading uniformly throughout the endosperm and the outer ring looks faint i.e. non-uniform yellow colour observed. Turmeric boiled for 35 minutes shows uniform yellow colour. Turmeric boiled for45 minutes shows little faint colour throughout the endosperm of rhizome because of more duration of boiling. Additionally, Shinde *et al*. (2011) revealed that turmeric rhizomes boiled for 15, 20, 25 and 30 minutes attains non-uniform yellow color with separate yellow core and outer layer, uniform yellow color with visible core, uniform yellow color with soft rhizomesand uniform yellow color with very soft rhizomes respectively.

Powder color

The result from this experiment confirmed that rating values for powder color showed very highly significant difference (p<0.0001) due to the interaction effect of boiling temperature levels and durations (Fig 7 and Appendix Table 2), independent of the rhizome set types. Also, rhizome set types showed significant variations (p=0.0183) of their whole rhizome color characteristics (Fig 8). High powder color value ratings, representing orange yellow color, were observed when boiling was run at 100°C temperature level for 45min (1.97) followed by boiling at 90°C for 60 (1.94), 45(1.79), 75 (1.82) minutes and 100°C for 30min (1.91). While small rating values, having dark brown color of powder, were recorded from boiling at 80°C and 30min (1.14) followed by boiling at 80°C for 45min treatment combination (1.28). On the other hand, boiling at 90°C for 30min gave rating value of 1.36 indicating light yellow color but boiling at 80°C for 60 and 75min yielded rating values of 1.56 and 1.66 respectively displaying nearest yellow powder color.

Concerning the powder colors from rhizome set types, finger rhizomes recorded the highest color rating value (1.73) than mother-finger mix (1.66) and mother rhizome (1.62) set types. Though the mean separation figure showed significant variations among the three rhizome set types, the rating values indicated nearly similar powder color characteristics existed among them. Significant and positive correlation values were observed between powder color and color value (r=0.47***) whereas significant and negative correlation with drying duration (r=-0.75***). The color value was recorded to be high for those treatment combinations taking short drying durations.

Summary and Conclusion

Primary processing is still being done with traditional means leading to many post harvest quality losses. Therefore, studies are necessary to investigate the role of different boiling durations and temperature levels on the quality of turmeric. Accordingly, the result of this study revealed that almost all of the parameters considered were significantly affected by the treatments or their interaction effects. The interaction effect among temperature levels, boiling durations and rhizome set types manifested significant variations in respect of corkish layer and length shrinkage. The interaction effect between boiling temperature levels and durations significantly affected the duration of drying, rhizome color and powder color; and that of between temperature level and rhizome set types affected drying duration and curing percentage. Again, rhizome set types showed significant effect on color of whole rhizome and powder. Curing percent significant differed according to boiling durations. Huge removal of corkish layer was observed from mother rhizome sets boiled at 100°C for 75min followed by 90°C for 75min whereas the smallest percents were gained from finger rhizome sets boiled at 80°C and 90°C temperature levels for 30min duration, respectively. High curing percent and long drying duration were obtained from mother rhizome sets boiled at 80°C, while the lowest values of curing and drying duration were recorded from finger rhizome sets boiled at 100°C. Maximum and minimum drying hours were recorded from boiling for 30min at 80°C and 75min at 100°C, respectively. Again boiling for 30min gave the highest curing value and the least from 75min.

Highest reduction in length was observed in finger rhizomes boiled at 100°C for 75min, while the lowest from mother rhizomes boiled at 80°C for 30min. The highest reductions in diameter were observed from 100°C, 75min and mother-finger mix rhizome sets, respectively; whereas the least reduction was from 80°C, mother and 30min. The value for whole rhizome color was yellowish-orange when boiling at 100°C for 45 min, 60min and 75min and at 90°C for 60min, whereas dull brown color was observed at 80°C for 30min. Powder color attained bright yellow color at 100°C for 45min boiling followed by at 90°C for 60, 45, 75 minutes and 100°C for 30min, yellowish brown color was recorded from boiling at 80°C for 30min. Again, color of rhizome and powder were high in finger rhizomes than the other two.

Taking in consideration the major quality determining factors, adopting boiling at 100°C for 30min for oleoresin and 100°C or 90°C for 30min for essential oil production are regarded as optimum. The advantage of using these treatment combinations further explained in that the curing percentage magnitude is good, extent of percent corkish layer removed kept affordable, drying duration is relatively acceptable and other decisive parameters are moderate. Boiling and drying mother and finger rhizome sets together is not advised. As the overall results of the experiment pertaining to the physical and chemical parameters considered proved, fixing optimum duration and temperature level of boiling was observed to be difficult. Additionally, during the course of this study, it was noticed that there was inconveniency in polishing work. By considering the advantages of reducing the losses of fuel, labor, time, quality and difficulties in turmeric processing, the package of boiling conditions are beneficial to the turmeric growers and processing industries. However, though it could be not easy to control the temperature level in farmers' boiling process, exhaustive practical training sessions need to be put in place in order to make them familiar with the technology. In this regard DAs, concerned technical and political persons have to work along with the farmers. Meanwhile formation of turmeric producing farmers' cooperatives particularly in FTCs can help to address the issue in a more comprehensive way. But interested turmeric oil producing factories can directly use the technology. To come up with sound recommendations, however, it would be imperative to repeat the study in replicated season and place.

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