International Journal of Agricultural Sciences
Volume 12 | Issue 2 | June, 2016 | 302-308 ■ e ISSN-0976-5670
☞DOI:10.15740/HAS/IJAS/12.2/302-308
Visit us : *www.researchjournal.co.in*

RESEARCH PAPER

Evaluation of the quality parameters of the turmeric rhizomes dried on different floors and conditions

M. PADMA*, B. SREENIVASULA REDDY[1] AND M. MADHAVA[1]
Agricultural College, Jagtial, KARIMNAGAR (TELANGANA) INDIA
(Email : padma2386@gmail.com)

Abstract : Turmeric is an important commercial spice crop grown in India and it is named as "Indian saffron". Turmeric is grown in tropical countries like India, Pakistan, Myanmar, Chile, Peru, El Salvador, Japan, China, Sri Lanka, Bangladesh, Indonesia, Taiwan, Jamaica, Thailand and West Indies. The quality of turmeric powder depends upon the initial quality of rhizomes and on-farm processing of turmeric rhizomes which effects curcumin content, organoleptic characteristics, size and general appearance of the dried turmeric rhizomes. The on farm post harvest processing operations consists of washing, curing, drying, polishing, grading and colouring. Curing is a process of cooking the raw rhizomes in hot water to obtain attractive colour, characteristic aroma, destroy the viability of the fresh rhizomes and obviate the raw odour, reduces the time of drying, ensures an even distribution of colour in the rhizomes and gives a better quality product by gelatinisation of the starch (Purseglove and Brown, 1981). The study was conducted to obtain fundamental data on the effect of different floor materials on open yard sun drying and polyhouse drying. It is observed that the moisture content of turmeric fingers increases with increase in temperature of curing and curing time. At the time of 90 minutes the moisture contents were 84.41, 84.48, 84.80 and 85.77 per cent (w.b.) at the curing temperatures of 60, 70, 80 and 90^0C, respectively. The moisture contents increased from the initial moisture content of 79.56 per cent (w.b.). It is observed that the floor materials affected the drying time marginally under the conditions of experiments, varied considerably from one method to the other. It is concluded that polyethylene sheet followed by tarpaulin are better floor materials to reduce the drying time and for good quality of turmeric powder.

Key Words : Turmeric rhyzomes, Polyhouse, Open sun drying, Curing, Floor materials,Curcumin content

View Point Article : Padma, M., Reddy, B. Sreenivasula and Madhava, M. (2016). Evaluation of the quality parameters of the turmeric rhizomes dried on different floors and conditions. *Internat. J. agric. Sci.*, **12** (2) : 302-308, **DOI:10.15740/HAS/IJAS/12.2/302-308.**

Article History : Received : 21.02.2016**; Revised :** 17.03.2016**; Accepted :** 13.05.2016

INTRODUCTION

Turmeric is used in diversified industries as condiment, as flavouring, colouring agent and principal ingredient in Indian culinary as curry powder. Oleoresin extracted from turmeric is used in brine pickles and to some extent in mayonnaise, relish formulations, non-alcoholic beverages, gelatins, butter and cheese etc. The colour curcumin extracted from turmeric is used as a colourant. Turmeric is also used as a dye in textile industry, in cosmetics, preparation of medicinal oils, ointments and poultice. It is stomachic, carminative, tonic, blood purifier and an antiseptic. The aqueous extracts have biopesticidal properties.

*** Author for correspondence:**
[1]College of Agricultural Engineering, Bapatla, GUNTUR (A.P.) INDIA

Open yard sun drying (OYSD) method has some disadvantages like contamination and non uniform drying, affecting the colour and quality parameters that cause significant losses. Even then many growers use OYSD, as it requires no capital investment. Further, mechanical drying and other alternative drying methods are not possible to adopt because of their high cost. In this, produce is spread on concrete, polyethylene sheets instead of dry in the fields. These innovative methods proved to be effective to some extent, but could not reduce drying time significantly.

The polyethylene sheets of black colour is mostly adopted for drying scientific studies have not been conducted to know the best of the different types available. Keeping the above points in view, the research work was conducted with the following objectives. Evaluation of the quality parameters of the turmeric rhizomes dried on different floors and conditions.

MATERIAL AND METHODS

This paper deals with the procurement of raw materials and dried the turmeric rhizomes on different floor materials and used this dried samples for determination of quality parameters of turmeric samples.

Raw materials :

Raw turmeric rhizomes :

About 150 kg of freshly harvested turmeric fingers of 'Tekurpet (Long duration type)' variety were procured from progressive farmers of Duvuluru Village of Guntur district, in Andhra Pradesh were used for drying at College of Agricultural Engineering, Bapatla.

The moisture ratio of the turmeric rhizomes dried on different floors and under different drying conditions were observed and noted that the moisture ratio was decreased in polyethylene sheet with respect to drying time in polyhouse conditions and then followed by tarpaulin, cement concrete and sand floors and the same trend was followed in open sun drying conditions.

Quality parameters of the turmeric rhizomes :

The quality parameters such as ash content, ash insoluble in diluted HCl, crude fibre, oleoresins, curcumin content and colour of turmeric were estimated using the Standard techniques as per the AOAC guidelines. About 250 g of representative samples of dried rhizomes dried on four floors were taken under two different drying conditions. The samples were then made into fine turmeric powder by using motorized pedal and pestle. These powder samples were used to estimate the different quality parameters for turmeric.

Determination of crude fibre :

To determine the crude fibre content of turmeric powder samples of 2.5 g ground turmeric powder was taken into a thimble and extracted for about 1 hour with petroleum ether in a soxhlet extractor. The extract was then transferred to a 1 litre flask. 200 ml of dilute sulphuric acid (1.25 % w/v) was taken in to a beaker and brought it to boil. The whole of the boiling acid was transferred to the flask containing fat free material and immediately connected to a water cooled reflux condenser and heated so that the contents of the flask begin to boil within 1 minute. Frequently the flask was rotated, to keep the material in contact with the acid. The boiling was continued for exactly 30 minutes. The flask was removed and filtered through hardened filter paper held in a funnel and washed with boiling water until the washings are no longer acid when tested with a litmus paper. The residue was transferred into the flask containing 200 ml of boiling sodium hydroxide solution. Immediately connected the flask with the reflux condenser and boil for exactly 30 minutes. The flask was removed and immediately filtered through the filter paper. The residue was thoroughly washed with hot water and transferred to a gooch crucible prepared with a thin but compact layer of asbestos. The residue was washed thoroughly first with hot water and then with about 15 ml of ethanol (95 % v / v) and with 3 successive washings of petroleum ether. The contents were dried in an air oven at 105 $\pm 1^0$ C for 3 hours. The process of heating and cooling was repeated until two consecutive readings were found to be same. Incinerate the contents of the gooch in a muffle furnace at 550±20 ^{0}C until all carbonaceous matter is burnt. The gooch crucible was cooled in a desiccator and weight was taken. The crude fibre content of the turmeric powder was calculated as follows :

$$\text{Crude fibre (on dry basis) \% by wt.} = \frac{(W_1 - W_2) \div 100 \div 100}{W(100 - M)} \quad (1)$$

where,

W_1 = Wt. of gooch crucible + contents + asbestos before ashing

W_2 = Wt. of gooch crucible + ash and asbestos after ashing

W = Wt. of sample taken for test

M = Per cent moisture content

Determination of oleoresins :

Acetone being organic solvent dissolves whole contents of turmeric. After pouring acetone from turmeric powder acetone can be evaporated. After boiling by mild heating at 15^0C to get oleoresin that can be quantified. This method was developed by Roger Brooth in 1965 and modified by Bajaj and Kaur (1979). Inorder to determine the oleoresins, finely meshed turmeric powder of 25 g was taken. A glass column was taken, the narrow end was plugged by cotton and powder was transferred into it. A thin layer of cotton over turmeric powder was placed. The glass column was placed on a stand. 25 ml of acetone was added to a glass column placed 250 ml beaker placed below the glass column. After all the acetone dessicated, 25 ml acetone was again added continuously till it accounts for 250 ml. After desiccation red color liquid in beaker was accumulated. The collected filtrate was transferred to a 250 ml volumetric flask and made up the volume with acetone. A dry 250 ml beaker was taken and its weight was noted as W_1 g. 250 ml of extract was transferred into beaker and kept it in a water bath at 50-60 ^{0}C for 15-30 min. Weight of the beaker was taken again and noted down as W_2 g. The (W_2 - W_1) g is the weight of oleoresin from 25 g turmeric powder. The contents of oleoresins obtained were calculated in percentage using the following formula :

$$\text{Oleoresin content, \%} = \frac{W_2 - W_1}{W_1} \times 100 \quad (2)$$

where,W_1= wt of the empty beaker, W_2= wt of the empty beaker + oleoresins.

Determination of curcumin content :

Turmeric rhizomes contains variety of pigments. The powder contains a large number of aromatic compounds and curcumin content is the major compound responsible for the characteristic colour. In pure form it is an orange yellow crystalline powder, soluble in alcohol and glacial acetic acid. Curcumin content is used as an index for the quality of the produce.

Preparation of standard curcumin solution :

Standard curcumin (25 mg) obtained from Loba Chemicals; Hyderabad was weighed into 100 ml volumetric flask. It was dissolved and diluted with absolute alcohol and volume was made up to the mark. 1 ml of the solution was transferred to 100 ml volumetric flask and made up to 100 ml with 99 per cent alcohol. This has an absorbance of 0.42 at 425 nm. The absorbance of different turmeric sample solutions obtained from different floors was measured in a spectrophotometer as follows.

Curcumin content was quantitatively extracted by refluxing the turmeric powder in absolute alcohol and its absorbance was determined by spectrophotometer at 425 nm wavelength (AOAC method). 0.5 g of weighed moisture- free sieved turmeric powder was dissolved in 250 ml of absolute alcohol. The contents was refluxed in the flask fitted with an air condenser over a heating mantle for 3 h. Alcohol loss if any due to evaporation was compensated by adding alcohol freshly into the flask. The extract was cooled and decanted into a volumetric flask and made up the volume. A suitable aliquot (1-2 ml) to 10 ml was diluted with absolute alcohol. The intensity of yellow colour was measured with a spectrophotometer.

Curcumin content was determined using the formula:

$$\text{Curcumin content} = \frac{\text{Absorbance at 425nm} \times 125 \times 0.0025}{0.42 \times \text{Weight of the sample (g)} \times \text{path length (cm)}} \quad (3)$$

Since 0.42 absorbance at 425nm = 0.0025 g curcumin and the path length is 1 cm.

Determination of colour :

The colour of turmeric powder was measured, using hunter Lab colour Flex (model No. A60-1010-615, Hunter Associates Laboratory, Virginia, USA), in terms of CIE 'L*' (lightness), 'a*' (redness and greenness) and 'b*' (yellowness and blueness). For this experiment about 50 g of turmeric powder was taken into a 2.5 inch (64 mm) cup and placed on the measurement port. The instrument port was arranged in the port up position. Then the L*, a* and b* values of the sample were measured. The measurement was repeated thrice for different turmeric powder samples on different drying conditions and the average values were reported.

True density :

True density was calculated by using multivolume pycnometer 1305. The multivolume pycnometer 1305 provides a rapid means for precisely determining the true volume of pores, porous materials, and irregularly shaped solid objects. A very wide range of sample volumes, from 0.5 to 150 cm^3 can be accommodated. Absolute density can then be calculated with an assured accuracy of 0.1 to 0.2 per cent. The sample cup of 35 cc was chosen for determination of true density. Turmeric rhizomes were

filled in sample cup and ensured 75 per cent of the cup is full with the sample material. The pycnometer valve was placed in the position for the 35 cc volume range. The sample cup was inserted in the chamber. The sample chamber was closed with lid. Purging was carried out 10 times in each time to remove the dust etc. from the surfaces of turmeric rhizomes by filling and venting the gas inside the chamber containing the sample. After the purging operation, the pressures P_1 before expansion (Valve in PREP position) and P_2 after expansion (Valve in TEST position) were taken. Then the vent valve gradually opened till the pressure approaches zero. The experiment was repeated 5 times for each sample dried on different floors and different drying conditions. From the pressures P_1 and P_2 the true volume of the sample was calculated by using the following formula:

$$V_{sample} = V_{cell} - \frac{V_{exp}}{\left(\frac{P_1}{P_2} - 1\right)} \qquad (4)$$

where

V_{sample} = The sample to be found,

V_{cell} = The empty volume of the sample cell with the empty sample cup in the place,

V_{exp} = The expansion volume added when the PREP/TEST valve is in the TEST position.

P_1 = The charge pressure

P_2 = The pressure after expansion

The true density of turmeric rhizomes was calculated with the weight of the sample and its true volume obtained from pycnometer using the formula.The average values of 5 samples are reported. True density :

$$\rho_t = \frac{Net\ weight}{V_{sample}} \qquad (5)$$

RESULTS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Quality parameters of the turmeric rhizomes :

The quality parameters such as ash content, ash insoluble in diluted HCl, crude fibre, oleoresins, curcumin content and colour of turmeric powder was estimated using the standard techniques as per the AOAC guidelines. True density of whole dried turmeric rhizomes was determined using multivolume pycnometer.

Crude fibre :

Crude fibre content of the turmeric powder obtained from different floors in polyhouse and open sun drying conditions are shown in the Table 1 and Fig. 1. The values of the crude fibre content in per cent were calculated based on the amount of sample turmeric powder used, moisture content of turmeric powder, asbestos content after and before ashing and crude fibre content remained in the crucible by the equation (1). It was observed that, the minimum crude fibre content of 3.54(±0.01) per cent was resulted in the powder obtained on tarpaulin sheet in polyhouse conditions, whereas maximum crude fibre content of 5.80(±0.01) per cent was resulted from sand floor drying in open sun drying. Crude fibre content was observed to be low in the powders obtained from all floors in polyhouse drying compared to their respective floors in open sun drying. But the maximum amount of crude fibre 5.80(±0.01) per cent obtained on sand floor drying in open sun drying is lower than the maximum allowed amount of 6.00 per cent.

Table 1 : Crude fibre content of turmeric powder dried in polyhouse and open sun drying conditions

Crude fibre content, %

Floor	Drying condition	
	Polyhouse	Open sun drying
LDPE sheet	3.98(±0.01)	5.16(±0.01)
Tarpaulin	3.54(±0.01)	4.31(±0.01)
Cement concrete	3.71(±0.01)	5.61(±0.01)
Sand floors	4.13(±0.01)	5.80(±0.01)

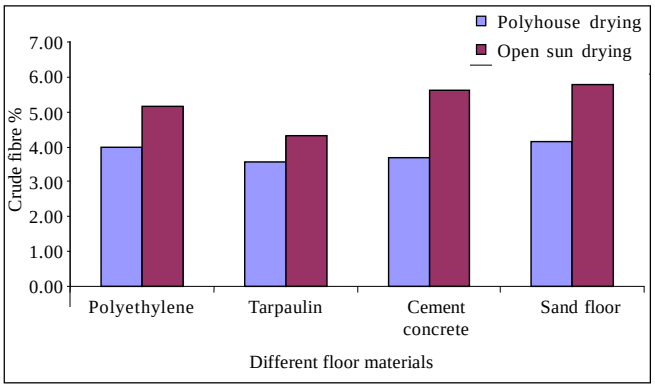

Fig. 1 : Comparison of crude fibre content of turmeric powder dried in polyhouse and open sun drying conditions

Oleoresins :

The values of the oleoresin content in per cent were calculated based on the amount of sample turmeric powder used and oleoresins remained in the beaker by the equation (3.7). It was observed that, the maximum

oleoresin content of 9.09(±0.07) per cent was resulted in the powder obtained on tarpaulin sheet in polyhouse conditions, whereas minimum oleoresin content of 6.19(±0.12) per cent is resulted from sand floor drying in open sun drying. Oleoresin content was observed to be high in the powders obtained from the floors in polyhouse drying compared to oleoresin on floors of open sun drying. The oleoresins contents obtained from the turmeric powder samples obtained from all the floors under polyhouse conditions are higher than the minimum limit of oleoresins of 7.00 per cent .But the oleoresins obtained on cement concrete and sand floors under open sun drying conditions, 6.79(±0.06) and 6.19(±0.12), respectively were lower than the minimum limit of oleoresins of 7.00 per cent (Table 2 and Fig. 2).

Table 2 : Oleoresins content of turmeric powder dried in polyhouse and open sun drying conditions

Floor	Oleoresins content, %	
	Drying condition	
	Polyhouse	Open sun drying
LDPE Sheet	8.59(±0.05)	7.41(±0.09)
Tarpaulin	9.09(±0.07)	7.53(±0.08)
Cement concrete	8.44(±0.02)	6.79(±0.06)
Sand floors	8.05(±0.06)	6.19(±0.12)

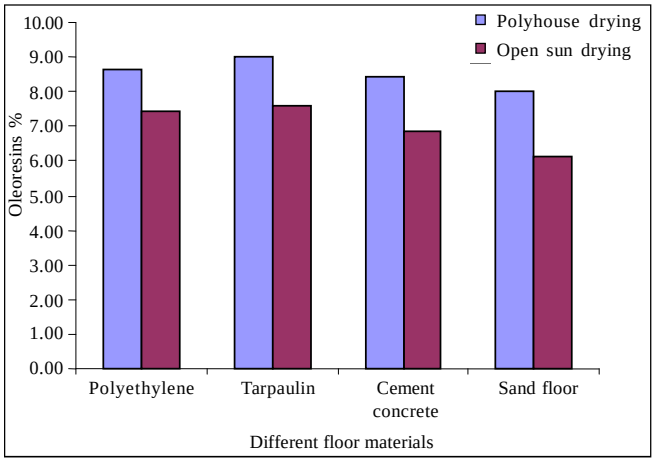

Fig. 2 : Comparison of oleoresins content of turmeric powder dried in polyhouse and open sun drying conditions

Curcumin content :

Curcumin content of the turmeric powder obtained from different floors under polyhouse and open sun drying conditions are shown in the Table 3 and Fig. 3. The values of the curcumin content in per cent were calculated based on the amount of sample turmeric powder used, absorbance at 425 nm and the path length (1 cm) by using the equation (3). It was observed that, the maximum curcumin content of 1.65(±0.00) per cent was resulted in the powder obtained on LDPE sheet in polyhouse conditions, whereas minimum curcumin content of 0.92(±0.02) was resulted from sand floor drying in open sun drying. Curcumin content was observed to be high in the powders obtained from the floors in polyhouse drying compared to curcumin content obtained on floors of open sun drying. The curcumin content obtained from the turmeric samples dried under all the floors under polyhouse and open sun drying are higher than the curcumin content range of 0.37-2.07 per cent.

Table 3 : Curcumin content of turmeric powder dried in polyhouse and open sun drying conditions

Floor	Curcumin content, %	
	Drying condition	
	Polyhouse	Open sun drying
LDPE sheet	1.65(±0.00)	1.10(±0.03)
Tarpaulin	1.52(±0.01)	1.03(±0.08)
Cement concrete	1.35(±0.02)	0.97(±0.05)
Sand floors	1.26(±0.02)	0.92(±0.02)

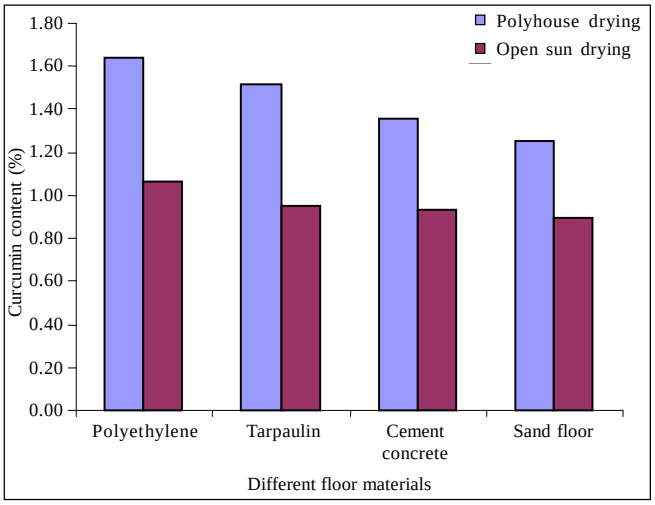

Fig. 3 : Comparison of curcumin content of turmeric powder

L, a and b colour values :

The L, a and b values for turmeric powder on different floors in polyhouse and open sun drying conditions are shown in the Table 3. It was seen from the table that, maximum values of a and b were 16.54(±1.68) and 30.48 (±0.04), respectively were recorded for turmeric dried on LDPE sheet under polyhouse conditions. And the L value of 51.07 (±2.05) was recorded for the same floor under polyhouse conditions. The minimum value 'a' of 12.51(±1.08) for LDPE floor and 'b' of 25.15 (±1.82) on sand floor were

recorded for turmeric dried under open sun drying conditions. The L, a and b values were recorded high for turmeric dried under polyhouse conditions compared to the open sun drying on four different floors. The higher values of L, a and b are desired for turmeric as positive values of L, a and b shows the brightness, redness and yellowness, respectively. These higher values also reflects the quality of color pigment.

True density :

True density of the whole turmeric rhizomes obtained from different floors under polyhouse and open sun drying conditions are shown in the Table 4 and Fig. 4. It was observed that the maximum value of true density is to be 1465.33 kg/m^3 in polyhouse drying condition and the minimum of 1440.76 kg/m^3 in open sun drying. True density values are observed to be higher for turmeric rhizomes dried on floors in polyhouse condition in comparison with floors in open drying condition. The higher true density values under polyhouse drying shows the soundness of dried rhizomes.

Table 4 : True density of turmeric rhizomes dried in polyhouse and open sun drying conditions

Floor	True density, kg/m^3	
	Drying condition	
	Polyhouse	Open sun drying
LDPE sheet	1465.33	1440.76
Tarpaulin	1459.87	1457.26
Cement concrete	1451.35	1443.33
Sand floors	1461.91	1449.22

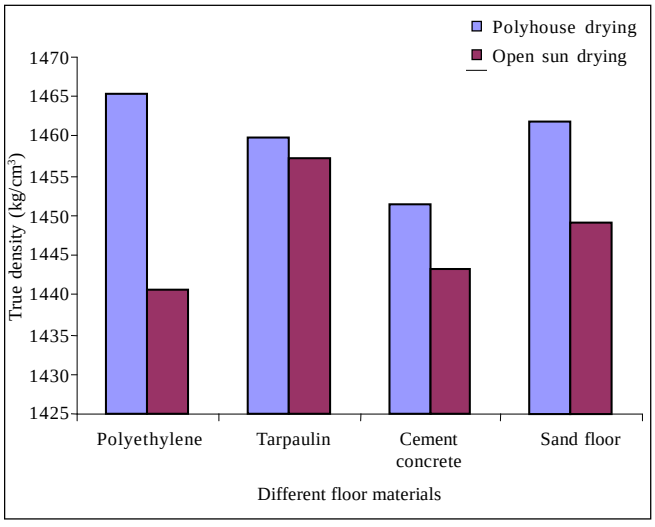

Fig. 4 : Comparison of true density of turmeric rhizomes dried in polyhouse and open sun drying conditions

Conclusion :

Crude fibre content was observed to be low in the powders obtained from the samples dried in polyhouse compared to their same floors in OYSD. But the maximum amount of crude fibre 5.80(±0.01) per cent was observed on sand floor in OYSD which is lower than the maximum allowed amount of 6.00 per cent as per the standards prescribed for turmeric powder.

Oleoresin content and curcumin content of the turmeric powder was observed to be high for samples dried on all floors for samples dried in polyhouse compared to their same samples dried on all floors in OYSD. It was also observed that the floor materials affected the drying time marginally under the experiment conditions from one method to anther method.

It was thus, concluded that polyethylene sheet followed by tarpaulin are better floor materials to reduce the drying time and were good in quality of turmeric powder.

REFERENCES

Abhishek, Niranjan and Prakash, D. (2008). Chemical constituents and biological activities of turmeric (*Curcuma longa* L.) A review. *J. Food Sci. Technol*., **45**(2) : 109-116.

Arora, M., Sehgal, V.K. and Sharma, S.R. (2007). Quality evaluation of mechanically washed and Polished turmeric rhizomes. *J. Agril. Engg*., **44**(2) : 39-43.

Athmaselvi, K.A. and Varadharaju, N. (2003). Heat utilization in different methods of turmeric boiling. *Madras Agric.J.,* **90** (4-6) : 332-335.

Bajaj, K. L. and Kaur, G. (1979). Colorimetric determination of capsaicin in capsicum fruits with the Folin Ciocalteu reagent. *Mikrochimica Acta,* **1** : 81-86.

Cousins, M., Adelberg, J., Chen, F. and Rieck, J. (2007). Antioxidant capacity of fresh and dried rhizomes from four clones of turmeric (*Curcuma longa* L.) grown *in vitro*. *Industrial Crops & Products,* **25**(2) : 129-135.

Desikachar, H.S.R., Srinivasan, M. and Subrahmanyam, V. (1959). Processing of Turmeric. *Res. Ind*., **4** : 172.

Goyal, R.K. and Korla, B.N. (1993). Change in the quality of turmeric rhizomes during Storage. *J. Food Sci. Technol.,* **30**(5): 362-664.

Gunasekar, J.J., Doraisamy, P., Kallemullah, S. and Kamaraj, S. (2006). Evaluation of solar drying for post harvest curing of turmeric (curcuma longa). *Agril. Mechanization in Asia, Africa & Latin America,* **37**(1) : 9-13.

Haribabu, S. and Anand, A. (1996). Feasibility testing and

olony,

evaluation of APAU rapid Chilli drier for drying turmeric. B.Tech. Thesis, College of Agricultural Engineering, Acharya N.G. Ranga Agricultural University, Bapatla, Guntur, A.P. (INDIA).

Jaishree Prasad., Vijay, V.K., Tiwari, G.N. and Sorayan, V.P.S. (2006). Study on performance evaluation of hybrid drier for turmeric (*Curcuma longa* L.) drying at village scale. *J. Food Engg.*, **75**(4) : 497-502.

Joseph Philip and Sethumadhavan, P. (1987). Curing of turmeric. Proceedings of the National seminar on ginger and turmeric, *Calicut*. pp. 198-201.

Li-Xiangzhau, Zhang-Yanqiang, Liu-Yanhua and Sum-Changlu (2006). Study on extraction of curcumin by different methods. *Chemistry & Industry Forest Products,* **26**(4) : 83-86.

Mangalakumari, C.K. and Mathew, A.G. (1986). Localisation of significant constituents of turmeric. *J.Food Sci.Technol*., **23** : 93-96.

Mangaraj, S., Singh, R. and Adewumi, B.A. (2008). Impact of milling techniques on the particle size distribution pattern of turmeric powder. *J. Food Sci. Technol*., **45**(5) : 416-419.

Mariyappan, H. and Vijayaragavan, M. (2007). Processing of turmeric (*Curcuma longa* L.) rhizomes to maintain its medicinal properties. *Plant Arch.,* **7**(2) : 926-928.

Mulet, A., Blasco, M., Garcia-Reverter, J. and Garcia-Perez, J.V. (2005). Drying kinetics of *Curcuma longa* rhizomes. *J. Food Sci.,* **70**(5) : 318-323.

Natarajan, C.P. and Lewis, Y.S. (1980). Technology and ginger and turmeric Proceeding of the National seminar on ginger and turmeric, *Calicut*. pp. 145-146.

Nazim, S.D. and Alpaslan, K. (2006). Essential oil contents and ethnopharmacological characteristics of some spices and herbal drugs traded in Turkey. *Internat. J. Pharmacol.,* **2**(2): 256-261.

Patil, M.R., Borse, M.K., Patil, S.D. and Kamble, Poonam (2009). Economic aspects of production, Processing and marketing of turmeric in western. *Maharashtra Internat. J. Agril. Sci*., **5**(1) : 60-63.

Patil, R.B. and Sapkal, R.T. (1988). Studies on the curing percentage of same varieties of turmeric. *Indian Spices*., **20**(2): 9-10.

Praditdoung, S., Kaewmanee, P., Ganjanagoonchorn, W. and Wanichgarnjanakul, K. (1996). Effect of curing on turmeric tissue and drying time. *Kasetsart J. Natural Sci.,* **30**(4) : 485-492.

Prasad, J. and Vijay, V.K. (2005). Open sun drying of *Tinospora cordifolia*, *Curcuma Longa* L. and *Zingier officinale*. Thermal analysis. *Food Sci. & Technol. Internat.,* **11**(6) : 409-416.

Pujari, P.P. and Patil, R.T. (1987). Studies on growth yield and quality components in different turmeric varities. *Indian Cocoa Arcanut & Spices J.,* **11**(1) : 15-17.

Purseglove, J.W., Brown, E.G., Green, C.L. and Robbins, S.R.J. (1981). *Spices*. Tropical Agricultural Series, **2**. Longman Inc., New York, 644–735pp.