International Journal of Enhanced Research in Science, Technology & Engineering
ISSN: 2319-7463, Vol. 10 Issue 11, November-2021, Impact Factor: 7.957

# Superheated Steam Drying of Turmeric Rhizomes

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**A study on processing of turmeric rhizome using Superheated Steam for simultaneous boiling and drying was carried out. The experimental setup for the study was arranged by using boiler and lab model rotary drying chamber along with additional necessary components. Temperature (130-150°C), time (1.5 – 2.5 h) and feed volume (60-80%) were taken as process variables and the ranges for the variables were selected empirically based on the study conducted by previous researchers on superheated steam drying. The turmeric rhizomes processed under these combinations were analyzed for their quality parameters namely curcumin content, oleoresin content, moisture content, essential oil content and color value, using box Behnken statistical design under response surface methodology. The experimental results showed that the moisture content decreased significantly ($P<0.05$) with an increase in temperature and time. Increase in feed volume percentage significantly reduced the moisture evaporation rate without affecting quality parameters. All parameters showed decreasing trend as temperature and time increases. The feed volume did not influence quality parameters except moisture content. The curcumin content was varied from 3.65-4.65 % and it was significantly influenced by temperature and time. The rhizomes dried at 130ºC for 1.5 h showed highest oleoresin (11.7%) and essential oil content (4.0 %). Turmeric drying at 142.19ºC temperature, 1.7 h time and 66.60 % of feed volume was considered to be the optimized condition for drying of turmeric rhizomes.**

**Keywords: Turmeric, Superheated Steam, Curcumin, Oleoresin, Essential Oil, Color**

## 1. INTRODUCTION

India is the global leader in turmeric which accounts for about 80% of the world production and 60% of the world exports. Fresh turmeric rhizomes are converted into a stable commodity through postharvest operations. Boiling is the necessary step before drying as boiling reduces drying time and retains high curcumin content and better color compared to turmeric obtained without boiling (Bambirra*et al*., 2002). The existing methods of boiling and drying separately consume significantly high energy and have certain disadvantages. Adoption of these methods for processing, produces low quality products and hence fetches lower price in the market. An innovative technique is therefore essential for boiling and drying that increases the drying rate and results in better quality of the product. The quality of turmeric is evaluated based on chemical parameters such as curcumin, oleoresin, moisture content, essential oil and color as these properties vary according to processing conditions. Thus choosing the right drying technique with optimal drying parameters is very important to improve the quality of the end produce.

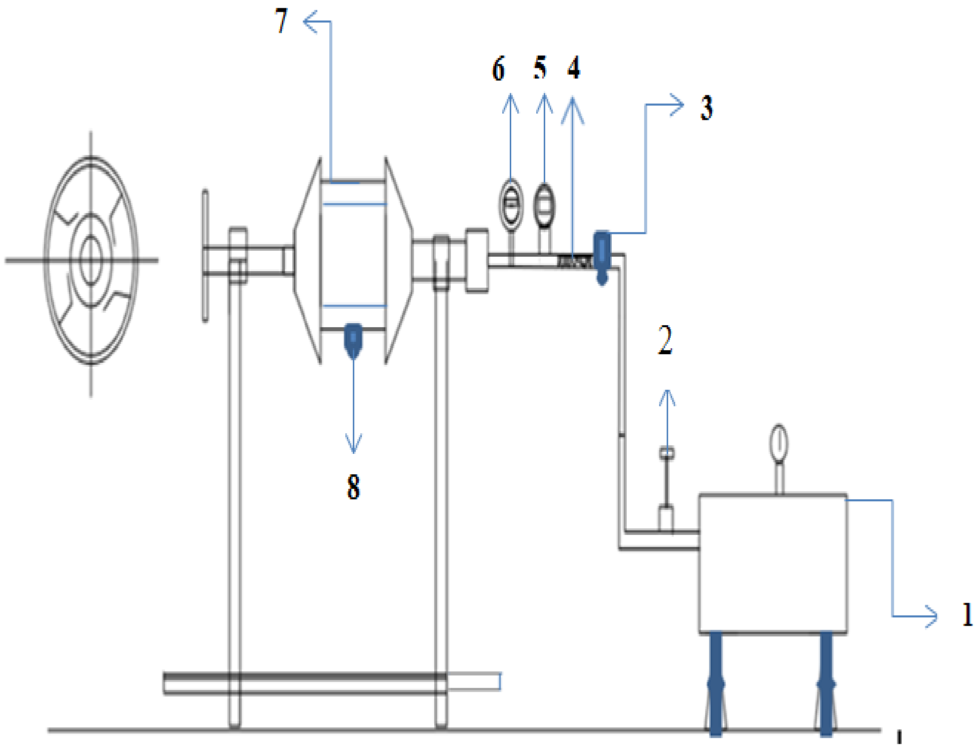
In that aspect 'Superheated Steam'(SHS) can be utilized for both boiling and subsequent drying of turmeric rhizomes as superheated steam allows concurrent blanching and pasteurization of food products during drying (Tang and Cenkowski, 2000). Superheated steam is the steam that has been given additional sensible heat to raise its temperature above the saturation point at a given pressure which behaves as a dry gas and therefore carries no moisture. Application of superheated steam for turmeric causes gelatinization of starch due to initial condensation and actual drying starts when the product temperature is above saturation temperature.

## 2. EXPERIMENTAL SET UP

It consists of a boiler which produces saturated steam, a centrifugal type moisture separator, clamp type electric heaters of 3000 W capacity, drying chamber, pressure gauge, K-type thermocouple and pipe and valve system for supply of steam.The detail information of the boiler and drying chamber are given below.

**(i). Boiler:** A 9 kW electric boiler used in the study (Lakshmi Engineering Works, Model-MB9G) generates saturated steam at a rate of 20 kg/ h. The boiler operates with a 3 phase electric power, 180 V voltage and 50 Acurrent. The boiler takes 10 to 12 min to produce the steam after it is switched on. The maximum allowable working pressure was 7 kg/ cm$^2$ which was sufficiently above the required pressure.

**(ii). Drying chamber:** The lab model rotary drying chamber of capacity 3 kg was employed in the study. This dryer was developed basically for the drying of coleus tubers (*Coleus forskohli*). The length to diameter ratio of the dryer was 2 which help to achieve uniform drying. The center portion of 10 cm of the drying chamber was fixed with 4 flights of length 10 cm, depth 3 cm and width 1.8 cm horizontally at equal distance on the inner surface of the drying chamber. The end portions of the drying chamber were provided with four numbers of baffles (9.5 x 3.0 cm size) in each part fitted at 45° to horizontal plane. A reduction gear box was used in conjunction with a motor and a set of pulleys to rotate the drum of the drying chamber at 15 rpm. The feed volume recommended for drying of coleus tubers was 70% of the dryer volume (Chandrasekar, 2007).




**A schematic diagram of prototype superheated steam dryer used for the study: (1) boiler, (2) gate valve, (3) moisture separator, (4) electric heater, (5) pressure gauge, (6) temperature sensor, (7) drying chamber, 8) steam trap.**

**Experimental Procedure**

At the beginning of the drying process, the air present inside the system is warmed up to the required temperature in order to avoid initial condensation. When the system gets heated to the required temperature, the saturated steam generated by the boiler was allowed to pass into the system through valve. Dry steam was obtained by removing moisture from the saturated steam at the moisture separator. The dry steam then passes through the electric heater it becomes superheated. The superheated steam enters the drying chamber containing turmeric rhizomes.

**Materials**

The details of the experimental material and methodologies adopted for the research are discussed as follows. Turmeric rhizomes of variety ‘CO 2’ were procured from a local farmer, near Kalipalayam, Coimbatore in 2018. The turmeric rhizomes were packed in a plastic bag and stored in temperature and humidity controlled chamber set at 4°C till the experiments were conducted. The turmeric rhizomes were cleaned to remove the foreign materials and washed with clean water to remove dirt adhering to the rhizomes before starting the experiment.

**Methods**

The experiments were conducted for processing of turmeric rhizomes at superheated steam temperature of 130, 140 and 150°C for time periods of 1.5, 2 and 2.5 h and feed volume of 60, 70 and 80% combinations. The range of values for temperature, time and feed volume were taken according to the review of previous research conducted and the trial and error basis. Determination of change in mass of the sample during the operation of the dryer was difficult task and hence measured by taking the sample out of the drying chamber at each 15 min interval using an electronic balance with an accuracy of ± 0.01 g.Each experiment was performed in triplicate. The experimental trials were carried out to find the optimal parameters of drying with maximum retention of quality.

**Design of the experiments**

| Independent variables | Level | | | Dependent variables |
|---|---|---|---|---|
| Temperature (°C) | 130 | 140 | 150 | Curcumin,<br>Moisture content<br>Oleoresin<br>Essential oil<br>Color |
| Time (h) | 1.5 | 2 | 2.5 | |
| Feed volume (%) | 60 | 70 | 80 | |

**3. Quality evaluation of turmeric rhizomes**

**1) Curcumin**

Estimation of curcumin content of turmeric was carried out as per the method given by BIS – 10925: 1984.

The curcumin content was estimated as follows:

$$Curcumin\ content\ (\%) = \frac{0.0025 \times A_{425} \times Volume\ \ madeup\ \ \times Dilution\ \ factor\ \times}{0.42 \times mass\ \ of\ \ the\ sample\ \ \times 1000} \text{ X } 100$$

**2) Moisture content**

Moisture content of turmeric samples was determined as per the AOAC method 1999.

$$Moisture\ content\ (\%) = \frac{W_1 - W_2}{W_1} \times 100$$

where, $W_1$ - weight of sample before drying (g)

$W_2$ - weight of sample after drying (g)

**3) Oleoresin**

Oleoresin content was estimated according to BIS, Specification no BIS 1797-1985.

$$Oleoresin\ content\ (\%) = \frac{weight\ of\ concentrate\ obtained\ after\ evaporation}{weight\ of\ the\ sample} \times 100$$

**4) Essential oil**

Essential oil content was determined according to IS Specification no IS 1797-1985 by steam distillation using Clevenger apparatus. The principle of this method is separation of oil and water into two distinct layers based on density difference.

Percentage of essential oil recovered can be estimated as follows:

$$Essential\ oil\ (\%) = \frac{Volume\ \ in\ ml\ of\ oil\ collected}{Mass\ in\ gram\ \ of\ \ sample} \times 100$$

**5) Colour value**

Colour value of turmeric was measured with spectrophotometer (Hunter Lab'sMiniScan EZ, Reston, Virginia, USA) which was provided with 31.8 mm port size and 25 mm viewed area. The readings were taken after the calibration of colorimeter using black and white tile.

**Statistical method**

A box behnken method of RSM design was used to analyse the interaction of process variables on quality of dried turmeric in 17 experiments, out of which 4 experiments were for centre point and 13 were for non-centre point. The process variables were maintained in different combinations [Table-1]. The response parameters were moisture content, curcumin, oleoresin, essential oil, color values in terms of L, a*, b*. The analysis of variance (ANOVA) tables were generated and the effect of individual linear, quadratic and the interaction term was studied using design expert program (V 6.0.8) of the state ease software (Design expert, 2002). The significance of all the polynomial was judged statistically by computing the F value; the significance of the F value was judged at a probability level (p) of 0.01 and 0.05.

**Response surface method design with coded values for finding optimal parameters of SHS processing such as temperature (A), time (B) and feed volume (C)**

| Sl. no | Process variable | | | Responses | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Temp (°C) | Time (h) | Feed volume (%) | Moisture (%) | curcumin (%) | Oleoresin (%) | Esssential oil (%) | L* | a* | b* |
| 1. | 140 (0) | 2 (0) | 70 (0) | 51.5 | 4.25 | 9.7 | 3.76 | 51.5 | 19.02 | 63.15 |
| 2. | 140 (0) | 1.5 (-1) | 60 (-1) | 51 | 4.5 | 10.7 | 3.9 | 55.46 | 20.23 | 65.81 |
| 3. | 140 (0) | 2 (0) | 70 (0) | 51.5 | 4.25 | 9.7 | 3.76 | 52.25 | 19.02 | 63.15 |
| 4. | 150 (+1) | 2 (0) | 80 (+1) | 46.5 | 3.8 | 7.7 | 3.65 | 50.24 | 17.2 | 56.78 |
| 5. | 150 (+1) | 2 (0) | 60 (-1) | 44 | 3.9 | 8 | 3.75 | 51.9 | 18.25 | 61.24 |
| 6. | 150 (+1) | 1.5 (-1) | 70 (0) | 47.12 | 4.25 | 8.4 | 3.8 | 54.1 | 18.04 | 59.44 |
| 7. | 140 (0) | 2 (0) | 70 (0) | 51.5 | 4.25 | 9.7 | 3.76 | 52.25 | 19.02 | 63.15 |
| 8. | 130 (-1) | 2 (0) | 60 (-1) | 51.4 | 4.6 | 11.5 | 3.98 | 52.24 | 21.12 | 66.04 |
| 9. | 150 (+1) | 2.5 (+1) | 70 (0) | 44.34 | 3.65 | 7.5 | 3.73 | 48.5 | 17.1 | 56.42 |
| 10. | 140 (0) | 2 (0) | 70 (0) | 51.5 | 4.25 | 9.7 | 3.76 | 52.25 | 19.02 | 63.15 |
| 11. | 140 (0) | 2.5 (+1) | 80 (+1) | 52.87 | 4 | 8.6 | 3.66 | 49.35 | 18.6 | 59.94 |
| 12. | 140 (0) | 1.5 (-1) | 80 (+1) | 55.02 | 4.4 | 10.5 | 3.8 | 54.13 | 20.1 | 61.72 |
| 13. | 130 (-1) | 1.5 (-1) | 70 (0) | 56.48 | 4.65 | 11.7 | 4 | 55.14 | 22.01 | 66.04 |
| 14. | 140 (0) | 2.5 (+1) | 60 (-1) | 49.2 | 4.1 | 8.8 | 3.79 | 49.5 | 19.05 | 63.45 |
| 15. | 130 (-1) | 2.5 (+1) | 70 (0) | 50.5 | 4.2 | 10.5 | 3.75 | 50.03 | 18.7 | 63.5 |
| 16. | 140 (0) | 2 (0) | 70 (0) | 51.5 | 4.25 | 9.7 | 3.76 | 52.25 | 19.02 | 63.15 |
| 17. | 130 (-1) | 2 (0) | 80 (+1) | 53.5 | 4.5 | 11.2 | 3.94 | 51.26 | 20.75 | 63.56 |

## 4. RESULTS AND DISCUSSION

### Curcumin content of turmeric rhizomes

Curcumin content of turmeric rhizomes at different combinations of the process parameters is presented in the Figure 1. The curcumin content of turmeric was maximum (4.65 %) at 130°C, 1.5 h of drying and 70% feed volume and minimum (3.64 %) at 150°C, 2.5 h of drying and 70% feed volume. The increase in temperature and time of drying significantly ($p<0.01$) reduced the curcumin content. Increase in feed volume reduced the curcumin content but did not affect significantly. Decomposition of substituent groups of turmeric and two benzene rings at high temperature and time might have reduced the curcumin content of the turmeric rhizomes. This was consistent with the results obtained in the study of thermal degradation behavior of curcumin in which it was reported that curcumin content decreases significantly with increase in temperature and time (Chen *et al.*, 2014).

The best fit second order quadratic equation ($R^2$ value = 0.9722) for curcumin content (Cu) of turmeric rhizomes affected by temperature, time and feed volume is as follows:

$$Cu = + 4.25 - 0.29 *A - 0.23 *B - 0.050*C - 0.056*A^2 -6.250E - 003+B^2+6.250E - 003+C^2- 0.038*A*B$$

where A is the temperature (°C); B is the time (h) and C is the feed volume (%)

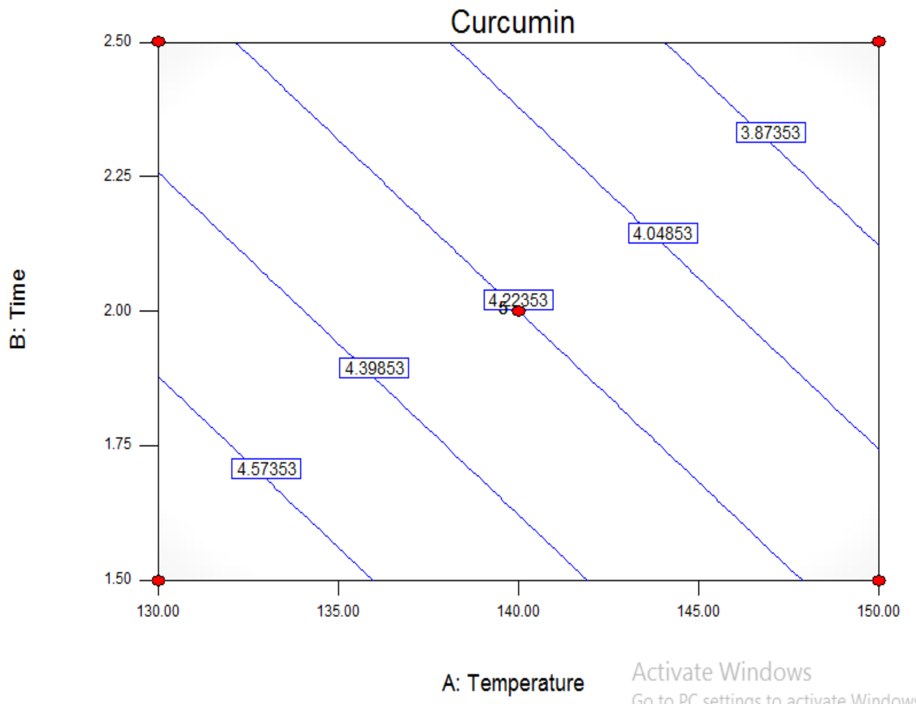



**Fig – 1 : Response surface for the effect of temperature and time on curcumin content at 70% feed volume**

**Moisture content of turmeric rhizomes**

Moisture content of turmeric rhizomes at different temperature, time and feed volume combinations is presented in the Figure 2 (a and b). Figure 2 a, showed increase in feed volume significantly ($p<0.01$) reduced the moisture evaporation rates). The quadratic equation 4.2 confirms the negative influence of A and B and positive influence of C on moisture content. Figure 2 b showed that the moisture content decreased significantly ($p<0.01$) with increase in temperature and time. The higher moisture evaporation rates due to increased temperature and time of drying might have reduced the moisture content. This was consistent with the results obtained in a study of superheated steam drying of cashew kernels in which it was reported that higher temperature of steam led to higher heat transfer rate of the sample and hence significantly reduced the moisture content (Eang and Tippayawong, 2017). Similar results were reported in drying of pork slices using superheated steam where the time of drying increased as slice thickness increased because of higher moisture content in thicker slices (Shinde *et al.*, 2011).

The moisture content (Mc) of turmeric rhizomes was empirically correlated ($R^2$ value = 0.9772) for the trial conditions as:

Mc = $- 340.07 + 6.32 * A - 34.61 * B + 0.21 * C - 0.025 * A^2 + 2.56 * B^2 - 1.18750E\text{-}003 * C^2 + 0.160 * A * B + 1.00000E\text{-}003 * B * C$

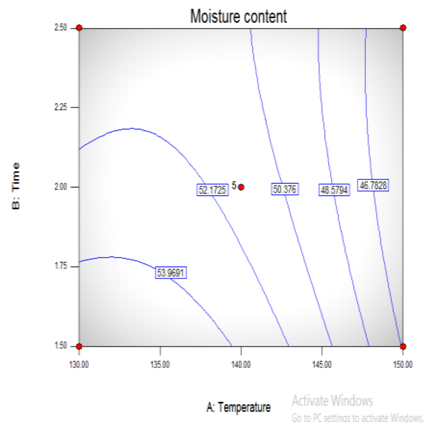
where A is the temperature (°C); B is the time (h) and C is the feed volume (%).

**Essential oil content of turmeric rhizomes**

Essential oil content of turmeric rhizomes at different combinations of the process parameters is presented in the Figure 3. The essential oil content of turmeric was maximum (4%) at 130°C, 1.5 h and 70% feed volume and minimum (3.65) at 150°C temperature, 2 h time, 80% feed volume.Essential oil decreased significantly ($p<0.05$) with increase in time and temperature and non-significantly with increase in feed volume. As temperature and time increases, turmerone which is a component of essential oil occupying 50% of the essential oil composition gets deteriorated.This might have decreased the essential oil content of turmeric rhizomes. The results were consistent with the drying study of turmeric rhizomes using microwave power in which it was reported that as power level increases essential oil content decreases (Hmar *et al*., 2017).

The best fit second order quadratic equation ($R^2 = 0.9205$) for essential oil (Es) of turmeric rhizomes is as follows:

Es = $+ 17.60 - 0.16 * A - 1.43 * B - 6.87500E\text{-}003 * C + 5.12500E\text{-}004 * A^2 + 0.035 * B^2 + 1.87500E\text{-}004 * C^2 + 9.00000E\text{-}003 * A * B - 150000E\text{-}004 * A * C - 1.50000E\text{-}003 * B * C$



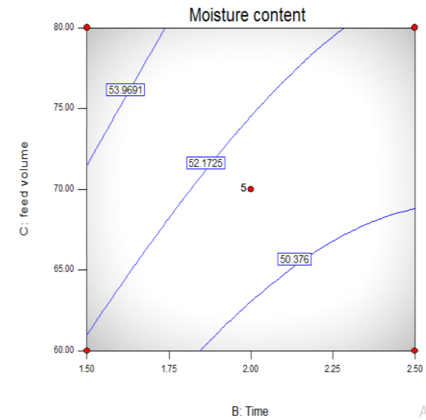
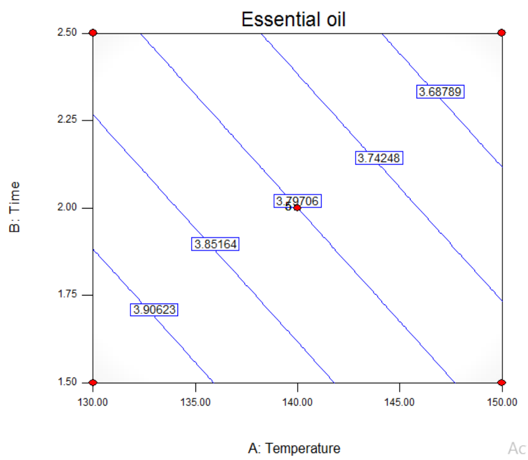




**Fig 2 a: Response surface for the effect of time and feed volume on moisture content at 140°C**

**Fig. 2b: Response surface for the effect of temperature and time on moisture content at 70% feed volume**



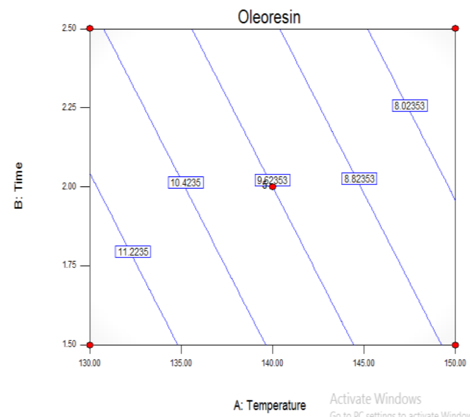




**Fig. 3 Response surface for the effect of temperature and time on essential oil at 70% feed volume**

**Fig. 4 Response surface for the effect of temperature and time on oleoresin content at 70% feed volume**

**Oleoresin content of turmeric rhizomes**

The oleoresin content of turmeric rhizomes at different combinations of temperature, time and feed volume is presented in Figure 4. The oleoresin content was maximum (11.7%) at 130°C, 1.5 h and 70% feed volume and minimum (7.5%) at 150°C temperature, 2.5 h time, 70% feed volume. Oleoresin content decreased significantly ($p<0.05$) with increase in time and temperature whereas decreased non-significantly with increase in feed volume. This may be due to reduction of curcumin as temperature and time increases which in turn have reduced oleoresin content as curcumin and oleoresin are interrelated. The negative coefficients of the second order terms of A, B and C confirmed that the oleoresin decreased with increase in these terms. Oleoresin is a mixture of compounds namely curcumin, volatile oil, non-volatile fatty and resinous material. Reduction in any one of these compounds results in reduction of oleoresin content (Suresh *et al.*, 2007). The best fit second order quadratic equation ($R^2 = 0.9205$) for oleoresin (Ol) of turmeric rhizomes is as follows:

$$Ol = + 18.56 + 0.118 *A - 2.57 *B - 0.030 *C - 1.12500E\text{-}003 * A^2 - 0.25000 * B^2 + 1.2500E\text{-}004 * C^2 + 0.0150 * A*B - 2.58960E\text{-}016 *A*C - 3.66374E\text{-}016 *B*C$$

**Color values of turmeric rhizomes**

These values of the turmeric rhizomes at different treatments varied from L* - 49.35 to 55.46, a*- 17.1 to 22.01 and b*- 56.42 to 66.04 indicating the influence of treatment combinations. The L* and a* values significantly ($p<0.01$) reduced as time and temperature increased. The b* value decreased significantly ($p<0.01$) as temperature, time and feed volume increased). At higher temperature and longer time exposure of rhizomes, feruloilmethane takes part in condensation reaction which turns yellow to yellow brownish color and hence reduces L*a*b* values (Hmar *et al*., 2017). Significant reduction in color values might be due to degradation of curcumin at high temperature and longer time exposure as the color is contributed by curcumin, demothoxy curcumin and bis-demethoxy curcumin.

## CONCLUSION

The influence of temperature, time and feed volume on quality attributes of turmeric rhizomes undergoing superheated steam drying was investigated. The experimental results showed that turmeric rhizomes dried at higher temperature and longer time significantly affected curcumin content, essential oil and oleoresin. The color of the sample was also reduced significantly as temperature and time increases. Feed volume has lesser influence on essential oil, oleoresin and color whereas significantly influenced on moisture content.

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