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Development of mobile boiling system for turmeric (*Curcuma longa*)

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ABSTRACT

Turmeric boiling system based on convectional boiling technique had been developed to retain curcumin content up to highest possible level and reduce the cooking time. The whole system consists of steam generation unit and blanching vessel. The blanching vessel was modified to mobile boiling vessel which consists of a steam inlet, turmeric holding body (100 kg), safety valve, pressure release valve, pressure and temperature gauge, condenser, steam distribution unit having centre-mounted perforated pipe with blinded end to distribute the steam uniformly throughout the vessel and vessel holding stand with wheels. The blanching time, drying rate, drying time and heat utilization factor were quantified. The cooking time under the developed vessel for turmeric was found to be 10 min compared to 15 min under parboiling drum and 25 min under open steaming used by the farmers. The color values for samples obtained by cooking using the developed vessel was found to be with L = 53.74, a = 58.46 and b = 18.16.

1. Introduction

India is the largest producer and exporter of turmeric and it ranks fourth in production among the spices. Importantly known for its Curcumin content, essential oils and oleoresin content for their medicinal, cosmetological, food and pharmaceutical uses it is found to have at least 235 compounds primarily phenolic compounds and terpenoids, including diarylheptanoids (including commonly known as curcuminoids), diarylpentanoids, monoterpenes, sesquiterpenes, diterpenes, triterpenoids, alkaloid, and sterols, etc. (Li et al., 2011).

Currently the boiling method used by the farmers is of open steaming with direct wood fired furnace. Since the system is open the amount of steam given for blanching of turmeric cannot be controlled. Other methods followed by the farmers are the cow dung method, plain water boiling and alkaline method. The main drawbacks of these systems of boiling are that there occurs a high amount of leaching of curcumin (Kamble & Soni, 2009). Moreover it has a high labor requirement. Losses during handling, inefficient use of fuel, unhygienic handling of the rhizomes, time consuming and huge cost of processing are some of the disadvantages of these methods (Patil & Chhapkhane, 2013; Shinde, Kamble, Harkari, & More, 2011). Over cooking spoils the colour of the final product and under cooking renders the dried product brittle. These methods when adopted for boiling, fetches lower price in the market, the main reasons being over/under cooking of the rhizomes which on drying and polishing affect the consumer acceptability (Shinde et al., 2011).

The loss of colour observed in turmeric, which is 1.5 to 2.5% in steam cooking whereas in boiling it is 1.6 to 3.5%. Thus the process of steam treatment is suggested to the turmeric business which is beneficial to farmers and turmeric process industries (Shinde et al., 2011). By using concept of pressured cooking, time for cooking turmeric rhizomes is reduced from 30 min to 17 min and quality of turmeric is also maintained (in terms of percentage of curcumin retained). (Patil & Chhapkhane, 2013; Yadao & Jachak, 2015).

Pressure boiling has become the most advanced methods in terms of saving of time in boiling, drying (Due to higher degree of starch gelatinization), efficient energy use and quality retention. It prevents the leaching of Curcumin in the medium which occurs in the case of traditional methods of boiling (Yadao & Jachak, 2015). Considering the above possible advantages, the present study was aimed at developing an improved vessel for field scale.

The methodology for developing and designing the new optimized turmeric curing system can be to: understand curing process of turmeric, identify various parameters affecting curing process, identify dominant parameters, optimize the process, design the complete process and study the effect of drying (Yadao & Jachak, 2015).

2. Materials and methods

2.1. Raw material

A new hybrid variety of turmeric (PTS 10) having high curcumin

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Table 1
Design layout of the experiment.

Independent variables	Polished turmeric samples a) Pressure (0.5 kg/cm^2,0.75 kg/cm^2,1 kg/cm^2,1.25 kg/cm^2 and 1.5 kg/cm^2) b) Time (5–15 min) c) Temperature (90–95 °C)	Method reference
Dependent variables	a) Curcumin content b) Moisture content c) Oleoresin content d) Essential oil e) Colour (L, a, b) f) Hardness g) Heat Utilization Factor	BIS – 10925:1984 IS: 1797-1985 AGMARK standard AGMARK standard Colour Flex Hunter lab Colorimeter Hardness meter Athmaselvi & Varadharaj, 2002

content (7–10%), oleoresin (4–5%), essential oil (9–13.5%) and high yield (7.41–9.88 t/ha) was considered for boiling studies. This was procured from Erode district of Tamil Nadu state. The uniformity of size could easily be ascertained from visual inspection.

The turmeric rhizomes were procured with initial moisture content of 75% (w. b.) and boiled after washing to remove dirt and impurities with a final moisture content of 84% (w. b.). The characteristic dimensions of the rhizomes were found to be length (90.73 ± 12.12 mm), breadth (22.03 ± 2.25 mm) and thickness (20.64 ± 2.2 mm).

2.2. Laboratory scale studies

The laboratory scale experimental trials were carried out for optimization of process parameters to develop boiler system. Design layout (Table 1) indicates the various levels at which the trials were carried out.

2.2.1. Estimation of curcumin content

Curcumin content was determined as per the procedure followed by BIS – 10925:1984. The standard curcumin solution was first prepared by taking 25 mg of standard curcumin into a 100 ml volumetric flask and diluted to mark with alcohol. 1 ml of the solution was transferred to 100 ml volumetric flask and diluted to mark with alcohol; this standard solution contains 2.5 mg (0.0025 g/l) curcumin. 50 mg of the prepared sample were taken with 50 ml of alcohol in a round bottom flask. The mixture was refluxed for 2 $\frac{1}{2}$ h in an air condenser.

The extract was cooled and filtered into a 50 ml volumetric flask. 1 ml of the extract was diluted to 9 ml of alcohol. The absorbance of the extract and the standard solution was measured at 425 nm against alcoholic blank in a spectrophotometer (Make: Systronics, Ahmedabad). Curcumin content was estimated by the following formula.

$$\text{Curcumin content (\%)} = \frac{0.0025\text{ X } A_{425}\text{ X volume made up X dilution factor}}{0.42\text{ X weight of the sample X 1000}}\text{X100} \quad (1)$$

A_{425} = absorbance at 425 nm. (BIS – 10925:1984)

2.2.2. Determination of hardness

Hardness of the cured rhizomes was determined by using hardness meter. The cured samples of turmeric fingers were kept on a platform provided on a hardness meter to measures its hardness. The cured fingers were put on the sample plate at the bottom of the instrument and its scale was set initially at zero reading. At this stage, the pressure plate was just allowed to touch the sample. The screw knob was then turned lower the pressure rod pressing the samples. The pressure was increased continuously till the sample got pierced. The corresponding reading on scale was recorded in kg force. Each observation was repeated three times.

2.2.3. Experimental design and statistical analysis

In the present study, the experimental parameters were selected based on preliminary laboratory trials. The process variables considered were: Steam pressure, P (0.5–1.5 kg/cm^2); cooking time, t (5–15 min) and temperature, T (90–95 °C). The experimental design was applied after selection of the ranges. A three variable (3 levels of each variable) Box Behnken RSM design was used to show interactions of P, t and T on the final quality of turmeric in 17 runs out of which 5 were for centre point, and 12 were for non-centre point. The steam pressure, time of blanching and temperature of cooking were maintained in different combinations (Table 1).

The response functions, y (dependent variables) were Mc, Cu, Ol, Eo, L, *a, *b, Hd and HUF.

$$y = b_0 + b_1P + b_2t + b_3T + b_4P^2 + b_5t^2 + b_6T^2 + b_7Pt + b_8tT + b_9TP + \varepsilon \quad (2)$$

The analysis of variance (ANNOVA) 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 terms in 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.

2.2.4. Optimization

Numerical and graphical optimization was carried out for the process parameters during blanching of turmeric in obtaining the best product. To perform this operation, Design Expert program (V 6.0.8, 2002) of the State-Ease software was used. Conventional graphical method was applied to obtain Moisture content (Mc) in range, maximum Curcumin content (Cu), Oleoresin content (Ol) in range, maximum Essential oil content (Es), maximum L *a *b, Hardness (Hd) in range and maximum Heat Utilization Factor (HUF). Predictive models (Table 2) were used to graphically represent systems through Figs. 5 to 13. Contour plots of the response variables were utilized applying superposition surface methodology, to obtain one contour plot (Fig. 12.) for observation and selection of superior combination of Mc, Cu, Ol, Es, L *a *b, Hd and HUF for production of optimized turmeric throughout the pressure blanching process.

2.2.5. Comparison between different systems of boiling with the developed system of the turmeric

The curing of the turmeric was compared under different systems in order to estimate the efficiency of the developed system in terms of the cooking time and drying time of the turmeric. The systems which were tested were:

1. Open steaming trolley of 100 kg capacity used by farmers in Erode district.
2. Parboiling drum developed at Tamil Nadu Agricultural University, Department of Agricultural and Food Process Engineering, AEC & RI.
3. Developed pressure vessel which was newly fabricated.

The field experimental setup of developed vessel is shown in Fig. 1. It comprises of a boiling vessel, a steam inlet pipe, steam distribution unit with perforations, safety valve, pressure release valve, pressure and temperature gauges, condenser, vessel holding stand with wheels and hose pipes.

2.2.6. Developed pressure boiling system

The developed pressure boiling system consists of mild steel vessel of 100 kg capacity with height of 812 mm and diameter of 712 mm. The