Post-Harvesting Practices of Steam Generator for Turmeric Boiling in India: Present Status and future strategies

Pradeep Kumar Kandasamy [1], M. Easwaramoorthi [2] , P.Sandhiyadevi [3]

[1,3] Department of Agricultural Engineering, Nandha Engineering College, Erode - Perundurai Main Road, Vaikkaalmedu, Erode - 638 052, India, Email ; pradeepbvn@gmail.com; sandhiyagg@gmail.com

[2]Department of Mechanical Engineering, Nandha Engineering College, Erode - Perundurai Main Road, Vaikkaalmedu, Erode - 638 052, India, Email ; eswaramoorthi65@gmail.com

Corresponding Author: Pradeep Kumar Kandasamy

Abstract: The turmeric is an ancient and important spice crop grown in India which has high medicinal value and economic importance in the Indian economy. The post- harvesting processes in turmeric value chain play a vital role in ensuring quality of end product, improving profitability and market acceptance. Investigations of literature revealed that the quality of the turmeric rhizome was predominantly influenced by the type of curing method followed by the drying process. The post-harvesting process of turmeric rhizomes involves cleaning, boiling (curing), drying and polishing to improve the quality of rhizome and to fetch better price for farmers. There are four boiling approaches such as water boiling, cow dung slurry boiling, pressure boiling, and steaming boiling with an open or closed combustion chamber customarily used by farmers. In order to know the type of post-harvesting practices followed by the farmers, an objective is set in this research to identify the method of post harvesting technology and challenges faced by the farmers with rhizome quality perspective. A survey has been conducted by developing a suitable questionnaire tool followed by validation. The data recorded through the survey among farmers have been analysed. The results showed that 1.5 % of the farmers were using improved techniques against 98.5 % of the farmers stay with conventional techniques. Further, the inclination towards practicing/implementing improved techniques by farmers in the agriculture sector is still in sluggish stage. Farmers are reluctant to adopt new methods or approaches for a variety of reasons, and appropriate solutions are given to solve these issues. This will help farmers better comprehend the advantages of producing high-quality agricultural goods and lay the foundation for future research.

Keywords Curcumin: Rhizome; Combustion Chamber; Drying; Agriculture;

1 Introduction

Turmeric (Curcuma Longa L) is one among the agricultural cash crops commonly used as ingredient in preparing dishes, other forms of food and herbal medicines[1]. India is one of the world's top producers of turmeric[2, 3]. The stages in turmeric farming involve land preparation, sowing, vegetative growth, rhizome initiation, rhizome maturity, harvesting and post-harvesting processes. The post-harvesting processes of turmeric rhizomes undergo various stages such as boiling, drying, polishing, grinding, and powder-making before their sale in the market [4, 5]. In the conventional method, turmeric rhizomes are boiled in an open pan by burning of agricultural residues followed by drying in the sun light[6]. The quality of the rhizomes is mainly influenced by the type of boiling and drying processes. The traditional post-harvesting practices have led to a loss of about 35% of agricultural products in India due to improper handling, poor preservation strategies and inappropriate storage system [7-10]

Various boiling (curing) methods are used for deactivation of enzyme and improve the bioactive constituents such as curcumin, oleoresin and volatile oil which vary with processing methods[8, 9]. It further helps to resist the thermal degradation of color constituents, removes the natural odor and

subsequently facilitates the drying process. Raw turmeric rhizomes must be submerged in water that is between 85 and 99 degrees Celsius or exposed to steam for a predetermined amount of time in order to boil. To boil turmeric rhizomes, traditional fuels include wood, turmeric leaves, and dung. Due to the lack of monitoring and control over the boiling process, the conventional approach consumes more energy[7, 11]. According to some studies, curcumin degradation is reported to occur at high temperature during boiling (curing), while others demonstrate that boiling (curing) process protects the bioactive ingredients from the effects of drying [6, 12]. In the burning of the waste for boiling turmeric rhizomes, it is realized that excessive pollution is a significant issue. [4, 7, 13]. The development of processing methods that can increase the stability of curcumin content is a crucial component.[14]

Turmeric must be dried after harvesting in order to stop bacterial and fungal development. It involves intricate heat- and mass-transfer phenomena. In India, open sun drying is traditionally used for drying process due its cost-effectiveness. However, the lengthy drying process (18–21 days), variations in sunshine, over dried, inclusion of foreign particles and nature of drying space would affect the quality of boiled turmeric rhizomes [7, 15]. Researchers have created many sun dryers to dry low moisture content items including corn, maize, oilseeds, paddy (raw), rice, wheat, etc., and have found numerous problems of the open Sun-drying technique.,[16-18]. A successful drying process is required for agricultural goods with a high moisture content, such as tomatoes, turmeric, apples, bananas, brinjal, chilies, garlic, grapes, guavas, onions, pineapple, and others [7, 18] investigated the effects of boiling and drying turmeric to preserve different bioactive components[19]. While curing for 5 minutes and 30 minutes had no impact, curing for 15 minutes resulted in a larger output of curcumin.

In particular, the use of machineries in post-harvesting activities for process improvement is also found to be inadequate due to limited access to modern machinery/technology by small and marginal farmers in India. Farmers expect effective solutions to shift from manual to machine for each and every operation of farming. Even though the modern farm machinery and technologies are made available to the farmers to increase agriculture productivity, many farmers still rely on conventional farming techniques. Further, the mechanisation for process improvement in post harvesting period has received little attention in the scientific literature [20, 21].

Hence, there is a need for scientifically investigating the requirements of process improvements in post-harvesting activities to enable the farmers for their adoption, produce quality products that will fetch good returns and reducing drudgery in farm operations. With this back ground, an objective is set to identify extent of implementation of modern technologies/machineries/tools in post-harvesting process of turmeric in A survey with a questionnaire was conducted, and the results are analysed. The survey findings such as prevailing post-harvesting practices, reasons for less priority towards modern technologies/machineries/tools, type of process/machinery/tools employed, and perceived level of turmeric quality and common difficulties encountered by the Indian farmers are discussed in this paper.

2 Research Objective and Methodology

The primary aim of this study is to identify extent of implementation of modern technologies /machineries /tools in post-harvesting process of turmeric boiling (curing) in India. The survey methodology depicted in Fig. 1.0 has been employed to summarize the research's overall goal.

The survey question design proceeds in an organised way, with each element in the flow chart depending on the effective completion of all the earlier elements. It is important to follow each step exactly as directed. The flowchart has two feedback loops that enable changes to the technique and instrument. The aims of the survey instrument are divided into the two following primary categories. These various topics were then translated into distinct research questions and elaborated in consultation with academics, turmeric farmer experts, and the most frequently cited literature. A 5-point Likert scale was used to indicate respondents' opinions, with a minimum rating of 1 and a maximum rating of 5, evenly spaced at 1[22, 23]. A complete set of questionnaires is included in the appendix.

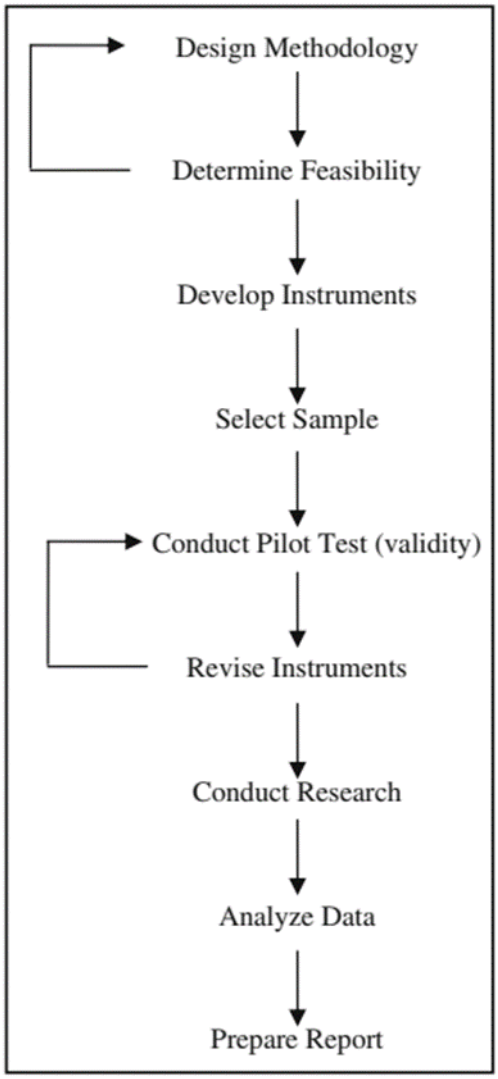

Figure. 1

Survey Methodology[16]

2.1 Sampling plan

The farmers are cultivating many crops. This survey mainly considers turmeric farmers in India as population for study. The population of turmeric in India under the organized category is about 500000 Numbers. The small and marginal farmers who have below 5 acres (hectres)land are considered as sample of this study. The farmers are the responds of this study.

The survey was designed to incorporate insights from the research literature. That is, in a face-to-face pre-test with a group of farmers were asked to fill out a questionnaire showing ambiguity and other difficulties in answering questions and to add suggestions. It is considered appropriate. Based on feedback from these farmers, some questions have been removed, others have been modified, and additional questions have been created. The response rates depend upon the questionnaire's length. It including the number of pages, number of questions and size of the pages.

The survey was designed to collect data based on the five objectives. The questionnaire consisted of two parts. The first part consisted of demographic elements. The main focus of the second part of the questionnaire was on processes related to turmeric post-harvesting methods.

We have identified problem through two important sources. First, we have consult with academic experts and turmeric farmers, industries who are familiar in the turmeric boiling process more than 20 years. And second through literature review of reputable journals listed in SCI, statistics of government of India website and reputable agencies report.

2.2 Construct validity

Farmers and academic experts who are familiar with the post-harvesting process for turmeric determined the face and content validity of the questionnaire. Before the surveys were delivered, certain adjustments were made based on their input[24]. Cronbach's alpha coefficient has been calculated using SPSS 26.0 (Statistical Package for Social Sciences) software in order to predict reliability[25].

2.3 Hypothesis formulation

This study's investigation included farmers, and the farmers' comments served as information sources. The following hypotheses have been developed to test the significance of the responses.

Null hypothesis H0: The responses given by the turmeric farmers to the survey items are not significant.
Alternative hypothesis H1: The responses given by the turmeric farmers to the survey items are significant[26].

3 Result and Discussion

The reliability of the data is very important because it can be influenced by the data collected. Following the validity of the face and content, the reliability of the questionnaire was checked by using Cronbach's alpha coefficient. Cronbach's alpha coefficient reflects the good internal consistency of the collected data. The range is 0.783 to 0.886, with values greater than 0.7 [27]. Hence, it can be concluded that the data collected from the field survey is reliable and can be used for further analysis.

Table 1

Cronbach’s alpha values for the related questions

Question	Cronbach's Alpha
The heat spreads evenly, Turmeric rhizomes boil evenly	.886
Turmeric rhizome is boiled quickly, The turmeric takes longer to boil	.783

3.1 Farmers demographic

The data was collected through two different methods. The first method was the face-to-face interview and the lateral method was a mail survey. In the first approach, the questions were asked to the farmers in person and in the second method the questions were sent by mail using a Microsoft document in a google form and followed with phone calls[28]. Overall, we received 397 complete and usable responses. The returned respondents 48.3% (approx.) of the total targeted responds. For further analysis the input from

the turmeric farmers and post processing equipment supplier were considered. As a result, the mean and standard deviation of the Likert scale are calculated in order to evaluate the level of technology deployment throughout the entire sample[29]. A higher level of implementation is reflected in higher scores, and vice versa[30]. The following sections present the findings from an analysis of respondents' perceptions of advanced technology practices.

3.2 Hypothesis testing

The data were examined using the Statistical Package for Social Science 26.0 (SPSS). A nonparametric Friedman's test with a 0.05 threshold of significant was conducted in order to determine the statistical difference between participants' responses[31] .the results are presented in table 2.

Table 2

Results of non-parametric Friedman's test

Sub-titles of questionnaire	Critical value ($\chi 2\alpha$)	Calculated test statistics	Result
Reason for giving low priority to implement the latest technology for turmeric boiling	9.488	58.076	H0 is rejected
Status of Latest technology employed in Agri field	9.488	41.224	H0 is rejected
Significant hurdles in the latest technology of turmeric boiling implementation	9.488	66.388	H0 is rejected

$\chi 2$ Chi-square distribution and α level of significance=.05

The sub-titles of the questionnaire and the critical value and Calculated test statistics values are displayed in Table 2. The critical value is taken from the statistical table. The critical value is compared with the test statistics calculated using SPSS. In all three cases, the calculated test statistics value exceeds the critical value. Therefore, the null hypothesis H0 is rejected and the alternative hypothesis H_1 is accepted.[32] This result revealed that there is a significant degree of difference among the farmers response.

3.3 Reason for giving low priority to implement new technologies in turmeric post-harvesting process

Based on the farmers response, the status of advanced technology implementation in the turmeric post harvesting is grouped into five categories. the category wise farmers response is portrayed in fig 1. it can see that out of 397 responses received from the turmeric farmers only 1.51% of the farmers have started implementing the advance technology in selected area. And about 23.37 % are at planning stage and 13.07 % farmers would implement the advanced technology after training with in at the most. The remaining 247 farmers (62.06 %) have not yet taken up the advanced technology implementation initiatives, for a number of reasons[33]. The Reason for giving low priority to implement new technologies in turmeric post-harvesting process are depicted in table 3.

Table 3 indicates the mean, standard deviation, and percentage of farmers who selected a particular reason with a response level higher than the mean value. Based on the average mean value, this result suggests that survey respondents who are turmeric farmers view the need to change farmers' mindset as the most critical factor and low perceived benefits as the least significant[34]. The following is a list of the causes behind the aforementioned observations.

Human behaviour (mean =3.94) is one of the main causes of reasons advanced technology is given such a low priority. The difficulty of changing mind set of the farmers was strongly supported by the literature[35-37]. The resistance to change may be because of fear of financial losses, perception of additional machinery purchasing, establishment costs, the way that the changes fit with the broader farming system, belief systems, other pressures from people associated with the farm business, habit, family and community expectations, etc.it may be possible to change the mind set of turmeric farmers if we could make them more aware of advanced technology implement benefits, consequence of time waste and quality reduction, and survival of the farmers in the emerging economy[38, 39]. In the same way more time required to implement technology, Latest technology awareness program in India is less, The latest technology equipment is designed based on high-scale farmers and not small-scale farmers, Frequent design changes in latest technology, Inadequate training opportunity, Lack of latest techniques awareness, are few more significant factors leading to low priority in advanced technology implementation[40, 41].it has been observed from the literature that the biggest challenge in adapting the latest technology is to know which of the latest technology to use and how to apply them effectively. In addition to the above reason, high initial investment equipment cost to be the obstacles to successful implementation of latest technology. These are related to cost factor. Therefore, ample support of government has to step in and help scientists deliver the technology while training these farmers to adapt to it. but the benefits could be achieved only by transforming the farmers as latest technology thinkers, suitable invention and are the appropriate solution[42, 43]. Further the reason like lack of stiff competition and lower perceived benefits are the choice of farmer for poor latest technology implementation. Also, latest technology will be failed then the associated people will not show interest for other technologies also.

Table 3

Reason for giving low priority to implement new technologies

Reason for giving low priority to implement new technologies in turmeric post-harvesting process	Mean Statistic	Std. Deviation Statistic	% Of farmers response>mean
Effect required to change the mind set	3.94	1.173	69.5
Implementing latest technology need more investment	3.88	1.245	63.9
Too much time and more effort are required to implement new technologies	3.37	1.050	61.2
Latest technology awareness program in our country is less	3.36	1.984	64.3
The latest technology are too high scale farmers and not small-scale farmers.	3.24	1.131	67
Frequent design changes in latest technology	3.19	1.37	57.4
Inadequate training opportunity	3.16	1.117	51
Lack of latest techniques awareness	2.57	1.648	49.4
Low perceived benefits	2.3	1.171	53.6

3.4 Analysis of Technology Employed

There are different types of advanced technology equipment available after harvesting turmeric. These technologies are employed post-processing such as curing (boiling), drying, grinding or polishing and powder making. The respondents are provided with a list of 13 technology and asked to indicate the frequency of application of these technology on a scale 1 to 5, where 1 indicates never used; 2 rarely used; 3, partially used; 4, frequently used and 5 continuously used[44]. The responses are presented in table 4.

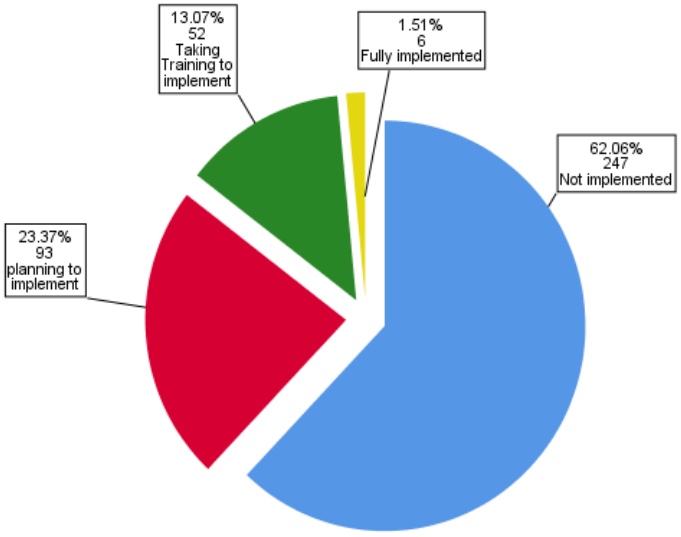

Figure 1

Implementation of technology in the post-harvesting process of turmeric

The result of the survey highlights the status of advanced technology practiced with mean value varying from and cover up to 1 tools (out of 13) and delivered important message that most of the advanced technology are rarely used in turmeric post- processing. The result further indicates that fundamental scientific technology like turmeric washing, boiling method, and drying methodology is partially used. Table 4 shows the comparison between conventional and advanced technology they partially used advanced technology in the following process turmeric washing, turmeric boiling method, drying and polishing process. Latest technology combustion chamber used to boil the turmeric mean value lower than the conventional combustion chambers. Understanding the reason behind low-level technology practices is important to make advanced technology in turmeric farmers.[42, 43, 45, 46] The main reasons are lack of awareness uneven adaptation of advanced technology and technology not convenient to the farmer's needs.

Table 4

Status of technology employed in post processing of turmeric

Type of technology employed in post processing of turmeric	Mean Statistic	Std. Deviation Statistic	% Of farmers response>mean
Turmeric washing			
Manual washing	2.78	1.321	62
A power-operated turmeric washer	3.05	1.275	42
Boiling			

Water boiling	2.59	1.142	46
Soaking in water and boiling	2.69	1.350	57
Steam boiling	3.87	1.221	69
Combustion chamber used to boil			
Open combustion chamber (Three stone stove)	2.56	1.677	41
Semi open combustion chamber	3.85	1.409	57
Gas stove	1.52	1.138	32
Closed combustion chamber	1.4	1.052	28
Drying			
Direct sun drying	3.41	1.323	68
Solar drying	1.55	1.201	24
Polishing			
Manual polishing	3.89	1.432	63
Mechanical polishing	2.06	1.47	39

3.4.1 Traditional practices followed to boil turmeric

The traditional method is to cook turmeric in a galvanized iron plate container. In Certain regions of India, such as Tamil Nadu in southern India and Rajasthan in the north In India, cow dung slurries are used in open containers for boiling. Figure 2 shows the turmeric boiling technology used by the farmers. This leads to Low price of final product[47]. It also loses energy, loses time, and Higher labor costs. Cooking turmeric in salt water has lower curcumin levels than cooking in plain water. Turmeric boiled in steam showed the highest heat utilization and give highest curcumin content, essential oil and oleoresin[43, 48].

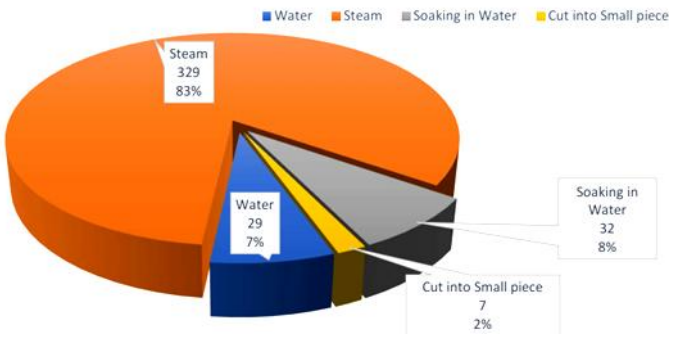

Figure 2.

Status of boiling technology employed by farmers

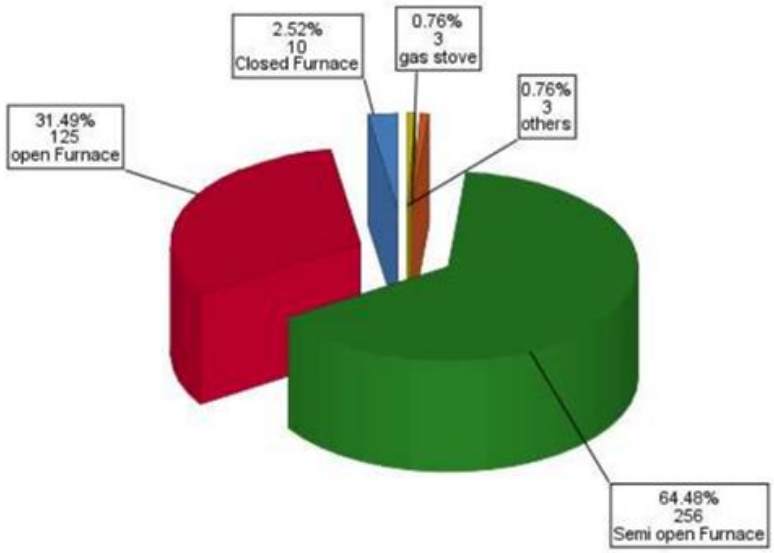

Figure 3

Fig 1. Steam generator used by farmers

However, steam cooking was superior than typical water-boiling cooking in a number of ways, including fuel usage, the number of rhizomes that could be cured in a batch, and labour savings. In turmeric boiling process agricultural biomass and wood used as fuel[49-51]. It could be observed from the Figure 3 31.49% of farmers used open furnace system. It consumed more agricultural biomass. 64.28 % of farmers used semi open furnace. Based on the farmers response 2.52 % farmers used closed furnace system. It reveals most of the farmers did not interest to use other than agricultural biomass. Even though the thermal efficiency of the open and semi-open type combustion chamber is not up to the standard levels the farmers did not prefer other technology[52].

3.5 Barriers in advanced technology implementation

The analysis of result summarized in table 5 indicates the difficulties experienced by the turmeric farmers to implement latest technology. Table 5 indicates that the frequent design changes, latest technology does not address small and medium scale turmeric farmers are the serious hurdles faced by the farmers (mean value=3.4). in the same way, the following reasons are indicated as other obstacles in latest technology implementation.

- Long lead time required to hire advanced technology
- High cost of using new technologies
- Lower volume of demand
- Difficulty of integrating advanced technologies into the existing Technology
- lack of adequate educational background and experience
- Perception of difficulties in handling advanced technology machineries
- Environmental barriers against using new technologies

The aforementioned factors may severely influence one's preference for latest technology [53]. According to the survey conducted as part of the current research study, time consumption has a significant impact on the majority of agricultural operations.

Table 5 Barriers in latest technology implementation

Barriers in latest technology implementation	Mean Statistic	Std. Deviation Statistic	% Of farmers response>mean
Frequent design changes	3.4	1.5	71
It does not address small and medium scale turmeric farmers	3.2	1.6	68
Lower volume of demand	2.8	1.4	53
Initial Manufacturing cost is high	2.4	1.6	62
Long lead time required to hire advanced technology	2.3	.984	64.3
Difficulty of integrating advanced technologies into the existing Technology	2.14	1.131	67
lack of adequate educational background and experience	2.09	1.37	57.4
Perception of difficulties in handling advanced technology machineries	1.98	1.117	51
Environmental barriers against using new technologies	1.57	1.648	49.4

Conclusion

Firstly, the effort has attempted to frame a simple questionnaire identify the existing level of latest technology, reasons for giving low priority to shift the latest technology for turmeric post processing process, Significant hurdles in the latest technology of turmeric boiling implementation

This paper presented an important awareness into the current status of advanced technology implementation in Indian turmeric farmers. Firstly, the work has attempted to formulate a simple questionnaire-based tool to identify the existing level of advanced technology, reasons for inadequate priority to advanced technology, type of lean technology employed, and the common difficulties encountered by the Indian turmeric farmers in post processing technology.

The tool was validated using face content and reliability tests, and its role in post-processing procedures was then explored and discussed. According to the survey's findings, 1.5% of farmers have used various forms of cutting-edge technology in some locations. The advanced technology has not yet been adopted by the remaining 98.5% of farmers. The application of advanced technology is also moving slowly, but there is still possibility to develop focused advanced technology that could be employed in other advanced technology for small-scale and low-volume farmers. It is concluded that the main causes of low levels of advanced technology are workers' worry about changing their mindset, a lack of information and training about the technology, and the expense and implementation time necessary. Systematic employee and group motivation is intended to produce motivating procedures that result in optimal and deliberate activity. Therefore, from a holistic perspective, the turmeric cultivators must give importance to the implementation of advanced technology throughout all of the essential sectors. Farmers prefer to believe by observation rather than taking chances. By outcome demonstration is the best technique. It will be much easier to urge farmers if we can find just one to adopt the technology and persuade the rest to do the same. Appropriate awareness and research set up in association with farmers have to be fostered and encouraged to stimulate the awareness. The role of deploying advanced technology in achieving this goal is immeasurable. This helps farmers improve the productivity of their existing systems.

Limitations and future research

The knowledge of respondents of current technological techniques in the post-harvesting process may have a limit on their ability to reply to the questionnaire. Only someone with in-depth expertise could respond to the questionnaire correctly; otherwise, the results would be unreliable input data and a low response rate. Despite these drawbacks, this research will serve as a springboard for additional cutting-edge technology research in turmeric post processing. Further research in this area is needed to develop a suitable training demonstrator to teach latest technology concepts, train the farmers, and transform them as latest technology thinker. Further, a detailed description of how the technology concepts could be systematically combined, to facilitate the farmers to meet the volatile environment, needs to be addressed. This new proposal has to be effectively implemented, not only to post processing equipment of turmeric farmers, but also to reach the minds of young engineers.

References

[1] 1Dr. Pankaj Yadav, 2Dr. Hemant Gupta, 3Dr. Neelam Grover *To study the burden of asthma and its comorbid factors among respiratory tract infection in paediatric population*. Eur. Chem. Bull. 2023, 12(Special Issue 13), 310-317

[2] Anandaraj, M., D. Prasath, K. Kandiannan, T.J. Zachariah, V. Srinivasan, A. Jha, B. Singh, A. Singh, V. Pandey, and S. Singh: *Genotype by environment interaction effects on yield and curcumin in turmeric (curcuma longa l.).* Industrial crops and products, 2014. **53**: p. 358-364.

[3] Jose, K. and C. Joy: *Solar tunnel drying of turmeric (curcuma longa linn. Syn. C. Domestica val.) for quality improvement.* Journal of Food Processing and Preservation, 2009. **33**: p. 121-135.

[4] Sampathu, S., N. Krishnamurthy, H. Sowbhagya, and M. Shankaranarayana: *Studies on quality of turmeric (curcuma longa) in relation to curing methods.* 1988. **25**(3): p. 152-155.

[5] Green, C.E. and S.A. Mitchell: *The effects of blanching, harvest time and location (with a minor look at postharvest blighting) on oleoresin yields, percent curcuminoids and levels of antioxidant activity of turmeric (curcuma longa) rhizomes grown in jamaica.* Modern Chemistry & Applications, 2014. **2**(140): p. 2-9.

[6] VijayaVenkataRaman, S., S. Iniyan, and R. Goic: *A review of solar drying technologies.* 2012. **16**(5): p. 2652-2670.

[7] Nukulwar, M.R. and V.B. Tungikar: *Drying kinetics and thermal analysis of turmeric blanching and drying using solar thermal system.* Sustainable Energy Technologies and Assessments, 2021. **45**: p. 101120.

[8] Meng, F.-C., Y.-Q. Zhou, D. Ren, R. Wang, C. Wang, L.-G. Lin, X.-Q. Zhang, W.-C. Ye, and Q.-W. Zhang: *Turmeric: A review of its chemical composition, quality control, bioactivity, and pharmaceutical application.* Natural and Artificial Flavoring Agents and Food Dyes, 2018: p. 299-350.

[9] Singh, S. and S. Kumar: *Development of convective heat transfer correlations for common designs of solar dryer.* 2012. **64**: p. 403-414.

[10] Singh, S. and S. Kumar: *Development of convective heat transfer correlations for common designs of solar dryer.* Energy Conversion and Management, 2012. **64**: p. 403-414.

[11] Adegoke, S.O., A.A. Adeleke, P.P. Ikubanni, C.T. Nnodim, A.O. Balogun, O.A. Falode, and S.O. Adetona: *Energy from biomass and plastics recycling: A review.* 2021. **8**(1): p. 1994106.

[12] Olomolaiye, P.O.: *An evaluation of the relationships between bricklayers' motivation and productivity.* 1990. **8**(3): p. 301-313.

[13] Saxena, S. and Raja, *Natural dyes: Sources, chemistry, application and sustainability issues*, in *Roadmap to sustainable textiles and clothing*. 2014, Springer. p. 37-80.

[14] Gupta, A., A.P. Costa, X. Xu, S.-L. Lee, C.N. Cruz, Q. Bao, and D.J. Burgess: *Formulation and characterization of curcumin loaded polymeric micelles produced via continuous processing.* 2020. **583**: p. 119340.

[15] Fudholi, A., K. Sopian, B. Bakhtyar, M. Gabbasa, M.Y. Othman, and M.H. Ruslan: *Review of solar drying systems with air based solar collectors in malaysia.* Renewable and Sustainable Energy Reviews, 2015. **51**: p. 1191-1204.

[16] Eswaramoorthi, M., G. Kathiresan, P. Prasad, and P. Mohanram: *A survey on lean practices in indian machine tool industries.* The International Journal of Advanced Manufacturing Technology, 2011. **52**(9): p. 1091-1101.

[17] Carvalho, R.L., O.M. Jensen, and L.A. Tarelho: *Mapping the performance of wood-burning stoves by installations worldwide.* Energy and Buildings, 2016. **127**: p. 658-679.

[18] Albanese, M.A. and S. Mitchell: *Problem-based learning: A review of literature on its outcomes and implementation issues.* Academic Medicine-Philadelphia, 1993. **68**: p. 52-52.

[19] Chen, L., G. Bai, S. Yang, R. Yang, G. Zhao, C. Xu, and W. Leung: *Encapsulation of curcumin in recombinant human h-chain ferritin increases its water-solubility and stability.* Food research international, 2014. **62**: p. 1147-1153.

[20] Hordofa, T.S. and T.T. Tolossa: *Cultivation and postharvest handling practices affecting yield and quality of major spices crops in ethiopia: A review.* Cogent Food & Agriculture, 2020. **6**(1): p. 1788896.

[21] Defilippi, B.G., A.M. Dandekar, and A.A. Kader: *Relationship of ethylene biosynthesis to volatile production, related enzymes, and precursor availability in apple peel and flesh tissues.* Journal of Agricultural and Food Chemistry, 2005. **53**(8): p. 3133-3141.

[22] Yamashita, T.: *Analyzing likert scale surveys with rasch models.* Research Methods in Applied Linguistics, 2022. **1**(3): p. 100022.

[23] Garai-Fodor¹, M. and A. Popovics: *Hungarian food consumers' preferences, from the aspect of ethnocentrism.* Acta Polytechnica Hungarica, 2021. **18**(8).

[24] Zhai, Z., J.F. Martínez, V. Beltran, and N.L. Martínez: *Decision support systems for agriculture 4.0: Survey and challenges.* Computers and Electronics in Agriculture, 170, 105256., 2020. **170**: p. 105256.

[25] Kalaycı, I., F. Başalan İz, and V. Kalınkara: *Validity and reliability of education participation scale (eps-a) in turkish older adults.* Educational Gerontology, 2022, 2022: p. 1-14.

[26] Thomas, J.M.: *Technical efficiency estimation: A study on small scale pineapple farms in kerala.* CLEAR International Journal of Research in Commerce & Management, 2020. **11**(4).

[27] Stribbell, H. and S. Duangekanong: *Validation of a research instrument to measure generation y parents' perception of service quality and effect on satisfaction and word of mouth in international schools.* Mobile Information Systems, 2022. **2022**.

[28] Amicarelli, V. and C. Bux: *Food waste measurement toward a fair, healthy and environmental-friendly food system: A critical review.* British Food Journal., 2020.

[29] Hytönen, H., R. Näpänkangas, T. Karaharju- Suvanto, T. Eväsoja, A. Kallio, A. Kokkari, T. Tuononen, and S. Lahti: *Modification of national osce due to covid‐ 19–implementation and students' feedback.* European Journal of Dental Education, 2021. **25**(4): p. 679-688.

[30] Makridakis, S., E. Spiliotis, V. Assimakopoulos, Z. Chen, A. Gaba, I. Tsetlin, and R.L. Winkler: *The m5 uncertainty competition: Results, findings and conclusions.* International Journal of Forecasting, 2022. **38**(4): p. 1365-1385.

[31] Cecchini, M.P., M. Riello, A. Sandri, A. Zanini, M. Fiorio, and M. Tinazzi: *Smell and taste dissociations in the modulation of tonic pain perception induced by a capsaicin cream application.* European Journal of Pain 2020. **24**(10): p. 1946-1955.

[32] Alam, A. and A. Mohanty, *Evaluation of software engineering virtual laboratory in determining undergraduate students' conceptual understanding: A blended learning model using collaborative-creative virtual learning environment employing critical pedagogy*, in *Sentiment analysis and deep learning*. 2023, Springer. p. 875-899.

[33] Salaisook, P., N. Faysse, and T.W. Tsusaka: *Reasons for adoption of sustainable land management practices in a changing context: A mixed approach in thailand.* Land Use Policy, 2020. **96**: p. 104676.

[34] Idowu- Adebayo, F., V. Fogliano, M.O. Oluwamukomi, S. Oladimeji, and A.R. Linnemann: *Food neophobia among nigerian consumers: A study on attitudes towards novel turmeric- fortified drinks.* Journal of the Science of Food and Agriculture, 2021. **101**(8): p. 3246-3256.

[35] Woltering, L., K. Fehlenberg, B. Gerard, J. Ubels, and L. Cooley: *Scaling–from "reaching many" to sustainable systems change at scale: A critical shift in mindset.* Agricultural Systems, 2019. **176**: p. 102652.

[36] Soubry, B., K. Sherren, and T.F. Thornton: *Are we taking farmers seriously? A review of the literature on farmer perceptions and climate change, 2007–2018.* Journal of Rural Studies, 2020. **74**: p. 210-222.

[37] Gosnell, H., N. Gill, and M. Voyer: *Transformational adaptation on the farm: Processes of change and persistence in transitions to 'climate-smart'regenerative agriculture.* Global Environmental Change, 2019. **59**: p. 101965.

[38] De Corato, U.: *Agricultural waste recycling in horticultural intensive farming systems by on-farm composting and compost-based tea application improves soil quality and plant health: A review under the perspective of a circular economy.* journal Science of the Total Environment, 2020. **738**: p. 139840.

[39] Balafoutis, A.T., F.K.V. Evert, and S. Fountas: *Smart farming technology trends: Economic and environmental effects, labor impact, and adoption readiness.* Agronomy, 2020. **10**(5): p. 743.

[40] Ahmad, L. and F. Nabi, *Introduction to precision agriculture*, in *Agriculture 5.0: Artificial intelligence, iot, and machine learning*. 2021, CRC Press. p. 1-23.

[41] Yu, Y., S. Yin, and A. Zhang: *Clean energy-based rural low carbon transformation considering the supply and demand of new energy under government participation: A three-participators game model.* Energy Reports, 2022. **8**: p. 12011-12025.

[42] Van Loon, J., L. Woltering, T.J. Krupnik, F. Baudron, M. Boa, and B. Govaerts: *Scaling agricultural mechanization services in smallholder farming systems: Case studies from sub-saharan africa, south asia, and latin america.* Agricultural Systems, 2020. **180**: p. 102792.

[43] Jeevarathinam, G., R. Pandiselvam, T. Pandiarajan, P. Preetha, M. Balakrishnan, V. Thirupathi, and A. Kothakota: *Infrared assisted hot air dryer for turmeric slices: Effect on drying rate and quality parameters.* LWT, 2021. **144**: p. 111258.

[44] Barrón Cuenca, J., N. Tirado, M. Vikström, C.H. Lindh, U. Stenius, K. Leander, M. Berglund, and K. Dreij: *Pesticide exposure among bolivian farmers: Associations between worker protection and exposure biomarkers.* Journal of exposure science environmental epidemiology, 2020. **30**(4): p. 730-742.

[45] Nair, K.P., *Technological advancements in coconut, arecanut and cocoa research: A century of service to the global farming community by the central plantation crops research institute, kasaragod, kerala state, india*, in *Tree crops*. 2021, Springer. p. 377-536.

[46] Shaikh, T.A., W.A. Mir, T. Rasool, and S. Sofi: *Machine learning for smart agriculture and precision farming: Towards making the fields talk.* Archives of Computational Methods in Engineering, 2022: p. 1-41.

[47] Nair, K.P., *Harvesting and postharvest management of turmeric*, in *Turmeric (curcuma longa l.) and ginger (zingiber officinale rosc.)-world's invaluable medicinal spices*. 2019, Springer. p. 173-193.

[48] Gill, R.S., S. Singh, V.S. Hans, and T.C. Mittal: *Turmeric (curcuma longa) drying in natural circulation solar dryer: An experimental evaluation.* Journal of Food Process Engineering, 2021. **44**(8): p. e13765.

[49] Rabha, D.: *Performance investigation of a passive-cum-active dryer with a biomass-fired heater integrated with a plate heat exchanger.* Renewable Energy, 2021. **169**: p. 598-607.

[50] Lamidi, R.O., L. Jiang, P.B. Pathare, Y. Wang, and A. Roskilly: *Recent advances in sustainable drying of agricultural produce: A review.* Applied energy, 2019. **233**: p. 367-385.

[51] Bisht, A.S. and N. Thakur: *Small scale biomass gasification plants for electricity generation in india: Resources, installation, technical aspects, sustainability criteria & policy.* Renewable Energy Focus, 2019. **28**: p. 112-126.

[52] Carvalho, R.L., O.M. Jensen, and L.A. Tarelho: *Mapping the performance of wood-burning stoves by installations worldwide.* Energy Buildings, 2016. **127**: p. 658-679.

[53] Jabeen, G., Q. Yan, M. Ahmad, N. Fatima, M. Jabeen, H. Li, and S. Qamar: *Household-based critical influence factors of biogas generation technology utilization: A case of punjab province of pakistan.* Renewable Energy, 2020. **154**: p. 650-660.