Asian Journal of Science and Appelied Technology (AJSAT)
Vol1.No.1 2013 pp 5-11.
available at: www.goniv.com
Paper Received :15-04-2013
Paper Published:28-05-2013
Paper Reviewed by: 1. James Williams 2. Dr. Sivaraj Kumar
Editor : Prof. P.Karthikeyan

AN OVERVIEW OF OPTIMIZATION TECHNIQUES USED IN SOLAR DRYING

Sunil[1*], Naveen Sharma[2], Amit Garg[1] and Suresh Kumar[1]
[1*]Department of Mechanical Engineering, BRCM CET Bahal, Bhiwani (HR)-127028
[2]Department of Mechanical and Industrial Engineering, Indian Institute of Technology, Roorkee (U.K.)-247667
[1]suniludmi@gmail.com [2]sharma.naveen28@yahoo.com [1]amitphogla@gmail.com [1]sureshjangra@rediff.com

ABSTRACT

In this paper, an attempt has been made to present an overview of different optimization techniques implemented for modelling and optimization of numerous solar drying processes. The review has also covered various solar drying techniques and design of different types of solar dryers. Applications of optimization techniques, such as artificial neural networks, genetic algorithms, response surface methodology and Taguchi method, in engineering have gained momentum in past decade. These techniques are widely used in practical engineering problems mainly for assessment, optimization and in process control. Some of the techniques such as Artificial Neural Networks and Genetic Algorithms are unambiguously used for process estimation and optimization for a large number of drying technologies. A limited amount of work has been carried out by the researchers in this field. Therefore, the main objective of this review paper is to discuss the various important findings of these studies by highlighting the applications of optimization techniques in optimizing the solar drying processes. Further, the scope for future work has also been discussed.

Keywords— Artificial neural networks, Genetic algorithms, Response surface methodology, Taguchi method

1. .INTRODUCTION

Solar energy has potential to cater the present and future needs of mankind. It is being used by man from prehistoric times for drying their food products and to preserve them for longer period. Drying of agricultural products not only increases their shelf life but also provides benefits in terms of lighter weight for transportation and small space for storage and finally results in lower transportation and handling cost [1].

Solar drying is one of the prospective applications of solar energy. Solar drying can be considered as an elaboration of sun drying and it is an efficient system of utilizing solar energy. The drying process takes place in two stages. The first stage occurs at the surface of the drying material at constant drying rate and is similar to the vaporization of water into the ambient. The second stage occurs with decreasing (falling) drying rate. The condition of the second stage depends upon the properties of the material being dried [2]. The product drying rate depends on various parameters like solar radiation, wind velocity, relative humidity, air and earth temperature, type of product, initial moisture content, product absorptivity, and mass of product per unit exposed area [3, 4].

Most agricultural products contain high initial moisture and are therefore highly perishable. Water loss and decay account for most of their losses, which are estimated to be more than 30–40% in the developing countries in the tropics and subtropics due to inadequate handling, transportation, and storage facilities. Apart from physical and economic losses, serious losses do occur in the availability of essential nutrients, notably vitamins and minerals. The need to reduce postharvest losses of perishable horticultural commodities is of paramount importance for developing countries to increase their availability, especially in the present context when the constraints on food production (land, water, and energy) are continually increasing. It is being increasingly realized that the production of more and better food alone is not enough and should go hand in hand with suitable postharvest conservation techniques to minimize losses, thereby increasing supplies and availability of nutrients besides giving the economic incentive to produce more [5]. Therefore, the introduction of solar dryers in developing countries can reduce crop losses and improve the quality of the dried product significantly when compared to the traditional methods of drying such as sun or shade drying [6].

Asian Journal of Science and Appelied Technology (AJSAT)
Vol1.No.1 2013 pp 5-11.
available at: www.goniv.com
Paper Received :15-04-2013
Paper Published:28-05-2013
Paper Reviewed by: 1. James Williams 2. Dr. Sivaraj Kumar
Editor : Prof. P.Karthikeyan

Solar drying methods are usually classified to four categories according to the mechanism by which the energy, used to remove moisture, is transferred to the product [7]:

(1) Sun or natural dryers: The material to be dried is placed directly under inimical climate conditions like solar radiation, ambient air temperature, relative humidity and wind speed to achieve drying.
(2) Direct solar dryers: In these dryers, the material to be dried is placed in an enclosure, with transparent covers or side panels. Heat is generated by absorption of solar radiation on the product itself as well as the internal surfaces of the drying chamber. This heat evaporates the moisture from the drying product and promotes the natural circulation of drying air.
(3) Indirect solar dryers: In these dryers, air is first heated in a solar air heater and then ducted to the drying chamber.
(4) Mixed-type solar dryers: The combined action of the solar radiation incident directly on the material to be dried and the air pre-heated in the solar air heater furnishes the energy required for the drying process.

The aim of this research paper is to draw attention towards the various optimisation techniques being used for optimizing the solar drying processes. This article presents an overview of mainly four optimization techniques such as ANN, GA, RSM and Taguchi etc. which are vastly used in optimizing solar drying processes. Initially, some fundamentals of solar drying techniques are presented in order to understand the purpose of solar dryers and what is required for optimization of solar dryers and then about the studies carried out using these optimization techniques.

2. SOLAR DRYING TECHNIQUES

Solar drying techniques can be divided into two types; open sun drying and controlled drying. The classification of solar drying technique is shown in Fig. 1.

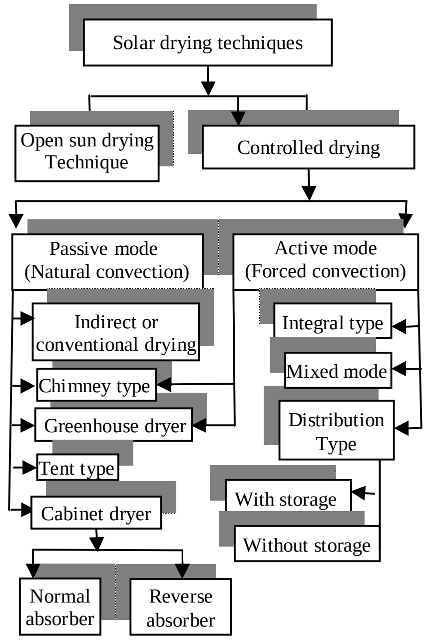

Figure. 1: Flow diagram of solar drying techniques.

Mainly active and passive techniques are the two main drying techniques that utilize solar energy. In passive techniques, a natural circulation is used to circulate air through the air collector to the product; heated air is circulated through the drying bed by buoyancy forces as a result of wind pressure. But in active system, a fan or blower is used to circulate heated air through the air collector to the drying products. Therefore, active system requires other non- renewable energy sources such as electricity and fans for forced circulation of air, in addition to solar energy. For more detailed investigation on solar drying techniques the reader can follow some of the good reviews presented in [7, 8, 9]. The design of different types of solar dryers is shown in Fig. 2.

3. DIFFERENT OPTIMIZATION TECHNIQUES USED IN SOLAR DRYING

The optimization techniques are used to model the different solar drying processes and their equipments to predict the optimal set of values which gives the best results. The most widely used optimization techniques which have been successfully applied in application of solar drying processes are: ANN, GA, RSM and Taguchi method.

goniv journals

Asian Journal of Science and Appelied Technology (AJSAT)
Vol1.No.1 2013 pp 5-11.
available at: www.goniv.com
Paper Received :15-04-2013
Paper Published:28-05-2013
Paper Reviewed by: 1. James Williams 2. Dr. Sivaraj Kumar
Editor : Prof. P.Karthikeyan

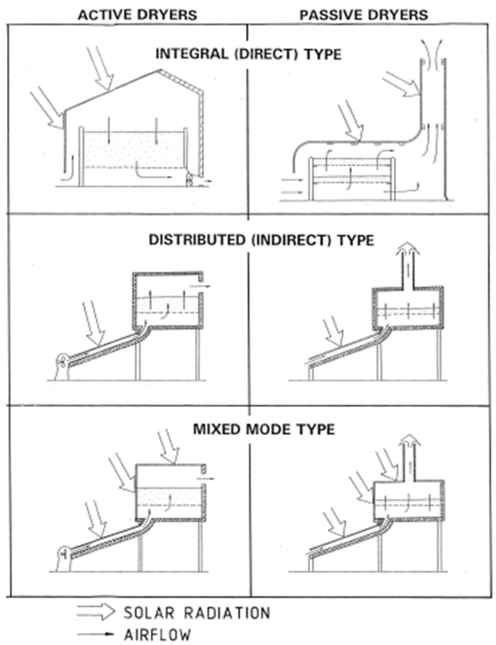

Figure. 2: Design of different types of solar dryers [8]

A. Application of ANN to Solar Drying Processes

Artificial neural networks are widely used in modelling complex and non-linear biological systems and technological faults. Several Neural Network (NN) topologies have been considered by different researchers for modelling the drying process. The selection of an appropriate NN topology is important in terms of model accuracy and simplicity. Dynamic modelling of the drying characteristics of agricultural products, using optimization techniques such as artificial intelligence methods including genetic algorithms and neural networks has gained momentum, because learning ability of the neural network is suitable for identifying plant and fruit responses, which are complex processes to which mathematical approaches are not easily applied. Studies to identify nonlinear and difficult-to-define system behaviour with aid of neural networks were conducted on grain drying [10, 11, and 12].

An attempt to predict the performance of a Yankee dryer has been made by Huang and Mujumdar [13] using neural networks. A 3-layer network with 4 inputs and 2 outputs was used for study. Training was performed using back-propagation algorithm and data from a Yankee simulation program based on Karlsson and Heikkila's model. The effect of number of training cases and hidden neurons were examined. Further, it was used for modelling of moisture content and quality index for vitamin C in sliced potatoes and green peas [14].

An experimental investigation on drying of tomatoes in a tray dryer covering different variables like power of heater and air flow velocity has been carried out [15]. The data were modeled using artificial neural network and empirical mathematical equations. The results were compared with experimental data and it was found that the predictions of the artificial neural network model fit the experimental data more accurately in comparison to the various mathematical equations.

The multilayered neural network approach was used to predict the performance of the solar tunnel drier by Bala et al. [16, 17]. The authors were trained the model using back propagation algorithm by utilizing the solar drying data of jackfruit bulbs and leather. The prediction of the performance of the drier was found to be excellent after it was adequately trained. The authors suggested that ANN can be used to predict the potential of the drier for different locations, and can also be used in a predictive optimal control algorithm.

The temperature variation of food product (potato cylinders and slices) was predicted by Tripathy and Kumar [18] of using ANN, where the input parameters for ANN modelling were solar radiation intensity and ambient air temperature. The authors proposed analytical heat diffusion model with apposite boundary conditions for testing the merit of developed ANN model.

A predictive model using artificial neural network was proposed in order to obtain on-line predictions of moisture kinetics during drying of sweet potato [19]. Comparing the coefficient of determination, relative mean square error and standard deviation using the developed ANN model it was concluded that the neural network could be used for on-line state estimation of drying characteristics and control of drying processes.

The optimization of solar box dryer was carried out by using multiple linear regression (MLR) analysis and artificial neural networks (ANN) [20]. The standard back-propagation learning algorithm was in the network and predictive neural network model showed better predictions than regression model for drying efficiency.

The artificial neural networks (ANNs) and mathematical models were applied for hot-air drying

Asian Journal of Science and Appelied Technology (AJSAT)
Vol1.No.1 2013 pp 5-11.
available at: www.goniv.com
Paper Received :15-04-2013
Paper Published:28-05-2013
Paper Reviewed by: 1. James Williams 2. Dr. Sivaraj Kumar
Editor : Prof. P.Karthikeyan

of Jujube fruit by Motevali et al. [21] and deduced that neural network modelling yielded a better prediction of moisture ratio and drying rate of jujube fruit compared to all of the mathematical models studied.

Recently, a feed forward artificial neural network (ANN) to predict the exergetic performance of a microencapsulation process via spray drying was implemented [22] and suggested that the selected ANN model can be applied to determine the optimal exergy efficient drying conditions to achieve a sustainable spray drying process.

B. Application of GA to Solar Drying Processes

The genetic algorithm is a global search algorithm, which is designed to imitate the principles of biological evolution in natural genetic systems. There are various types of operators that are used in GA; however, selection, recombination and mutation are used quite often. The GA simulates this process and calculates optimum objective functions. The genetic algorithm is one of the search methods and optimization techniques for an optimal value of a complex objective function by simulation of the biological evolutionary process based, as in genetics, on crossover and mutation. Morimoto, De Baerdemaeker, & Hashimoto (1997a) [23] developed an artificial neural network-genetic algorithm intelligence approach for optimal control of fruit-storage process. Morimoto, Purwanto, Suzuki, & Hashimoto (1997b) [24] used genetic algorithm for optimization of heat treatment for fruit during storage.

The applications of artificial neural networks and genetic algorithms were introduced by Hashimoto [25] to optimize the agricultural systems. Erenturk and Erenturk [26] investigated drying kinetic of carrot considering different drying conditions and in order to optimize, mathematical models obtained by using regression analysis, genetic algorithm and feed-forward artificial neural network were employed. It was concluded that neural network represented drying characteristics better than the others.

Xueqiang Liu et al. [27] optimized the neural network topology for predicting the moisture content of grain drying process using genetic algorithm and simulation test on the moisture content prediction of grain drying process showed that the SMNN optimized using genetic algorithm performed well and the accuracy of the predicted values was excellent.

A feed-forward neural network was used to estimate moisture ratio via temperature, air velocity, time period and moisture content to predict the next moisture content and therefore the drying rate [28]. Later by using a genetic algorithm the optimum input conditions were obtained. The results showed that the drying procedure time was minimized perfectly by using the optimum conditions. Shahsavar et al. [29] applied fast and exclusive non-dominated sorting genetic algorithm (NSGA-II) method to find the optimum values of geometric characteristics of the studied PV/T system to achieve higher thermal and electrical efficiencies.

C. Application of RSM to Solar Drying Processes

RSM is a collection of mathematical and statistical techniques that are useful for modelling and analysis in applications where a response of interest is influenced by several variables and the objective is to optimize this response [30].

Response Surface Methodology (RSM) was used to optimize the operating conditions of soybean seed drying [31]. The study was performed using a three-level, four-factor fractional factorial design and aimed at determining the optimum combination of initial moisture content, drying air temperature, air velocity and depth of loading that could result in high germination, vigor and field emergence.

An investigation to study the effect of sugar concentration, solution temperature, solution to fruit ratio and immersion time on the water loss, solute gain, vitamin-C loss and overall acceptability of osmo-convectively of dried aonla slices having moisture content of 10% wb was studied [32]. The sweet aonla flakes developed under optimized condition were of high consumer acceptability and were in close agreement to the predicted quality values.

The optimization of pretreatment process before solar cabinet drying of bitter gourd slices has been carried out by Jadhav et al. [33] using RSM. The responses taken were chlorophyll retention and texture of dehydrated bitter gourd slices. The optimum process condition was found using RSM.

Nazghelichi et al. [34] recommended an integrated response surface methodology (RSM) and genetic algorithm (GA) for developing artificial neural networks (ANNs) with great chances to be an optimal one. A multi-layer feed forward (MLFF) ANN was applied to correlate the outputs (energy and exergy) to the four exogenous inputs (drying

Asian Journal of Science and Appelied Technology (AJSAT)
Vol1.No.1 2013 pp 5-11.
available at: www.goniv.com
Paper Received :15-04-2013
Paper Published:28-05-2013
Paper Reviewed by: 1. James Williams 2. Dr. Sivaraj Kumar
Editor : Prof. P.Karthikeyan

time, drying air temperature, carrot cubes size, and bed depth). The RSM was used to build the relationship between the input parameters and output responses, and used as the fitness function to measure the fitness value of the GA approach. Finally, GA was applied to find the optimal topology of ANN. The ANN topology had minimum MSE when the number of neurons in the hidden layer, momentum coefficient, step size, number of training eons and training times were 28, 0.66, 0.35, 2877 and 3, respectively. The energy and exergy of carrot cubes during fluidized bed drying were predicted with R^2 values of greater than 0.97 using optimal ANN topology.

Recently, Narang and Pandey [35] used RSM for quantitative investigation on water and solids transfer during the osmotic dehydration process of the grapes in sucrose solution using Box-Behnken experimental design. The purpose of this study was to optimize the osmotic dehydration of seedless grapes using sucrose solution by RSM.

D. *Application of Taguchi method to Solar Drying Processes*

Taguchi is a tool of DOE. This method reduces the number of experiments as compared to DOE. The Taguchi method is mainly used to achieve the optimized set of values and effectively reduces the number of experimental trials. The studies on application of Taguchi method in solar drying processes are sparse.

Chung et al. [36] applied Taguchi method to determine optimum conditions for submerged culture of Monascus spp. fermentation to produce a high yield of monacolin K (also known as lovastain, mevinolin or mevacor). The control factors included carbon, nitrogen, oil, and salt sources and pH values.

Chung et al. [37] applied Grey-based Taguchi Method to find the optimal conditions of medium composition to enhance the production of biomass, monacolin K, pigments synthesis, and to reduce the yield of citrinin, metabolites in the Monascus purpureus fermentation process. The optimal combination obtained from this study could be a reference for production line fermentation processing.

Further, the Taguchi method was applied to determine optimum extraction conditions for drying ginger to produce a high yield of ginger oil [38]. The control factors included reaction time, drying temperature, extraction pressure and particle size of the ginger powder.

4. CONCLUSION AND RECOMMENDATIONS FOR FUTURE WORK

In the present study, a review of optimization techniques used in solar drying systems has been carried out. One of the most important potential applications of solar energy is the solar drying of agricultural products. Among the various optimization techniques reviewed in this paper artificial neural network and genetic algorithm are most widely and successfully applied techniques for modelling the solar drying processes. Moreover, these techniques can be applied to different type of processes with simple changes in configuration. Furthermore, before using the drying systems on large scale, optimization techniques must be applied to find the optimum set of different parameters that affect the performance of the drying systems. The studies conducted on solar drying systems using response surface methodology and Taguchi method are few in the literature. The researchers can apply these techniques for modelling the solar drying systems because these techniques reduce the number of experimental trials.

REFERENCES

[1] Erteken C., and Yaldiz O. Drying of eggplant and selection of a suitable thin layer drying model. Journal of Food Engineering 2004;63:349–59.

[2] Can A. Drying kinetics of pumpkin seeds. International Journal of Energy Research 2000;24: 965–75.

[3] Medugu D.W. Performance study of two designs of solar dryers. Scholars Research Library: ISSN 0975-508X Coden (USA) 2010;2(2): 136-48.

[4] Jain D. and Tiwari G.N. Thermal aspects of open sun drying of various crops. Journal of Food Technology 2003;28(1): 37-54.

[5] Jayaraman K.S. and Das Gupta D.K. Handbook of industrial drying- Drying of Fruits and Vegetables. 2006;pp-606, by Taylor & Francis Group, LLC.

[6] Yaldiz O., Erteken C. and Uzun H.I. Mathematical modelling of thin layer solar drying of sultana grapes. Energy 2001; 26: 457–65.

[7] El-Sebaii A.A. and Shalaby S.M. Solar drying of agricultural products: A review, Renewable and Sustainable Energy Reviews 2012;16:37–43.

[8] Ekechukwua O.V. and Norton B. Review of solar-energy drying systems II: an overview of

solar drying technology. Energy Conversion & Management 1999;40: 615-55.

[9] Fudholi A., Sopian K., Ruslan M.H., Alghoul M.A. and Sulaiman M.Y. Review of solar dryers for agricultural and marine products. Renewable and Sustainable Energy Reviews 2010;14: 1–30.

[10] Farkas I., Reményi P. and Biró A. A neural network topology for modelling grain drying. Computers and Electronics in Agriculture 2000a; 26: 147–58.

[11] Farkas I., Reményi P. and Biró A. Modelling aspects of grain drying with a neural network. Computers and Electronics in Agriculture 2000b; 29: 99–113.

[12] Trelea I. C., Courtois F. and Trystram G. Dynamic models for drying and wet-milling quality degradation of corn using neural networks. Drying Technology 1997; 15:1095–102.

[13] Huang B. and Mujumdar A. S. Use of neural network to predict industrial dryer performance. Drying Technology 1993;525-41.

[14] Kaminski W., Strumillo P. and Tomczak E. Neurocomputing approaches to modelling of drying process dynamics. Drying Technology 1998;16:967–92.

[15] Movagharnejad K. and Nikzad M. Modelling of tomato drying using artificial neural network. Computers and Electronics in Agriculture 2007;59(1-2):78-85.

[16] Bala B.K., Ashraf M.A., Uddin M.A., and Janjai S. Experimental and neural network prediction of the performance of a solar tunnel drier for drying jackfruit bulbs and leather. Journal of food process engineering 2005;28 (6):552–66.

[17] Bala B.K. and Janjai S. Solar drying technology: potentials and developments. Energy, environment and sustainable development 2012;69-98.

[18] Tripathy P.P. and Kumar S. Neural network approach for food temperature prediction during solar drying. International Journal of Thermal Sciences 2009;48:1452–59.

[19] Singh N.J. and Pandey R.K. Neural network approaches for prediction of drying kinetics during drying of sweet potato. Agricultural Engineering International: CIGR Journal. Manuscript No.1734. 2011;13(1).

[20] Kassem A.E.W.S., Al-Sulaiman M.A., Abd El-Wahed M. Aboukarima Samira S. Kassem. Predicting drying efficiency during solar drying process of grapes clusters in a box dryer using artificial neural network. Australian Journal of Basic and Applied Sciences 2011;5(6):230-41,.

[21] Motevali A., Abbaszadeh A., Najafi G. H., Minaei S. and Ghobadian B. Drying of jujube (Zizyphus jujube mill) fruit: comparison of prediction from mathematical models and artificial neural networks. AJCS 2012;6(2):210-18.

[22] Aghbashlo M., Mobli, H., Rafiee S. and Madadlou A. The use of artificial neural network to predict exergetic performance of spray drying process: A preliminary study. Computers and Electronics in Agriculture 2012;88:32-43.

[23] Morimoto T., De Baerdemaeker J. and Hashimoto Y. An intelligent approach for optimal control of fruit-storage process using neural networks and genetic algorithms. Computers and Electronics in Agriculture 1997a;18: 205-24.

[24] Morimoto T., Purwanto W., Suzuki J., and Hashimoto, Y. Optimization of heat treatment for fruit during storage using neural networks and genetic algorithms. Computers and Electronics in Agriculture 1997b;19: 87-101.

[25] Hashimoto Y. Applications of artificial neural networks and genetic algorithms to agricultural systems. Computers and Electronics in Agriculture 1997;18:71-72.

[26] Erenturk S. and Erenturk K. Comparison of genetic algorithm and neural network approaches for the drying process of carrot. Journal of Food Engineering 2007;78 (3): 905-12.

[27] Xueqiang Liu, Xiaoguang Chen, Wenfu Wu, Guilan Peng. A neural network for predicting moisture content of grain drying process using genetic algorithm. Food Control 2007;18(8):928-33.

[28] Banakar A. and Karimi Akandi S. R. Genetic algorithm optimizing approach in rosa petals hot air dryer. International Journal of Agricultural and Food Science 2012;2(3):60-65.

[29] Shahsavar A., Talebizadeh P. and Tabaei H. Optimization with genetic algorithm of a PV/T air collector with natural air flow and a case study. J. Renewable Sustainable Energy 2013;5(2).

[30] Myers R. and Montgomery D. (2002). Response surface methodology. New york: John wiley & Sons.

[31] Abbasi Surki A., Sharifzade F., Tavakkol Afshari R., Majnoun Hosseini N. and Gazor H. R., Optimization of processing parameters of soybean seeds dried in a constant-bed dryer

using Response Surface Methodology. J. Agr. Sci. Tech. 2010;12: 409-23.

[32] Shafiq Alam Md. and Singh A. Optimum process parameters for development of sweet aonla flakes. IJRRAS 2010;3(3): 323-33.

[33] Jadhav D.B., Visavale G. L., Sutar P.P., Annapure U.S. and Thorat, B. N., Solar Cabinet Drying of Bitter Gourd: Optimization of Pretreatments and Quality Evaluation. International Journal of Food Engineering, 6.4 (2011).

[34] Nazghelichi, T., Aghbashlo, M. and Kianmehr, M.H. Optimization of an artificial neural network topology using coupled response surface methodology and genetic algorithm for fluidized bed drying. Journal Computers and Electronics in Agriculture 2011;75 (1): 84-91.

[35] Narang G. and Pandey J.P. Optimization of Osmotic Dehydration Process of Grapes Using Response Surface Methodology. Focusing on Modern Food Industry (FMFI) 2013;2(2):78-85.

[36] Chung C.C., Chen H.H. and Hsieh P.C. Application of the Taguchi method to optimize Monascus spp. Culture. Journal of Food Process Engineering, 2007; 30 (2):241-54.

[37] Chung C.C., Chen Ho-Hsien and Hsieh P.C. Optimization of the Monascus purpureus Fermentation Process Based on Multiple Performance Characteristics, Journal of Grey System 2008;11: 85-96.

[38] Chen Ho-Hsien, Chung C.C., Wang H.Y. and Huang T.C. Application of Taguchi Method to Optimize Extracted Ginger Oil in Different Drying Conditions, International Conference on Food Engineering and Biotechnology IPCBEE vol.9 (2011) IACSIT Press, Singapoore.