Comparative ANN-TLBO and RSM Optimisation Approach for Bioactive Potential of Microwave Convective Dried Mango (*Mangifera indica*) †

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Abstract: The mango (*Mangifera indica*) is a rich source of antioxidants like phenolic acids and flavonoids. Polyphenol oxidase (PPO) and polyphenol peroxidase (POD) enzymes oxidize monophenols and diphenols, and thus the antioxidant potential diminishes. For cost-effective and sustainable preservation of this subtropical climacteric fruit, microwave convective dehydration is a prospective choice. Drying operations deactivate PPO and POD. Microwave convective drying was done at 100–300 W of power in a temperature range of 40–80 °C, with a total soluble solid content of 20–30 °B and a puree load of 0.4–0.6 g/cm² to investigate the effect of the process parameters on the total phenolic content (TPC) of the final product. Response surface methodology (RSM) was employed to optimize the TPC value. Furthermore, an artificial neural network (ANN) with the back propagation-feed forward modeling approach was adopted for the experimental results obtained, teaching–learning–based optimization (TLBO) was then employed to acquire the optimized drying condition for samples with the maximum TPC value. The optimized process conditions obtained from both methods were virtually compatible. From RSM analysis, the maximum TPC value of 13.36 mg GAE/100 g was observed at a 170.27 W power level, 57.84 °C oven temperature, 0.60 g/cm² of puree load and 29.05 °B total soluble solid content, whereas from the ANN-TLBO technique, 14.29 mg GAE/100 g of TPC was attained for the following combination of drying parameters: 175.08 W, 57.15 °C, 0.60 g/cm² and 29.25 °B. The ANN-TLBO approach predicted a more optimized result (TPC value) in comparison with the RSM method.

Keywords: food processing; biocatalysis; polyphenol; ANN; enzyme

1. Introduction

The mango is a widely cherished subtropical fruit, full of antioxidants like phenolic acids, flavonoids and carotenoids. Mango leather is produced by drying mango pulp [1]. The polyphenol oxidase (PPO) and polyphenol peroxidase (POD) enzymes degrade the phenolic compounds, thus reducing the antioxidant potential. Microwave–convective (MWC) drying is an emerging technique in developing countries in this era of the Fourth Industrial Revolution. Heat and microwave radiation may deactivate the PPO and POD, thus increasing the phenolic content in the dried sample. The MWC dryer should be optimized to produce mango leather with a higher phenolic content with a lower cost of production. The response surface methodology (RSM) and artificial neural networks...
(ANNs) are widely used for food production, though teaching–learning-based optimization (TLBO) is considered in this research for the first time in fruit processing for the optimization of process parameters in MWC drying.

2. Materials and Methods

The samples were prepared as per our previous work [2], but using a microwave–convective (MWC) dryer instead of hot air drying. The central composite design was adopted for MWC drying, with a power level in the range of 100–300 W, temperature from 40 to 80 °C, total soluble solid from 20 to 30 °B and pulp amount from 0.4 to 0.6 g/cm³ (Table 1). Sample extract preparation and estimation of the total phenolic content (TPC) was done following our previous work [3]. The response surface methodology (RSM) and ANN-TLBO [4] was conducted using Design Expert 7.0.0 and MATLAB 2018a (Figure 1).

Table 1. A central composite design was adopted for the microwave–convective drying of mangos.

| Parameters           | −1 Level | +1 Level | −alpha | +alpha |
|----------------------|----------|----------|--------|--------|
| Temperature (°C)     | 40       | 80       | 20     | 100    |
| Puree load (g/cm³)   | 0.4      | 0.6      | 0.3    | 0.7    |
| Brix (°B)            | 20       | 30       | 15     | 35     |
| Power level (W)      | 100      | 300      | 0      | 400    |

Figure 1. Flowchart of teaching–learning-based optimization (TLBO) optimization.
3. Results and Discussion

From the developed model (non-linear), it was evidenced that the amount of pulp being used affected the TPC value the most, followed by the temperature of MWC drying, total soluble solid and power level [5]. The interactive effect of the temperature and pulp amount, followed by the interaction between the pulp amounts and total solid, and then the puree load and power level, affected the TPC results. The $R^2$ value which appeared from the RSM was 0.8560; the model was significant ($p < 0.01$), and the lack of fit was insignificant ($p > 0.01$).

The ANN model was built with a feed forward back-propagation type of network, where trainlm was the training function, learngdm was the learning function, performance was measured by the mean squared error, the optimum number of layers was five, the numbers of neurons was seven and transig was used for the transfer function (Stalin et al., 2019). The coefficient of correlation for predicted versus actual values was 0.9136. The proposed ANN model is represented in Figure 2.

For TLBO criteria, the student size was 40, the factor of teaching was 1–2 and the best value for the last 50 generations. For the best teacher, the set of parameters which provided the maximum TPC was considered as the best teacher value. Thereafter, the means of all the parameters were calculated. After the teaching phase, the inputs responsible for the maximum TPC values were considered for improved inputs, whereas the maximum TPC value achieved from the input set was considered as the student phase performance. The maximum TPC value achieved by ANN-TLBO was 14.29 mg GAE/100 g for the optimized input set of 175.08 W, 57.15 °C, 0.60 g/cm² and 29.25 °B.

4. Conclusions

The inhibition or deactivation of polyphenol oxidase was present, resulting in a higher TPC content along with the availability of free polyphenols during microwave–convective drying. Using RSM optimization, the highest TPC value observed was 13.36 mg
GAE/100 g for the combination of 57.84 °C (MWC dryer temperature), 29.05 °B (total soluble solid content), 170.27 W (microwave power level) and 0.60 g/cm² (pulp amount). The maximum TPC value of 14.29 mg GAE/100 g was found using ANN-TLBO for the following combination of drying parameters: 175.08 W, 57.15 °C, 0.60 g/cm² and 29.25 °B. A more robust model with a higher coefficient of correlation was achieved by the ANN-TLBO technique than that of RSM.

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