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Modeling of melon drying by application of microwave using mamdani fuzzy inference system

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ABSTRACT

Mamdani fuzzy inference system (MFIS) was used to model melon drying in a microwave dryer. Melon pieces 3, 5 and 10 mm thick, were dried in a microwave dryer at 200 and 400 w in triplicate. For data analysis MFIS in MATLAB software was used with 58 if – then rules and trigonometric functions with three drying times as inputs and thickness of melon pieces and microwave power for prediction of moisture ratio (MR) as outputs. Given the high correlation coefficient, 0.98 and mean error percentage 7.7%, the obtained experimental and theoretical data showed great correlation, consequently it could be said that MFIS was a suitable and reliable method for modeling and predicting the kinetics of dried melon pieces and the like products.

Key words: Modeling, melon, drying, microwave

INTRODUCTION

Recently, melons have become the fourth most commercially important fruit in the world, after oranges, bananas and grapes. Melons are a popular fruit because of their pleasant odor and sweet taste [1].

Melons have a high commercial price and are appreciated because of its sensorial characteristics but have a short post-harvesting life, at room temperature. This short life makes difficult the commercialization and transport of melons to places distant from the production centre, thus contributing to increase fruit losses. As such, melons can be dried in order to save part of the production that would not be readily consumed, as drying is a classical method of food preservation, which provides an extension of shelf-life, lighter weight for transportation and less space for storage [2].

Melon (Cucumis melon) belongs to cucurbitaceae family. 100 g of melon contain 8g carbohydrate with glucose and fructose being the most predominant sugars. 100 g of melon also contain 1 g fiber, 12 mg calcium, 17 mg phosphorous, 238mg potassium 1250 u precursors of vitamin A and 31 Kcal energy [3]. Melons are high in sugar content. High – temperature drying of fruits containing high level of sugars requires more time and higher temperature likely resulting in damaged flavor, color, nutrients, and reduced volume density and re-hydration capacity of dried products. In high – temperature dryers the energy efficiency is declined and drying requires longer duration because of low heat conductivity and heat transfer limited to internal parts of food. To avoid this problem and diminishing the quality and also to achieve an effective heat processing microwave treatment was applied. There are various examples of microwave – assisted drying. Microwave application provides many advantages. Microwave – assisted drying systems and have significantly shortened the time of drying without having any negative effects on the quality of product. In microwave – assisted drying process heat is generated through transforming microwave energy into heat inside the moist matters providing desirable pressure and temperature for rapid drying. Bulk heating resulting from microwaves penetration as well as reduced costs have made microwave an attractive heat energy source. Shorter times of processing reduce significantly the production costs of some products. Also due to its focused energy, microwave system requires only 20-35% of total space as computed to other drying techniques [4].

Fuzzy logic and Fuzzy inference systems are attractive because they are able to deal with complicated problems without a need for accurate mathematical models. The predictions of kinetic of food drying could be considered as a complex system, which may result in significant deviations between simulation results and experimental data if conventional modeling techniques are used. Therefore, fuzzy logic was adopted because it is highly-suited for such complex problems. Researchers in the food engineering field have recently used several modeling techniques [5].

However modeling of food drying by use of fuzzy system has not been studied well. Few studies on this subject have conducted by Vaquiro [6] who applied fuzzy logic for modeling of kinetics of mango drying as well as by Atthajariyakul and leephakpreeda [7] who used fuzzy logic for drying of rice rouphage in a fluid bed under optimized conditions. Also Ganjeh *et. al*., modeled the kinetics of onion drying in a fluid bed dryer by using regression, fuzzy logic and artificial neural networks. They reported that a combination of fuzzy logic rules and artificial neural networks was suitable and reliable for modeling and prediction of kinetics of onion drying and the like [8].

The aim of this study was to dry melon pieces with different thickness by use of microwave treatment at different powers a new method i. e. MFIS.

MATERIALS AND METHODS

Materials

In this study, cultivar khatooni was used for producing dried melon pieces. To do this sound fruits of high quality were selected. First they were washed thoroughly, then peeled off and cleaned. The sample was cut into thin pieces 3, 5, and 10 mm thick, using a very thin – blade knife 50×30mm. then the sample weighed using a digital weighing machine with accuracy of 0.001g. Microwave dryer, Black & Decker, model M×30PGSS at 1000w was used for drying the pieces.

Microwave – assisted drying

Three samples with the same thickness were placed on a reticulated plate. Then, it was placed in the dryer system. The samples, initially were removed every 2 min to record their weights. Weighing continued until weight difference between two weighing was 0.1g.

The following equation was used for calculating the moisture ratio (MR) of melon pieces during the drying process:

$$MR = \frac{Mt - M_e}{M_0 - M_e} \qquad (1)$$

where MR stands for moisture ratio (dimensionless); Mt, the mean moisture content of mushroom at any time (kg water/kg dry matter); M0, the initial moisture content of mushroom (kg water/kg dry matter); and Me, the equilibrium moisture content of mushroom (kg water/kg dry matter).

As the value of Me is negligible compared to that of M0 and Mt, the error of omitting Me is often insignificant, so the equation simplified as follows [9].

$$MR = \frac{Mt}{M_0} \qquad (2)$$

The experiments were conducted three times with three thickness, 3, 5 and 10 and different microwave powers, 200 and 400 w. the experimental data was analyzed by MATLAB software using fuzzy logic.

Modeling by use of mamdani fuzzy inference system:
Fuzzy logic embodies the nature of human's mind in some sense,as the conception of possibility and probability is truly underlined in this logic in contrast with the traditional Boolean logic. Hence, any studied object in fact, can be described as a fuzzy system. A fuzzy system is based on fuzzy set, fuzzy membership and fuzzy variable, the three basic concepts of fuzzy logic.A fuzzy system consisting of a fuzzifier, a knowledge base (rule base), a fuzzy interference engine and defuzzifier has been considered (Fig. 1). The knowledge base of the fuzzy system is a collection of fuzzy IF-THEN rules. The term fuzzy logic denotes a modeling approach, where functional dependencies between the input and output variables are described by means of a set of IF-THEN rules following the reasoning with the operators AND, OR and NOT. The domain of both the input and output values is subdivided in the fuzzy sets according to technologically reasonable estimates. Fuzzification means that the degree of membership of a given crisp input value to its fuzzy sets is calculated. The fulfillment of the IF part, the premise, is calculated by fuzzy inference. The fuzzy sets and their combination by the operators AND, OR are used the standard models of minimum, maximum according to Eq. (3) and finally the fulfillment of the THEN part is calculated. Defuzzification ponders the several IF–THEN rules according to their degree of fulfillment, i.e., the degree of membership to the output sets and a crisp value is assigned to the output variable [10].

$$\begin{aligned} &\text{AND} : \mu(x \text{ AND } y) = \min(\mu(x), \mu(y)) \\ &\text{OR} : \mu(x \text{ OR } y) = \max(\mu(x), \mu(y)) \end{aligned} \tag{3}$$

The Sugeno and Mamdani types of fuzzy inference systems can be implemented in the fuzzy logic toolbox of MATLAB. When the output membership functions are fuzzy sets, the MFIS is the most commonly used fuzzy methodology [11]

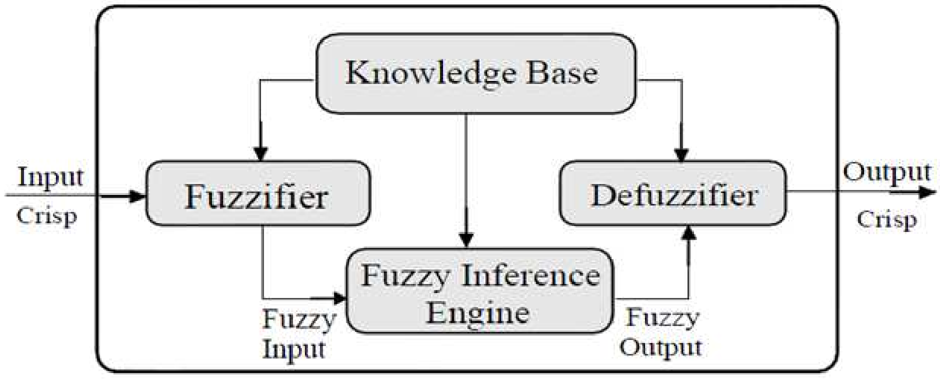


Fig.1. Block diagram of a fuzzy inference system

To apply the technique ‹Modeling by using mamdani technique was implemented with three inputs and one output by IF-THEN rules. Moisture ratios at certain intervals (every 2 min) based on selected microwave power at two levels, high (400 w) and low (200w) (figure 2) and thickness of dried melon pieces at three levels high (10mm) medium (5mm) and low (3mm) (figure 3) and time at 16 levels very very high (L16) very high (L15) high (L14) little high (L13).

very very high (L16),very high (L15), high (L14), little high (L13), few high(L12), a bit high (L11), very positive medium (L10),positive medium (L9), medium (L8), negative medium(L7), very negative medium (L6), low (L5), little low (L4),few low (L3), very low (L2) and too much low (L1).

(figure 4) and moisture ratios obtained from applied power / thickness treatments, very very high (L11) very very very high (L11),very high (L10), high (L9), little high (L8), few high(L7), (L8),positive medium (L7), medium (L6), negative medium(L5), low (L4), few low (L3), very low (L2) and too much low (L1).

(figure 5) were simulated in the fuzzy logic toolbox of MATLAB software.

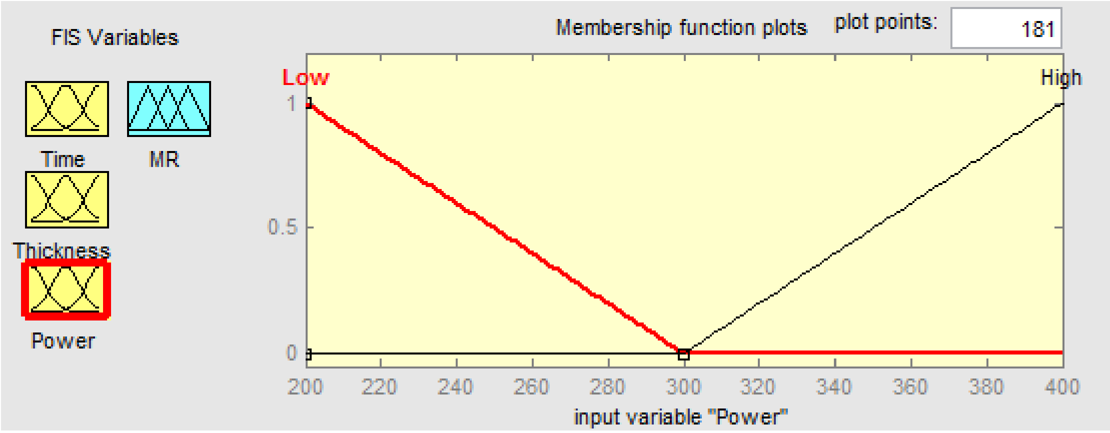


Fig.2.Membership functions for the power(w)

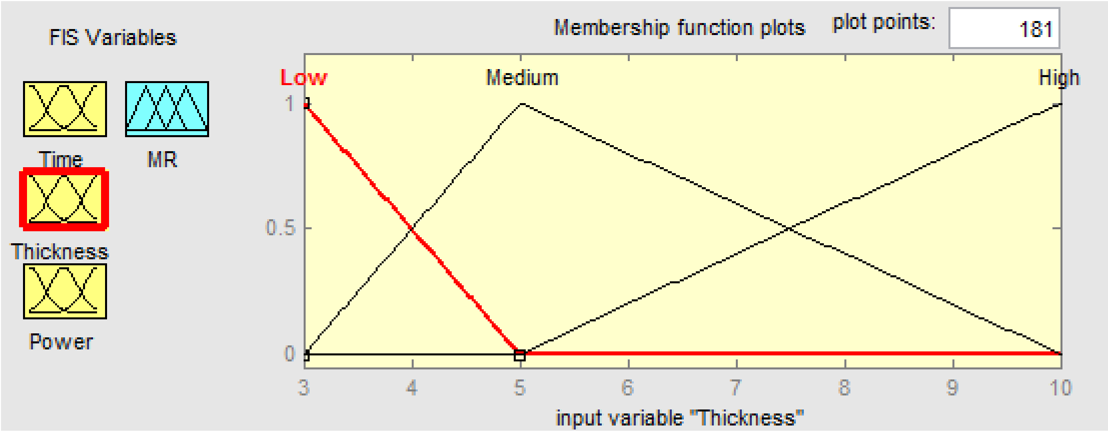


Fig.3.Membership functions for the thickness(mm)

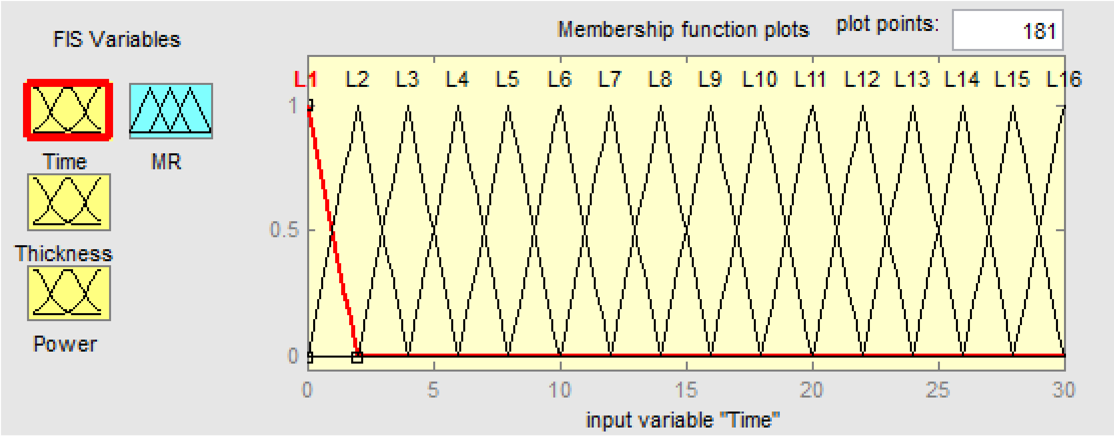


Fig.4.Membership functions for the time(min)

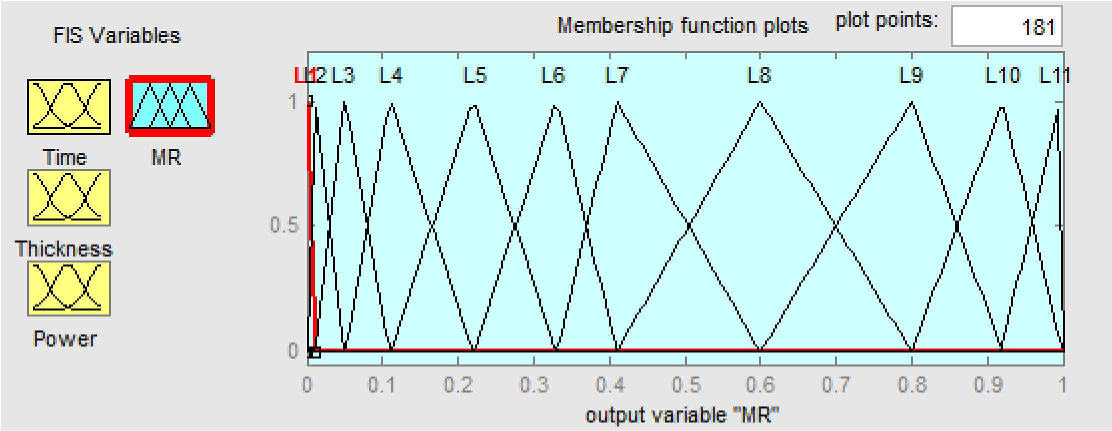


Fig.5.Membership functions for the MR

Trigonometric functions were used for adjusting four variables, time thickness power and moisture ratio A trigonometric membership function with three parameters {a, b, c} is defined as relation 4.

$$f(x;a,b,c)=\begin{cases}0, & x<a\\ \frac{x-a}{b-a}, & a\le x\le b\\ \frac{c-x}{c-b}, & b\le x\le c\\ 0, & c\le x\end{cases} \qquad (4)$$

The fuzzy system is implemented using some fuzzy inference system properties in Table 1.

Table 1: some properties of MFIS

MFIS properties	Method
Decision method for fuzzy logic operators AND	"MIN"
Decision method for fuzzy logic operators OR	"MAX"
Implication method	"MIN"
Aggregation method	"MAX"
Defuzzification	"CENTROID"

Figure 6 shows mamdani model with three inputs time power and thickness as well as one output moisture ratio (MR) applied for melon pieces drying.

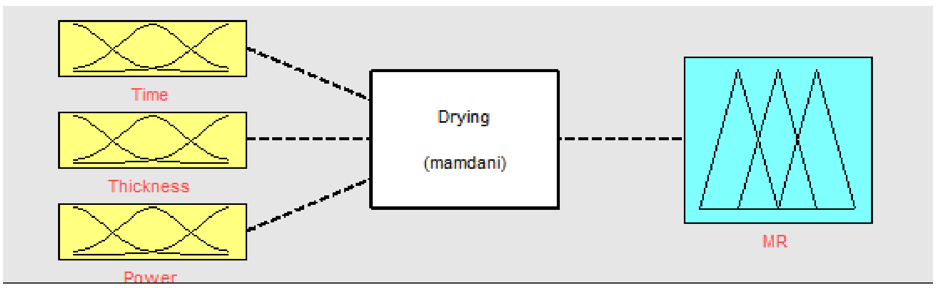


Fig.6. The mamdani fuzzy inference system (MFIS) for predicting the MR

Then fuzzy rules between input and output variables were defined. Totally 58 IF-THEN rules with the operator AND were obtained for melon pieces drying of which 17 rules are presented in figure 7.

1. If (Time is L1) and (Thickness is Low) and (Power is Low) then (MR is L11) (1)
2. If (Time is L2) and (Thickness is Low) and (Power is Low) then (MR is L10) (1)
3. If (Time is L3) and (Thickness is Low) and (Power is Low) then (MR is L9) (1)
4. If (Time is L4) and (Thickness is Low) and (Power is Low) then (MR is L9) (1)
5. If (Time is L5) and (Thickness is Low) and (Power is Low) then (MR is L8) (1)
6. If (Time is L6) and (Thickness is Low) and (Power is Low) then (MR is L7) (1)
7. If (Time is L7) and (Thickness is Low) and (Power is Low) then (MR is L6) (1)
8. If (Time is L8) and (Thickness is Low) and (Power is Low) then (MR is L4) (1)
9. If (Time is L9) and (Thickness is Low) and (Power is Low) then (MR is L3) (1)
10. If (Time is L10) and (Thickness is Low) and (Power is Low) then (MR is L3) (1)
11. If (Time is L11) and (Thickness is Low) and (Power is Low) then (MR is L2) (1)
12. If (Time is L1) and (Thickness is Medium) and (Power is Low) then (MR is L11) (1)
13. If (Time is L2) and (Thickness is Medium) and (Power is Low) then (MR is L11) (1)
14. If (Time is L3) and (Thickness is Medium) and (Power is Low) then (MR is L10) (1)
15. If (Time is L4) and (Thickness is Medium) and (Power is Low) then (MR is L9) (1)
16. If (Time is L5) and (Thickness is Medium) and (Power is Low) then (MR is L9) (1)
17. If (Time is L6) and (Thickness is Medium) and (Power is Low) then (MR is L8) (1)

Fig 7- some of fuzzy rules applied for melon pieces drying

RESULTS AND DISCUSSION

Figure & shows the output of fuzzy inference system in MATLAB software for prediction of moisture ratio of melon pieces drying. For example if the values of input variables i. e. drying time thickness of dried melon piece and microwave power were 20 min 3mm and 200w respectively then the values of output variables, i. e. moisture ratio would be 0.02, belonging to language variable (L2).

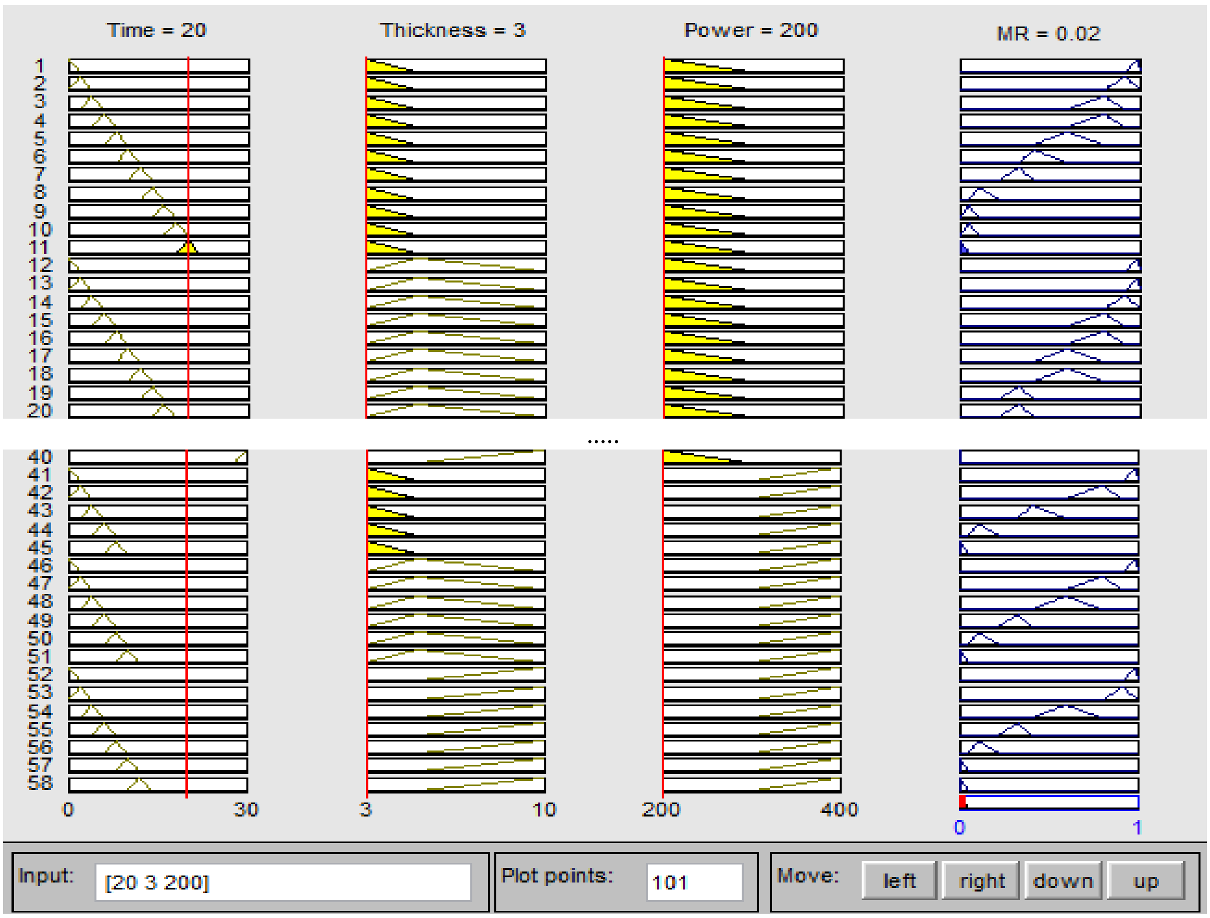


Fig.8.Moisture Ratio with centroid defuzzification

Controlling levels between input variables of melon pieces drying with IF-THEN rules are presented in fig. 9, 10, and 11. As shown in figure 9, moisture ratio decreases as the drying time increases and the thickness of dried melon piece decreases.

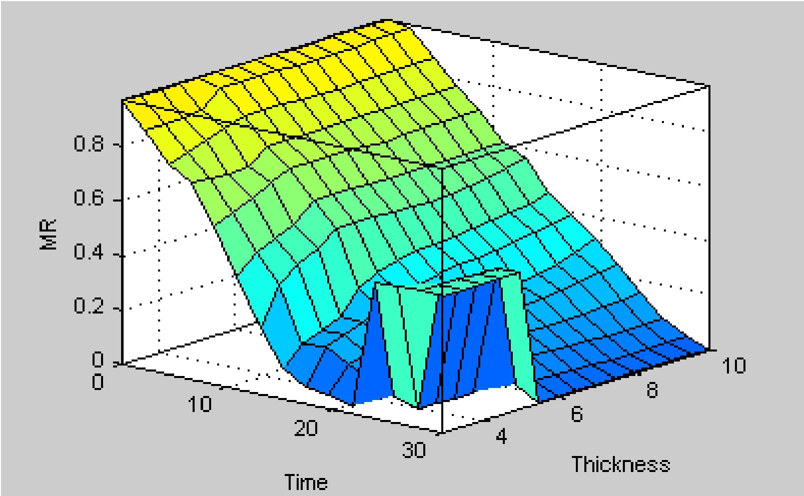


Fig.9. A surface graph representing the interactions between Thickness , Time and MR

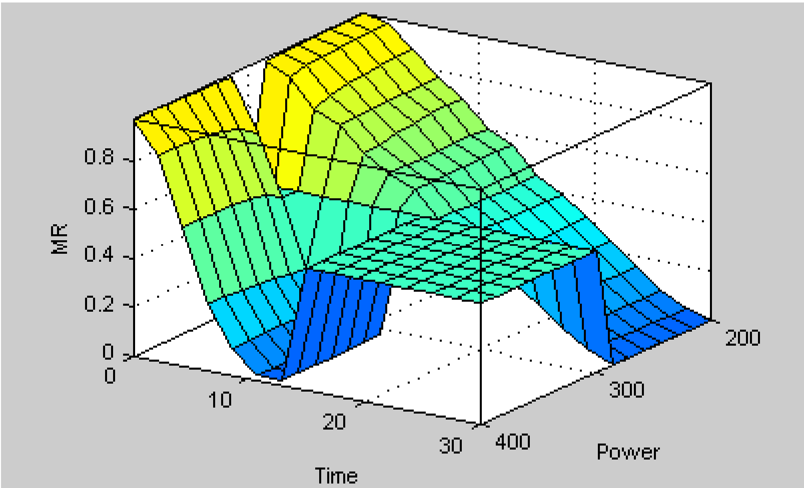


Fig.10. A surface graph representing the interactions between Time , Power and MR

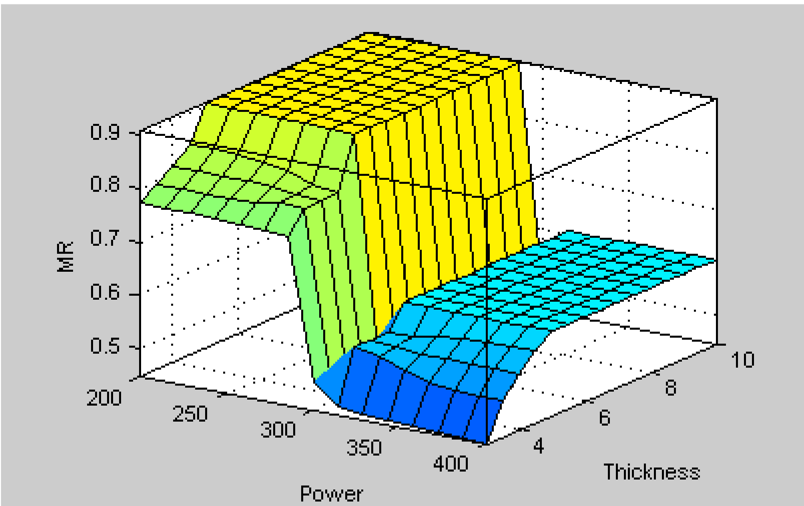
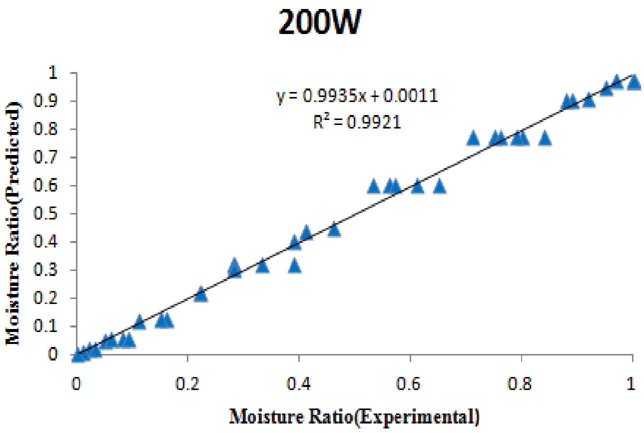
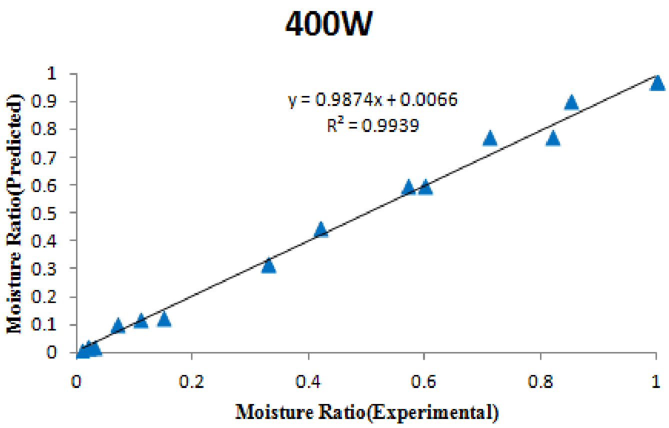


Fig.11. A surface graph representing the interactions between Thickness , Power and MR

Analysis diagram of sensitivity of the predicted values of MR by MFIS vs. empirical data revealed that the data was distributed completely randomized around the regression line with a explanation coefficient higher than 0.987 confirming the accurate assessment of predicting MR of dried melon pieces by MFIS (figure 12).
Also MFIS models achieved an average prediction error of viscosity of only 7.7%.



(A)



(B)

Fig.12.Correlation between the experimental data and MFIS model for prediction of moisture ratio(A) microwave power 200 W(B) microwave power 400 W

CONCLUSION

Given the applications of regression models for drying process, it could be said that regression model is merely a simple mathematical relation which only shows the variations of moisture ratio as a function of time base on a set of coefficients. It will never be able to determine non-linear complicated relationship between input and output variables of complex processes such as food drying. The results demonstrated that MFIS model would be acceptable for prediction of kinetics of agricultural products drying influenced by different complicated variables. These models are capable of generating non-linear complicated relations between input and output variables as well as determining all interactions of input variables.

Also this study may be the base of other studies on related subjects and further research may be focused on different parameters. This system can be further developed by adding intelligent and genetic algorithm.

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