



# Techno-Science

Scientific Journal of Mehmet Akif Ersoy University  
www.dergipark.gov.tr/sjmakeu

Original  
Research  
Article

hosted by  
**Turkish  
JournalPark**  
ACADEMIC

## Determination of the Osmotic Dehydration Parameters of Mushrooms using Constrained Optimization

Ihsan PENÇE<sup>1\*</sup> , Melike ŞİŞECİ ÇEŞMELİ<sup>2</sup> , Ramazan KOVACI<sup>2</sup> 

<sup>1</sup> Department of Computer Engineering, Burdur Mehmet Akif Ersoy University

<sup>2</sup> Department of Management Information Systems, Burdur Mehmet Akif Ersoy University

### ARTICLE INFO

#### Article History

Received : 29/07/2019  
Revised : 30/12/2019  
Accepted : 30/12/2019  
Available online : 30/12/2019

#### Keywords

Constrained optimization, IOT, Mushroom, Netduino, Osmotic dehydration.

### ABSTRACT

*To keep and transport the agricultural products have importance especially in terms of health. These products have to be kept properly so as to transport distant places. Recently, Osmotic Dehydration Technology has become more important in keeping the products well for a longer time and among the other food dehydration methods it provides better color, flavor, and nutritiousness. In this study, it is studied on the drying of mushrooms with osmotic dehydration method which is also one of the most significant export commodities in Turkey and determination of the best dehydration parameters is carried out using optimization. For optimization process, a heuristic method is used and internet of things based prototype design which can control the system automatically is formed.*

## 1. INTRODUCTION

To keep and transport the agricultural products in a good light has become an important issue with regard to the possibility of food spoilage in a shorter period of time and human health risk. In order to preserve the food and extend the consumption life as much as possible with the developments and technology throughout the human history, various methods such as dehydration, freezing, salt-cured or canning have been used. Turkey is a fertile country with a wide range of agricultural products. Therefore, exporting the agricultural products is so significant in terms of national economy. Truffle mushroom, which is the most expensive mushroom in the world with 500 - 3000 Euro per kilo, is grown in Bucak, Burdur due to the proper climate conditions. For Turkey, production, storage, dehydration and logistics of truffle mushroom have an increasing importance in terms of economic aspects.

Although mushrooms are generally consumed as fresh, recently, they have been consumed after dried under proper conditions. 90% of the mushrooms' total weight is water. Mushroom requiring high energy for drying is preferred since it completely preserves its nutritional values after drying. Like mushrooms, various products such as tomato, apricot, plum, cherry, blueberry, mango, coconut, Asian persimmon, apple, and grape are also dried. It is so important to dry the product properly in order to eliminate the risk of being waste due to human health, energy and time consuming, improper drying of the product. The process of mushroom drying is affected by various factors. Some of these factors are the type, thickness, moisture content, and temperature of mushroom, air circulation, moisture diffusion, drying method and oven structure [1]. During drying process, the color, structure, and taste of mushroom change and therefore various parameters should be taken into consideration during process.

Although solar drying has been preferred for centuries due to being free and accessible, other systems are needed owing to taking a long time, hygiene problems and poor quality of dried food. Osmotic Dehydration is a process during which fruits and vegetables are placed into concentrated solution and then dehydrated. Besides water loss, particular molecules dissolved due to the concentration difference between osmotic solution and the product are diffused and then added to the product. Since it provides better color, flavor and nutritiousness than the other food drying methods, Osmotic Dehydration

\* Corresponding Author: [ihsanpence@mehmetakif.edu.tr](mailto:ihsanpence@mehmetakif.edu.tr)

To cite this article: Pençe, İ., Şişeci Çeşmeli, M., Kovacı, R., (2019). Determination of The Osmotic Dehydration Parameters of Mushrooms Using Constrained Optimization. Techno-Science, vol. 2, no. 4-Special Issue p. 77-83.

Technology is preferred especially by bakeries and ice cream industry. Furthermore, mountaineers, children and soldiers prefer the products dried using Osmotic Dehydration Technology more [2].

In recent years within the context of Industry 4.0, Artificial Intelligence techniques in agriculture have been a significant issue to be emphasized. With the help of Artificial Intelligence techniques, productivity of the agricultural products can be increased, harmful and unhealthy products can be detected, various problems such as automatic harvesting, irrigation, disinfection, cleaning, and drying can be solved without the need for human. Within this scope, machine instruction techniques for optimization of parameters of the drying systems have become an important subject studied on by the researchers.

Several Artificial Intelligence examples applied to each period of agricultural products can be seen in literature. Among these studies, some of them using drying methods on agricultural products can be stated in this order: in his study, Çınar [3] mentioned about basic principles, mechanism of the osmotic dehydration method and its practices in food industry. Mehta et al. [4] used response surface methodology in order to analyze the effect of a specific solution temperature and osmosis duration values on water loss and salt gain for salty water concentration. They stated that they estimated optimum working conditions with multiple regression and analysis of variance (ANOVA). Karimi et al. [5] stated that they carried out optimization of objective functions with artificial neural network (ANN) and response surface technique for an air drying process. Şevik et al. [1] indicated that in their studies, they designed a heat-aided mushroom drying system with solar energy and then modeled moisture content, humanity rate and drying rate parameters with ANN. Sun [6] mentioned about food processing and storage technologies in his book. Yeomans [7] carried out studies in order to determine the optimum parameter settings of mushrooms during osmotic dehydration process by using firefly algorithm. By changing the parameter values of algorithm, the effects of it on the solution quality were analyzed. In another study, Yeomans [8] carried out the same tests on daisies instead of mushrooms and analyzed the results. Yıldız et al. [9] stated that in their study they modeled drying performance and kinetics of banana fruit by using ANN method. Gupta et al. [10] presented their observations during osmotic dehydration of button mushroom in their studies. In his thesis Smith [11] aimed to characterize the effect of vacuum on the temperature and concentration of osmotic solution and mass transfer of blueberry. Ahmed et al. [12] examined the osmotic dehydration processes which are used as a popular method in remaining freshness of fruits and vegetables. Bahmani et al. [13] used mathematical models and ANN to define the water loss and salt gain of eggplant during osmotic dehydration. Cao and Yeomans [14] updated the studies with response surface technique which had been carried out to determine the optimum parameter settings during papaya osmotic dehydration process. In his another study, Yeomans [15] emphasized that firefly algorithm had more influence than the other algorithms with regard to calculation. Goula et al. [16] applied ultrasound-aided osmotic dehydration method to shorten the dehydration duration of potatoes. Ramya and Jain [17] mentioned about the factors affecting the osmotic dehydration process and their latest developments. In their studies Akpınar and Daş [18] indicated that they designed air-heated solar collector and modeled moisture content, humanity rate and drying rate parameters with ANN to dry the mushroom product. Das and Arora [19] aimed to develop an alternative drying system for button mushroom and carried out a drying process with microwave. Anshu and Anju [20] evaluated the findings obtained from sun-drying and cabinet drying methods using osmotic dehydration in order to improve the quality of oyster mushroom. González-Pérez et al. [21] examined shrinkage and deformation behavior and mass transfer during osmotic dehydration of white mushroom.

Differently from the previous studies, in this study parameters of osmotic dehydration which is the best method for drying of mushroom product are optimized for the best values and internet of things (IOT) based prototype system is developed for automatic control of the system. In order to ensure the system to work real-time, global optimization method based on clustering and parabolic approximation (GOBC-PA) which provides fast and efficient results for optimization in literature is used.

## 2. MATERIALS AND METHODS

In this study, Imanirad and Yeomans's [22] mathematical modeling is used to determine the mushroom's osmotic dehydration parameters to be optimized. In the process when salt water solution is used for mushroom dehydration, salt is carried to the mushroom and mushroom dehydrates. The most important three factors that affect the osmotic dehydration process are temperature of salt water solution, salt rate of solution, and osmosis duration. According to the optimum values of these parameters, the highest dehydration and proper salt rate on mushroom can be achieved. Mathematical model optimized in this study have some limitations and a constrained heuristic algorithm has been used for the best solution. Furthermore, it is informed about prototype stage of an IOT based system so as to enable the process to be operated real-time and automatically. One of the biggest problems faced during real time applications is time. For a momentary evaluation, the relevant problem has to be solved in a short period of time and then solution stages have to be applied. Therefore, in this study as a heuristic algorithm GOBC-PA [23] which gives better results in terms of rate and success ratio in comparison with other methods is used. In order to carry out constrained optimization, penalty function is added to the method.

The values of mushroom water loss (WL) and mushroom salt gain (SG) as a result of mathematical statement formed by Imanirad and Yeomans [22] for osmotic dehydration of mushrooms are given at Equation (1) and Equation (2), respectively.

$$WL = -19.58 + 0.13t + 1.7c + 0.98d + 0.00357td + 0.00673cd - 0.0343c^2 - 0.0106d^2 \quad (1)$$

$$SG = -13.87 + 0.11t + 1.09c + 0.14d - 0.000973t^2 - 0.0296c^2 - 0.00129d^2 \quad (2)$$

While it is required that WL value calculated at Equation (1) should be maximum, SG value calculated at Equation (2) is needed to be at a certain value when the taste of mushroom is also taken into consideration. Among the independent variables appeared at both equations temperature of  $t$  salt water solution is stated in °C, salt intensity of  $c$  salt water solution is stated in %, and  $d$  means osmosis duration in minute. While it is tried to minimize  $t$ ,  $c$ , and  $d$  forming variables in mathematical model, it is demanded that WL value calculated should be maximum and SG value should be equivalent to 2.98 values. In order of priorities primary output values are WL and SG and in terms of cost and energy saving,  $t$ ,  $c$  and  $d$ 's having low values form the second primary field. It is required that in order to find the optimum values of the relevant variables, limits or, in other words, the relevant constraints which may be WL and SG values to be calculated with these variables have to be taken into consideration.

Variables constraints are given in Equation (3).

$$\begin{aligned} 26.18 &\leq WL \leq 45.04 \\ 0.33 &\leq SG \leq 3.24 \\ 35 &\leq t \leq 55 \\ 10 &\leq c \leq 20 \\ 30 &\leq d \leq 60 \end{aligned} \quad (3)$$

As is understood also from the constraints in case that salt gain of mushroom is 2.98, its  $t$ ,  $c$ , and  $d$  values have to be determined in order that water loss of mushroom reaches 45.04 values which is the maximum value. Furthermore, since these values are also required to be minimum, the problem to be optimized is formed to the formula in Equation (4).

$$Min. \quad W_1(t - 35) + W_2(c - 10) + W_3(d - 30) + W_4(45.04 - WL) + W_5(|2.98 - SG|) + P \quad (4)$$

The terms W at Equation (4) mean weights and are used to increase the importance of variables.

P value is added to the mathematical statement so as to ensure the statement minimized to achieve the limits of Equation(3). P value is calculated as shown at Equation (5).

$$P = \begin{cases} 0, & WL, SG, t, c, d \in Equation (3) \\ 1E4, & otherwise \end{cases} \quad (5)$$

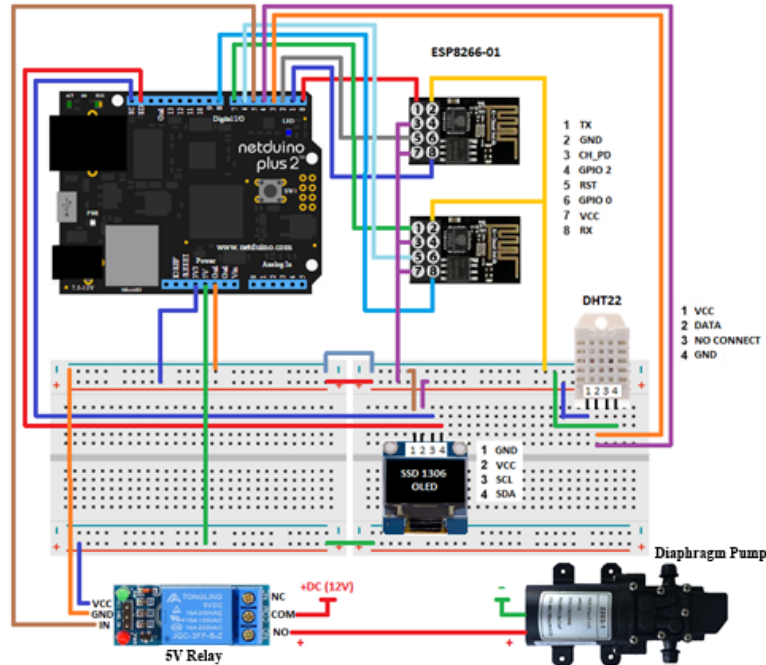
It is seen that P value is zero in case that the relevant constraints at Equation (5) are observed and it is consistent with the minimum value at Equation (4). GOBC-PA algorithm used for optimization in the study executes the process of clustering by using the values of population and their objective scores. New populations which will form the generation are selected by these cluster centers and minimum and maximum points are found with clusters' parabolic curve fitting. Besides that the method has heuristic feature, it provides a big advantage in terms of rate and performance against other algorithms [23]. Since GOBC-PA method establishes the population forming mechanism around the cluster centers, it enables to reach local and global minimum points.

### 3. EXPERIMENTAL STUDIES

In this study, an IOT based system which has various sensors in order to enable the osmotic dehydration process to be control real-time is also advised. The system that is still a prototype checks  $t$ ,  $c$ , and  $d$  values automatically which compose optimization parameters and thereby maintains continuity. As an IOT system, Netduino platform allowing C# programming language is used. Temperature value to be measured currently and  $t$  value will be able to be checked and  $c$  value will be determined after regulating water volume of salt water solution with the help of diaphragm water pump. With the help of the system that can save these values to the server's database wirelessly by means of Wi-Fi module after measuring the

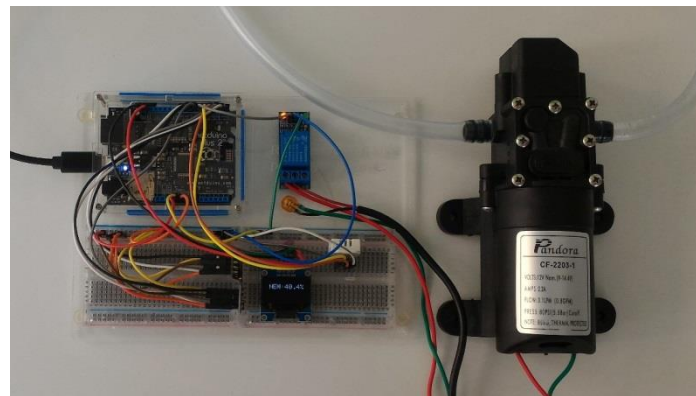
relevant values,  $d$  value signifying osmosis duration can be checked by also using server clock. The circle diagram of the proposed system is given at Fig 1.

In the system seen at Fig 1, DHT sensor family is utilized to measure the temperature change, ESP8266 Wi-Fi module is used to publish the data obtained on internet wirelessly. I2C Oled screen module is used so as to monitor the values measured on the prototype. Furthermore, a single-channel 5V Relay is triggered so as to enable diaphragm water pump to open and close.



**Fig 1.** Circuit diagram of IOT system.

An actual design view of the developed IOT based prototype system is seen in Fig 2.



**Fig 2.** Actual view of IOT system.

As also seen in Fig 2, the developed system can be controlled remotely or programmed automatically with the help of internet connection and it is able to control the drying processes.

#### 4. RESULTS AND DISCUSSION

In this study it is tried to optimize the osmotic dehydration process. Since Bucak district, Burdur province where the study was carried out has an important place in mushroom production, especially in truffle mushrooms; mushroom product has been examined in this study. GOBC-PA method which is a heuristic algorithm is used in this study for determining the optimal parameters required for osmotic dehydration of mushrooms. The method is run 10 times to test the success rate and standard deviation values are evaluated. At the end of the tests it is concluded that 60 populations and 200 iteration parameters decreased the standard deviation and provided more constant results. When Equation (4) tried to be minimized and the relevant constraints are analyzed, it is apparent that due to the theoretical limitations on  $WL$  and  $SG$  values, it is not

possible to make improvement for these values according to the results of Imanirad and Yeomans [22]. However, improvement of  $t$ ,  $c$ , and  $d$  parameters which is so significant economically will be beneficial in terms of time and cost. In this study, two different scenarios are emphasized when it is taken into consideration which of the parameters at Equation (4) is more important; a proper result is obtained after changing  $W$  coefficients at the equation.

In the first scenario it is assumed that  $t$ ,  $c$ , and  $d$  parameters are equal; all of these three values are decreased. For that purpose, [2, 1, 2, 7.5, 70] are preferred as  $W$  coefficients. In the second scenario [1, 1, 2.8, 7.5, 70] are taken as  $W$  coefficients since to shorten the osmosis duration would be more economic in completion of the process as soon as possible in comparison with other parameters. The average value, standard deviation and algorithm calculation durations of the results obtained for both scenarios are given at Table 1.

**Table 1.** GOBC-PA results of osmotic dehydration parameters

	Temperature (t, °C)	Concentration (c, %)	Duration (d, minutes)	Water Loss (WL, %)	Salt Gain (SG, %)	Run Time (second)
<b>GOBC-PA (V1)</b>	51.465±0.09	19.363±0.007	48.658±0.089	45.04±0.002	2.98±1.5E-04	2.32±0.25
<b>GOBC-PA (V2)</b>	55.00±0.00	18.894±0.018	46.191±0.038	45.04±6E-04	2.98±0.001	2.34±0.24

As seen in Table 1, the optimum result for  $WL$  and  $SG$  values together with the low standard deviations in all parameters have been reached. Running time of algorithm is 2.3 seconds and it is appropriate for real-time systems. According to the values that Imanirad and Yeomans [22] received and mentioned as the best results, better results are obtained in this study. Accordingly, in the first scenario total variable values are tried to be decreased. While 2.578 °C temperature is gained, there is a 0.332% and 1.881 minute-loss respectively in intensity and osmosis duration values. When the total gain is evaluated, it is seen that the improvement rate is 0.365; when the intensity is taken into consideration it is seen that the improvement rate is 0.697.

In the second scenario especially osmosis duration is tried to be decreased. Duration value has gained 0.5856 minute, intensity value has gained 0.137% and temperature value has lost 0.957°C. When the total value is examined, to shorten the duration more than 0.5 minute is regarded as a factor that decreases all cost although there is a loss at the level of 0.234. The results obtained from both scenarios and the comparisons to the other studies are given at Table 2.

**Table 2.** GOBC-PA results of osmotic dehydration parameters Optimum values of osmotic dehydration parameters

	Temperature (t, °C)	Concentration (c, %)	Duration (d, minutes)	Water Loss (WL, %)	Salt Gain (SG, %)
<b>Mehta et al. (2012)</b>	44.89	16.53	47.59	40.55	2.98
<b>Imanirad and Yeomans (2015)</b>	54.043	19.031	46.777	45.04	2.98
<b>KTGO-PY (V1)</b>	51.465	19.363	48.658	45.04	2.98
<b>KTGO-PY (V2)</b>	55.00	18.894	46.191	45.04	2.98

Determination of the most optimum values in Table 2 also enables a real-time application to be controlled by using these values. For this purpose, an IOT based prototype system that controls osmotic dehydration duration of mushrooms and keeps the parameters at the most optimum values has been designed as shown at Fig 2. The system seen at Fig 2 is able to control temperature, water rate and duration and keep the relevant records on a database at a remote server. Thanks to the internet connection through Wi-Fi module, the system can maintain online status as required for IOT system. It can control the water ratio with a pump on the prototype and thereby control the intensity of solution. Furthermore it can keep temperature of solution under control with a temperature sensor. It is planned to develop the prototype design and to turn into an industrial system that is waterproof and control all process automatically.

## 5. CONCLUSIONS

As a result of rapidly-developing technology in our world, several production fields are going to transfer autonomous control and production within the scope of Industry 4.0. Agricultural industry will also be affected by this process and thereby, food crops will be produced, disinfected and picked without the need for manpower. After that process, the second stage is to transfer these products to consumers and to improve the storage conditions. In this study it is tried to find the most appropriate values of the parameters of Osmotic Dehydration process used to store mushroom under the best conditions. Constrained optimization of the relevant parameters is carried out by using a heuristic algorithm GOBC-PA and better results than Imanirad and Yeomans's [22] results are obtained. According to GOBC-PA's results, at the first scenario there is an improvement at the rate of 0.365 in terms of total gain, and when the intensity value is not taken into consideration, there

is an improvement at the rate of 0.5856. At the second scenario, the process is completed earlier by providing 0.5856 minute gain in terms of duration and thereby, it is proved that it is possible to reduce the cost.

Besides that IOT based prototype that is able to control Osmotic Dehydration process automatically in the light of Industry 4.0 has been developed. For the further studies it is planned to design a real system by enriching the prototype with waterproof sensors etc.

## ACKNOWLEDGEMENT

This study is an extension of "Determination of The Osmotic Dehydration Parameters of Mushrooms Using Constrained Optimization" presented in the International Conference on Technology and Science (Techno-Science 2018).

## REFERENCES

- [1]. Şevik, S., Aktaş, M., Doğan, H. & Koçak, S. (2013). Mushroom drying with solar assisted heat pump system. *Energy Conversion and Management*, 72, 171-178.
- [2]. Indian Institute of Horticultural Research, Indian Council of Agricultural Research (ICAR-IIHR), (02.10.2018). Retrieved from <https://www.iihr.res.in/post-harvest-technologies>.
- [3]. Çınar, İ. (2009). Osmotic dehydration, mechanism and applications. *The Journal of Food*, 34(5), 325-329.
- [4]. Mehta, B. K., Jain, S. K., Sharma, G. P., Mudgal, V. D., Verma, R. C., Doshi, A., & Jain, H. K. (2012). Optimization of osmotic drying parameters for button mushroom (*Agaricus bisporus*). *Applied Mathematics*, 3(10), 1298.
- [5]. Karimi, F., Rafiee, S., Taheri-Garavand, A., & Karimi, M. (2012). Optimization of an air drying process for *Artemisia absinthium* leaves using response surface and artificial neural network models. *Journal of the Taiwan Institute of Chemical Engineers*, 43(1), 29-39.
- [6]. Sun, D. W. (2014). *Emerging technologies for food processing*. Elsevier, London: Academic.
- [7]. Yeomans, J. S. (2014). A parametric testing of the firefly algorithm in the determination of the optimal osmotic drying parameters of mushrooms. *Journal of Artificial Intelligence and Soft Computing Research*, 4(4), 257-266.
- [8]. Yeomans, J. S. (2015). Determining optimal osmotic dehydration process parameters for papaya: a parametric testing of the Firefly Algorithm for Goal Programming optimization. *Scientia Agriculturae*, 10, 127-136.
- [9]. Yıldız, A. K., Polatçı, H., & Uçun, H. (2015). Drying of the banana (*Musa cavendishii*) fruit and modeling the kinetics of drying with artificial neural networks under different drying conditions. *Journal of agricultural Machinery Science*, 11(2), 173-178.
- [10]. Gupta, P., Bhat, A., Chauhan, H., Ahmed, N., & Malik, A. (2015). Osmotic dehydration of button mushroom. *International Journal of Food and Fermentation Technology*, 5(2), 177.
- [11]. Smith, A. M. (2015). *Optimization of pulsed-vacuum osmotic dehydration of blueberries*. (Doctoral dissertation), West Virginia University.
- [12]. Ahmed, I., Qazi, I. M., & Jamal, S. (2016). Developments in osmotic dehydration technique for the preservation of fruits and vegetables. *Innovative Food Science & Emerging Technologies*, 34, 29-43.
- [13]. Bahmani, A., Jafari, S. M., Shahidi, S. A., & Dehnad, D. (2016). Mass transfer kinetics of eggplant during osmotic dehydration by neural networks. *Journal of food processing and preservation*, 40(5), 815-827.
- [14]. Cao, T., & Yeomans, J. S. (2017). An evolutionary firefly algorithm, goal programming optimization approach for setting the osmotic dehydration parameters of papaya. *Journal of Software Engineering and Applications*, 10(2), 128.
- [15]. Yeomans, J. S. (2018). Computing optimal food drying parameters using the firefly algorithm. *GSTF Journal on Computing (JoC)*, 4(1).
- [16]. Goula, A. M., Kokolaki, M., & Daftsiou, E. (2017). Use of ultrasound for osmotic dehydration. The case of potatoes. *Food and Bioproducts Processing*, 105, 157-170.
- [17]. Ramya, V., & Jain, N. K. (2017). A Review on osmotic dehydration of fruits and vegetables: an integrated approach. *Journal of Food Process Engineering*, 40(3), e12440.
- [18]. Akpınar, E. K., & Daş, M. (2018). Mushroom drying in air heated solar collector drying system and modeling of drying performance with artificial neural network. *Erzincan University Journal of Science and Technology*, 11(1), 23-30.
- [19]. Das, I., & Arora, A. (2018). Alternate microwave and convective hot air application for rapid mushroom drying. *Journal of Food Engineering*, 223, 208-219.
- [20]. Anshu, S., & Anju, B. (2018). Effect of osmotic dehydration on quality of oyster mushrooms. *IJCS*, 6(2), 1601-1605.

- [21]. González-Pérez, J. E., López-Méndez, E. M., Luna-Guevara, J. J., Ruiz-Espinosa, H., Ochoa-Velasco, C. E., & Ruiz-López, I. I. (2019). Analysis of mass transfer and morphometric characteristics of white mushroom (*Agaricus bisporus*) pilei during osmotic dehydration. *Journal of Food Engineering*, 240, 120-132.
- [22]. Imanirad, R., & Yeomans, J. S. (2015). Fireflies in the fruits and vegetables: combining the firefly algorithm with goal programming for setting optimal osmotic dehydration parameters of produce. In *Recent Advances in Swarm Intelligence and Evolutionary Computation* (pp. 49-69). Springer, Cham.
- [23]. Pence, I., Cesmeli, M. S., Senel, F. A., & Cetisli, B. (2016). A new unconstrained global optimization method based on clustering and parabolic approximation. *Expert Systems with Applications*, 55, 493-507.
- 

Techno-Science Paper ID: 598077

