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RESEARCH PAPER

Drying and Rehydration Characteristics of Microwave Dried *Mytilus edulis*

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Abstract

Rehydration is a critical factor in the processing and consumption of dried food products. This study investigated the kinetics of microwave drying and rehydration of blue mussels (*Mytilus edulis*) in the range of 140 - 350 W power levels and 20 - 40°C temperatures, respectively. The drying data were utilized to calculate effective diffusivity coefficients (D_{eff}) and activation energy (E_A), while rehydration rates and time were also determined. Mathematical modeling was employed to describe the drying and rehydration processes, and the performance of different models was evaluated. The drying process took between 13 - 4.5 minutes, while rehydration was concluded within 360 - 480 minutes. The D_{eff} values ranged from 1.22 - 3.91×10^{-7} m^2/s, and the E_A was calculated as 11.417 kW/kg. Rehydration rates resulted in 0.000061 - 0.000126 g/g×min at the highest 40°C and 0.000018 - 0.000032 g/g×min at the lowest 20°C. The drying and rehydration processes were best described by the Alibas model among 11 models and the Two-Term Exponential model among 2 models, respectively. Overall, this study aims to provide valuable insights into the kinetics of microwave drying and rehydration of blue mussels, which can help optimize the processing and preservation of dried food products before consumption.

Introduction

Drying is an important method of preserving food as it removes moisture that promotes the growth of microorganisms and enzymes that can cause food spoilage and reduce the shelf life of food (Aravindakshan et al., 2021). Microwave ovens (MW) are a popular alternative to conventional drying methods that use electromagnetic radiation in the microwave frequency range to heat, cook, or dry food. Microwave energy penetrates the food, causing the water molecules in it to release rapidly and produce heat. It provides fast and even heating of food due to direct heating of food without heating the surrounding air. It leads to higher-quality food due to homogeneous drying and reduces the risk of contamination and spoilage (Guzik et al., 2022; Rattanadecho & Makul, 2016).

Seafood is consumed at increasing rates worldwide due to its protein content, nutritional value, and distinctive taste and aroma. Studies have shown that seafood is a rich source of beneficial fatty acids, vitamins, and minerals that can improve heart health, brain function, and overall health and well-being (Govzman et al., 2021). The world's largest seafood producers vary in the type of seafood produced. However, some of the largest seafood producers in recent years are China, Indonesia, the United States, Thailand, Vietnam, and India. According to the Food and Agriculture Organization of the United Nations (FAO), in 2020, China was the world's largest producer of seafood with a production of approximately 17.5 million tons (FAO, 2021).

The blue mussel (*Mytilus edulis*) is a species of bivalve mollusk commonly found on the Atlantic and

Pacific Oceans coasts. Capable of adapting to a wide variety of environmental conditions, blue mussels are generally found in intertidal and subtidal environments from the Arctic to the subtropics (Brenner et al., 2014). In terms of nutritional content, blue mussels are a rich source of protein, omega-3 fatty acids, and other essential nutrients, making them a popular and healthy food choice for many consumers (Chen et al., 2021; Grkovic et al., 2019). Regarding blue mussels, some of the biggest producers are New Zealand, Canada, and the Netherlands. Blue mussel production has increased globally in recent years, with a total production of over 1.1 million tons reported in FAO 2020 (FAO, 2021).

Rehydration is the process of adding moisture back to dried food, restoring its original texture and flavor, and increasing its usability in a variety of applications. The rehydration process is affected by several factors such as temperature, time, and the addition of salts, sugars, and other substances (Aravindakshan et al., 2021). This process is an important factor in dried food processing as it affects the sensory properties, nutrient content, and safety of the rehydrated food product (Ansari et al., 2015).

The rehydration process is evaluated in terms of rehydration rate, final moisture content, and quality characteristics of the rehydrated food, such as texture and taste. Temperature and time are the main factors in determining the evaluation parameters of rehydration processes. While the appropriate temperature-time relationship is used for the optimization of the rehydration process, mathematical models are used for the mathematical expression of the process (Lopez-Quiroga et al., 2020).

Numerous studies on rehydration have shown its benefits in regards to dry food intake and usability. Examples of vegetables and fruits that have been the focus of studies include pumpkin (Rojas et al., 2019), wolfberry (Zhou et al., 2020), apple slices (Kağan Tepe & Tepe, 2020), onion slices (Maftoonazad et al., 2022), green olives (Aydar, 2021), kiwifruit (Bhat et al., 2022), potato slices (Rojas et al., 2019). When it comes to seafood, studies have been conducted on products such as grass carp fillets (Ma et al., 2017), squid cubes (H. Chen et al., 2013), shrimp (Castañeda-López et al., 2021), sea cucumber (Jiang et al., 2022), but the number of studies and variety of products studied is limited. The purpose of this study was to investigate the rehydration of blue mussels that have been dried using different energy levels in a microwave oven for varying rehydration temperatures. It is well known that there have been numerous studies conducted on rehydrating dried fruits and vegetables, however, the number of studies on rehydrating seafood is limited in comparison. The study aimed to determine the rehydration behavior of blue mussels through the use of mathematical models, which will analyze the results of the drying process. The end goal is to gain a better understanding of how different energy levels of drying and temperatures of rehydration affect the rehydration of blue mussels and to provide insights that can be applied to other similar studies in the future.

Materials and Methods

Drying Experiments and Kinetics

Frozen mussels were purchased from a local supermarket in Istanbul, Turkey, in October 2018. The frozen mussels were brought to +4 °C in the refrigerator just before the experiments and then to room temperature in a desiccator. The beards of the mussels were cleaned. Moisture content was determined in a Nuve EV-018 model oven (Nüve, Ankara, Turkey) at 105 °C for 3 hours according to the Association of Official Analytical Chemists procedure (AOAC, 2016). For the drying process, 5 mussels with a diameter of 3.7 ± 0.3 cm and 3.5 ± 0.5 g weighed using Radwag AS 220.R2 digital balance (Radwag, Radom, Poland) were selected. A household type Delonghi MW205S microwave oven (Delonghi, Treviso, Italy) was used for drying at energy levels of 140, 210 and 350 W. The samples were taken out of the microwave oven and weighed at 60 second intervals, and the drying process was continued by putting them back into the microwave oven. The weighing process was completed in 5 seconds hence the margin of error was kept to a minimum. The drying process was terminated when the moisture percentage of the samples fell below 7% by mass.

The drying rate (DR, kg water/kg dry matter × min), moisture content (M, kg water/kg dry matter), and moisture ratio (MR, dimensionless) can be determined using Equations 1-3, based on the moisture and dry matter amounts of the sample obtained from the drying experiments.

$$M = \frac{m_w}{m_d} \tag{1}$$

$$MR = \frac{\mathrm{M_t} - \mathrm{M_e}}{\mathrm{M_0} - \mathrm{M_e}} \tag{2}$$

$$DR = \frac{\mathrm{M_{t+dt}} - \mathrm{M_t}}{\mathrm{dt}} \tag{3}$$

where m_w and m_d refers to water and dry matter content (kg), respectively. M_0, M_t and M_e refers to the moisture content at time zero, at any time, and at equilibrium (kg water/kg dry matter), respectively. $\mathrm{M_{t+dt}}, \mathrm{M_t}$ refers to moisture content at $t + dt$ and time t (kg water/kg dry matter), respectively (Kipcak, 2017; Ozyalcin & Kipcak, 2022).

Effective Moisture Diffusivity and Activation Energy

The drying process substantially takes place in the falling rate period. In this period, moisture diffuses from the center to the surface then to the drying medium.

This mechanism is explained by Fick's second law of diffusion. For substances with spherical coordinates, D_{eff} (m^2/s) values can be calculated with Equation 4 derived from this law. For the applicability of this equation, assumptions are made that the mass transfer only occurs by diffusion, the diffusion coefficient is constant, there is no shrinkage in the sample, and the drying temperature is constant (Kipcak & Doymaz, 2020).

$$\ln(MR) = \ln\left(\frac{6}{\pi^2}\right) - \left(\pi^2 \frac{D_{eff} \cdot t}{R^2}\right) \quad (4)$$

where, t is the drying time (s) and R (m) is the radius of the sample. D_{eff} can be calculated from the slope of the plot of ln(MR) versus time in relation to the sample diameter as in Equation 5 (Maneesh Kumar et al., 2018).

$$D_{eff} = -\left(\frac{slope \cdot R^2}{\pi^2}\right) \quad (5)$$

E_A (kW/kg) can be calculated by Equation 6, which is formed by rearranging the Arrhenius-type equation for the power levels used instead of temperature in the MW process.

$$D_{eff} = D_0 exp\left(-\frac{E_A . m}{P}\right) \quad (6)$$

where D_0 is the pre-exponential factor of the Arrhenius equation (m^2/s), P is MW power (W) and m is sample weight (kg) (Kipcak & Doymaz, 2020).

Statistical Analysis and Mathematical Modelling for Drying

The determination of the optimal mathematical model for MW drying of blue mussels relied on the weighing time and weight values obtained from the corresponding experiments. This process entailed subjecting 11 distinct mathematical models to testing, which was accomplished through the application of the nonlinear regression method utilizing the Lavenberg-Marquardt algorithm in the Statistica 8.0 (StatSoft, Tulsa, USA) program. The equations for the applied mathematical models are given in Table 1. The starting value is 0.1 for the models of Aghbaslo et al., Henderson & Pabis, Lewis, Logarithmic, Page, Parabolic, Verma et al., and Wang & Singh. The initial value for the Alibas model is 0, 1, 0, 1, 0 for the constants a, k, n, b, and g. The initial value for the Jena & Das model is 0, 1, 0, 1 for the constants a, k, b, and c, and the initial value for the Midilli et al model is 0, 1, 0, 1 for the constants a, k, n, and b.

Following the application of mathematical equations utilizing formulas for drying data, the resultant values were analyzed based on the coefficient of determination (R^2), root mean square error (RMSE), and reduced chi-square (χ^2). A model that exhibited the most optimal fit for the drying data was selected based on the criteria of R^2 approaching 1 and χ^2 and RMSE approaching 0. The parameters for the chosen model were calculated using Equations 7 and 8 (Kipcak & Doymaz, 2020).

$$\chi^2 = \frac{\sum_{i=1}^{N}(MR_{exp,i} - MR_{pre,i})^2}{N - z} \quad (7)$$

$$RMSE = \left(\frac{1}{N}\sum_{i=1}^{N}(MR_{pre,i} - MR_{exp,i})^2\right)^{\frac{1}{2}} \quad (8)$$

where MR_{exp} and MR_{pre} denote experimental and predicted values of moisture ratios, respectively. N is the total number of experiments and z is the constant number in the models (Kipcak, 2017).

Rehydration Experiments and Kinetics

MW-dried samples were rehydrated with 1:100 (w/v) water obtained from Liston A1104 model water distiller (Liston LLC, Zhukov, Russia). The process temperature was selected as 20, 30 and 40 °C and the process was carried out without stirring on a Hot plate Magnetic Stirrer (Four E's Scientific, Guangzhou, China) of MI0102003 to keep the temperature constant. The samples undergo rehydration by being submerged in

Table 1. Mathematical model equations for drying (Doymaz et al., 2015; Jahanbakhshi et al., 2020; Kipcak & İsmail, 2021)

Model Name	Model equation
Aghbaslo et al.	$MR = \exp(-k_1 t/(1 + k_2 t))$
Alibas	$MR = a.exp((-ktn) + bt) + g$
Henderson and Pabis	$MR = a \cdot \exp(-kt)$
Jena and Das	$MR = a \cdot \exp(-kt + b\sqrt{t}) + c$
Lewis	$MR = \exp(-kt)$
Logarithmic	$MR = a \cdot \exp(-kt) + c$
Midilli et al.	$MR = a \cdot \exp(-kt^n) + bt$
Page	$MR = \exp(-kt^n)$
Parabolic	$MR = a + bt + ct^2$
Verma et al.	$MR = a \cdot \exp(-kt) + (1 - a).\exp(-gt)$
Wang and Singh	$MR = 1 + \mathrm{at} + \mathrm{bt}^2$

water for 30-minute intervals and the excess water on their surfaces is taken off with coarse filter paper and then weighed. The weighing process is carried out in under one minute and the rehydration process is continued until the sample weights are stabilized.

Rehydration experiments are related to rehydration ratios (or contents) (R_C, dimensionless) and rehydration rate (R_R, g/g×min) were calculated with Equation 9 and 10 (Kipcak, 2017).

$$R_C = \frac{W_t - W_{dry}}{W_{dry}} \quad (9)$$

$$R_R = \frac{R_{c\,(\Delta t+t)} - R_{c\,(t)}}{\Delta t} \quad (10)$$

where W_t and W_{dry} represent the anytime and dry weights (g) of samples and, $R_{c\,(t)}$ and $R_{c\,(\Delta t+t)}$ represent Rc values at any time and at time t + Δt (g/g dry weight).

Statistical Analysis and Mathematical Modelling for Rehydration

To ascertain the most fitting mathematical model for the rehydration of MW-dried blue mussels, the weighing time and weight values obtained from pertinent experiments were analyzed. The analysis was conducted via the application of the nonlinear regression method, utilizing the Lavenberg-Marquardt algorithm within the Statistica 8.0 (StatSoft, Tulsa, USA) software. Two frequently employed mathematical models for food products were tested in modeling the rehydration process. The equations for the applied mathematical models are given in Table 2. The starting value is 0.1 for the models of Peleg and Two-Term Exponential.

The compatibility of models was assessed with R^2, χ^2, and RMSE values with the formulas provided in Equation 11 and 12. Models with R^2 values close to 1 and χ^2 and RMSE values close to 0 were determined to be more compatible with the data (Cox et al., 2012).

$$\chi^2 = \frac{\sum_{i=1}^{N}(RR_{exp,i} - RR_{pre,i})^2}{N - n} \quad (11)$$

$$RMSE = \sqrt{\frac{\left(\sum_{i=1}^{N}(RR_{pre,i} - RR_{exp,i})^2\right)}{N}} \quad (12)$$

where RR_{pre} is the predicted rehydration rate, RR_{exp} is the experimental rehydration rate, and N is the number of experimentals.

Results and Discussion

Drying Experiments and Kinetics Results

The initial moisture content of the mussels was calculated as 66.19% on a wet basis, whereas it was found to be 1.958 kg water/kg dry matter. Drying times were obtained as 13, 7.5, and 4.5 minutes for 140, 210, and 350 W MW power levels. In addition, the initial moisture content, which was 1.958 kg water/kg dry matter, was reduced to 0.096, 0.088, and 0.076 kg water/kg dry matter for 140, 210, and 350 W, respectively. The relationship between moisture content and time; and drying rate and moisture content are shown in Figure 1. As expected, increasing the power transferred to the sample for drying resulted in an increase in the sample's internal energy and a higher mass transfer driving force. This results in lower final moisture content and shorter drying time. The mussels before and after drying are given in Figure 2.

When a comparative literature review was conducted for drying blue mussels, infrared (IR) drying for samples with similar dry matter content, Kipcak et. al (2019) at 88-146 W power levels, drying times were found to be between 110 - 45 minutes, and Sevim et al. (2019) found drying times between 405 - 165 minutes in their study at 60 - 80°C (Kipcak et al., 2019; Sevim et al., 2019). For blue mussels with lower moisture content, Kipçak et al. (2021), in their research at 60 - 80 °C, drying times were found to be between 270 - 120 minutes for the cabinet dryer, 570 - 300 minutes for the oven and 390 - 210 minutes for vacuum oven. Accordingly, it has been observed that MW shortened the drying time considerably and gave more rapid outcomes than the compared dryers for drying (Kipcak et al., 2021).

Effective Moisture Diffusivity and Activation Energy Results

The D_{eff} values were determined by analyzing the slopes obtained from Figure 3, which depicted the plots of ln(MR) versus time for the blue mussels at different drying powers (140, 210, and 350 W). The calculated D_{eff} values were found to be 1.22×10^{-7}, 2.33×10^{-7}, and 3.91×10^{-7} m^2/s at the respective drying powers. It was observed that the D_{eff} values increased with an increase in drying power, indicating that the drying rate of the blue mussels was enhanced at higher power levels. In support of the values found, in the studies conducted by Kipcak et al. (2021) and Kipcak et al. (2019) drying of blue mussel with a cabinet-type dryer, oven, vacuum oven, and infrared dryer, it was found that D_{eff} values tend to increase with the increase in temperature (Kipcak et al., 2019, 2021).

Table 2. Mathematical models used for rehydration (Cox et al., 2012; Maneesh Kumar et al., 2018)

Model Name	Model equation
Peleg	$R_c = M_0 + t/(K_1 + K_2 t)$
Two-term Exponential	$R_c = a.\exp(b.t) + c.\exp(d\,.t)$

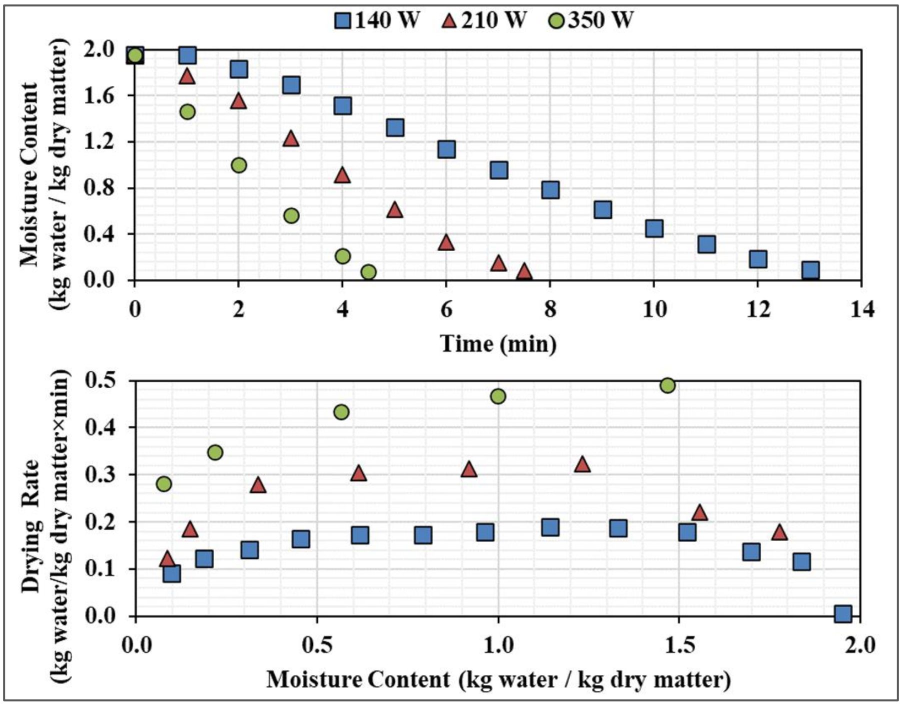

Figure 1. Drying curves of mussels at various MW power levels.

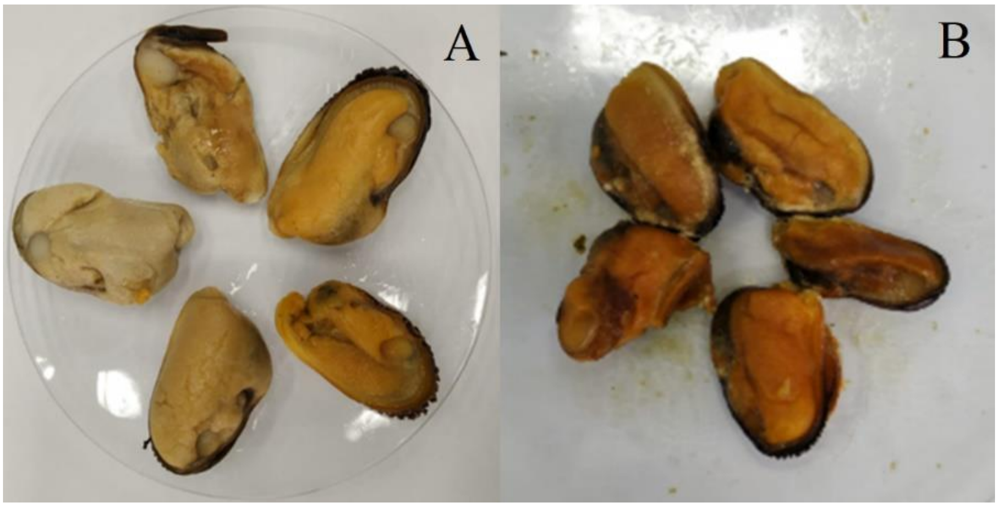

Figure 2. Sample of blue mussels A. before and B. after MW drying (210 W).

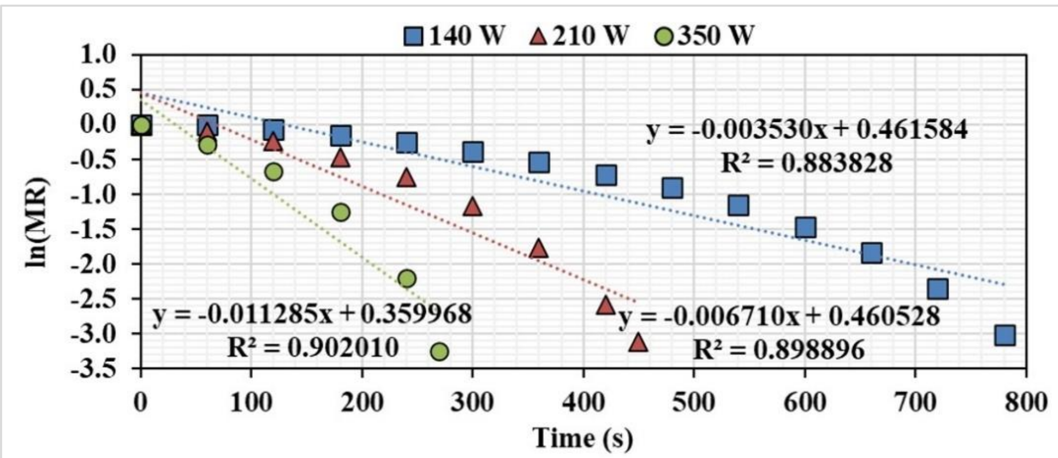

Figure 3. Drying time against ln(MR) graph.

Furthermore, the activation energy, which is an important parameter in understanding the drying behavior of the blue mussels, was calculated from the slope of the ln(D_{eff}) versus m/P plot. The activation energy was determined to be 11.417 kW/kg, which suggests that the drying process is controlled by the diffusion of moisture within the blue mussels. The E_A value was determined by Kipcak et al. (2019) to be 20.85 kW/kg with 60 - 80°C IR drying (Kipcak et al., 2019). This figure can be interpreted as MW offering a drying process with lower energy consumption than IR drying. These findings can aid in the development of more efficient and effective drying processes for blue mussels, as they provide insight into the underlying mechanisms involved in the drying process.

Rehydration Experiments and Kinetics

Mussels dried at different power levels were rehydrated in distilled water at 20, 30, and 40°C. This process was carried out with 3 parallel samples for each parameter. Figure 4 shows the rehydration process for 350 W dried samples.

Graphs showing the variation of rehydration ratios and rehydration rates of mussels with rehydration times are given in Figure 5. As the figure indicates, the rehydration ratios (g/g) were obtained as 0.35, 0.40 and 0.48 at 20°C, as 0.38, 0.46, and 0.50 at 30°C, and as 0.49, 0.57 and 0.58 at 40°C for the samples dried at 140, 210 and 350 W, respectively. These results led to the conclusion that when power level increased, the rehydration ratio also increased. Similar to this result, Horuz et al. (2017) with microwave-dried cherries and Maftoonazad et al. (2022) hybrid microwave-hot air tunnel dried onion slices, found that the rehydration rate increased with increasing microwave power levels in their studies (Horuz et al., 2017; Maftoonazad et al., 2022). This scenario, can be attributed to the thermal deformation during the drying process, which shortens with increasing power level. Rehydration times at 20°C, took 360 min at 140 W and increased to 450 min at 210 and 350 W. Rehydration at 30°C took 420 min at 140 W and increased to 480 min at 210 and 350 W. At 40°C, rehydration took 480 min for all power levels. The rehydration behaviour changes to a tendency to exchange water after the dry samples reach saturation of water absorption. According to Sevim & Kipcak's (2019) research, the rehydration times of blue mussels dried at 60 - 80 °C with IR were found to be 480 - 390 minutes, 480 minutes, and 480 minutes at rehydration temperatures of 20, 30, and 40 °C, respectively. This suggests that mussels dried using MW technology exhibit superior rehydration properties compared to those dried with IR (Sevim & Kipcak, 2019).

Figure 4. Rehydration of 350 W dried mussels.

Rehydration rates (g/g×min) peaked at 30 minutes for all temperatures. As rehydration progresses, the rehydration rates decrease to 0.000018, 0.000004, and 0.000032 at 20°C, to 0.000023, 0.000010, and 0.000051 at 30°C, and to 0.000051 at 30°C and to 0.000061, 0.000132 and 0.000126 at 40°C for 140, 210 and 350 W, respectively. Accordingly, the ultimate values of rehydration rates continue to show a decreasing profile from high temperature to low. Similarly, in Ozyalcin & Kipcak (2021) rehydration study of blue mussels dried using an oven and vacuum oven, peaks were obtained in 30 minutes, and then the final rehydration rate values were found in a decreasing profile for 40, 30 and 20 °C (Ozyalcin & Kipcak, 2021).

Statistical Analysis and Mathematical Modelling for Drying Results

The Statistica software was used to examine the applicability of the acquired data for various drying models. Table 3 lists the applicable mathematical models with R^2 values over 0.92 along with the model's parameters and coefficients. These models are considered to be the most compatible ones. The Alibas mathematical model with the highest values of R^2 as 0.999927, 0.999732, 0.999993; the lowest values of χ^2 as 0.000012, 0.000070, 0.000005 and lowest values of RMSE as 0.002799, 0.005594, 0.000905 for 140, 210 and 350 W respectively, exhibited a best agreement with the

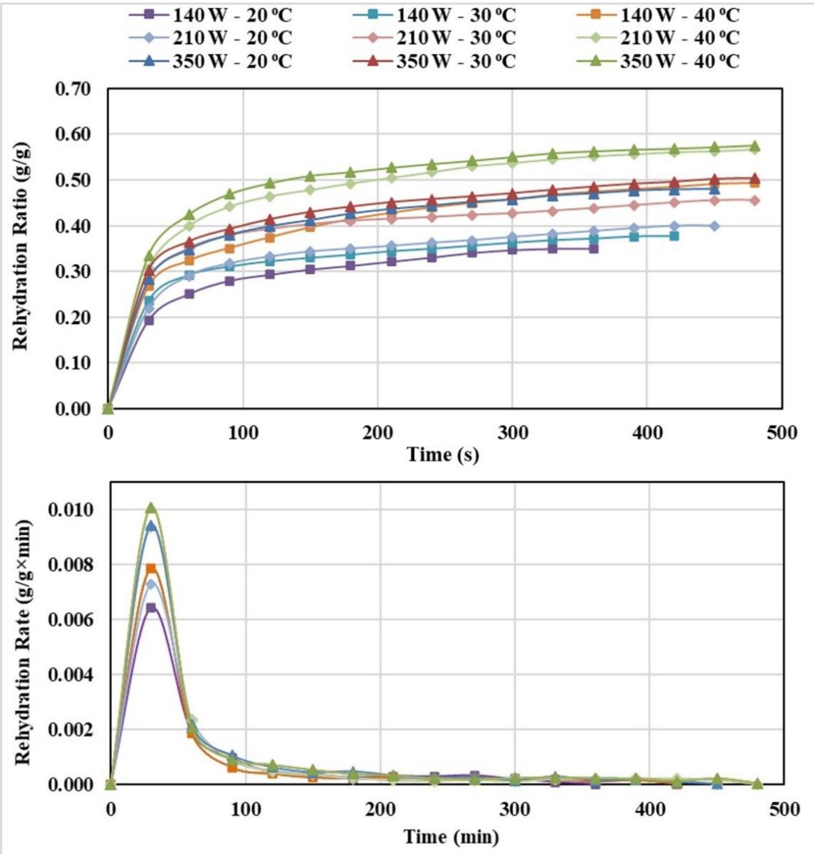

Figure 5. Rehydration ratios and rehydration rates of mussels.

Table 3. Mathematical model constants and statistical parameters of drying data (R^2>0.92)

Model	Drying Power	R^2	χ^2	RMSE	a	b	c	g	k	n
	140 W	0.999927	0.000012	0.002799	3.49699	0.085270	-	-2.496910	0.026100	1.376780
Alibas	210 W	0.999732	0.000070	0.005594	0.421984	-0.072628	-	0.574438	0.027064	2.481464
	350 W	0.999993	0.000005	0.000905	-0.796778	-0.249768	-	1.796367	0.000845	3.72562
	140 W	0.999718	0.000043	0.005523	1.011236	-0.007735	-	-	0.017465	1.832043
Midilli	210 W	0.999492	0.000107	0.007699	0.991645	-0.014267	-	-	0.056947	1.748899
	350 W	0.999914	0.00003	0.003183	0.999432	-0.053475	-	-	0.215472	1.186841
	140 W	0.998270	0.000218	0.013659	-	-	-	-	0.014392	2.016963
Page	210 W	0.996694	0.000496	0.019635	-	-	-	-	0.056540	1.912144
	350 W	0.993938	0.001070	0.026710	-	-	-	-	0.243544	1.556632
	140 W	0.99219	0.001074	0.029049	-13.9615	-	15.0258	-	-0.0056	-
Logarithmic	210 W	0.993501	0.001137	0.027531	12.4129	-	-11.3792	-	0.0115	-
	350 W	0.999578	0.000099	0.007047	2.32596	-	-1.32117	-	0.12052	-

MW drying data for blue mussels, as seen in Table 3. In Midilli model, the R^2 values were calculated as 0.999718, 0.999492, and 0.999914; χ^2 values as 0.000043, 0.000107, and 0.00003 and RMSE values as 0.005523, 0.007699, and 0.003183 for 140, 210 and 350 W respectively. In Page model, the R^2 values were calculated as 0.998270, 0.996694, and 0.993938; χ^2 values as 0.000218, 0.000496, and 0.001070; and RMSE values as 0.013659, 0.019635, and 0.026710 for 140, 210 and 350 W respectively. In the last applied model, Logarithmic, the R^2 values were calculated as 0.99219, 0.993501, and 0.999578; χ^2 values as 0.001074, 0.001137, and 0.000099; and RMSE values as 0.029049, 0.027531, and 0.007047 for 140, 210 and 350 W respectively. According to these values, among the models applied for MW drying of blue mussels, those that fit the best after the Alibas model can be listed as Midilli, Page, and Logarithmic.

Statistical Analysis and Mathematical Modelling for Rehydration Results

The modelling analysis was conducted using the Statistica software, and the goodness of fit of each model was assessed by computing the R^2, χ^2, and RMSE values, which are presented in Table 4. The results show that the Binary Exponential model outperforms the Peleg model in rehydration of blue mussel in terms of agreement with experimental data at all rehydration temperatures and drying powers. For the Two-Term Exponential model, for 20 °C rehydration temperature and 140, 210 and 350 W drying, R^2 were found as 0.998261, 0.999473, and 0.996226; χ^2 values as 0.000021, 0.000006, and 0.000068; and RMSE values as 0.003848, 0.002209, and 0.007125, respectively. For 30℃ rehydration temperature, R^2 were found as 0.998959, 0.999212, and 0.996246; χ^2 values as 0.000012, 0.000011, and 0.000067; and RMSE values as 0.002961, 0.002962, and 0.007179 for 140, 210, and 350 W drying, respectively. Likewise, for 40°C rehydration temperature, R^2 were found as 0.991132, 0.996724, and 0.997501; χ^2 values as 0.00016, 0.000078, and 0.000061; and RMSE values as 0.011066, 0.007739, and 0.006815 for 140, 210, and 350 W drying, respectively.

On the other hand, in the Peleg model, where the compatibility is lower, 20°C rehydration temperature for drying at 140, 210, 350 W and R^2 were found as 0.996719, 0.994973, and 0.995153; χ^2 values as 0.000036, 0.000057, and 0.00008; and RMSE values as 0.005285, 0.006827, and 0.008075, respectively. For 30°C rehydration temperature, R^2 were found as 0.994721, 0.996199, and 0.992476; χ^2 values as 0.000056, 0.000051, and 0.000125; and RMSE values as 0.00667, 0.006505, and 0.010164 for 140, 210, and 350 W drying, respectively. Likewise, for 40°C rehydration temperature, R^2 were found as 0.986341, 0.996075, and 0.998672; χ^2 values as 0.000229, 0.000087, and 0.000029; and RMSE values as 0.01373, 0.008471, and 0.004968 for 140, 210, and 350 W drying, respectively.

Considering all rehydration data, R^2 values for Two-term Exponential were found to be between 0.991132 - 0.999473, while for Peleg this value was found to be between 0.992476 - 0.998672. Ozyalcin & Kipcak (2021) found R^2 values between 0.993200 - 0.999584 for Peleg and 0.988083 - 0.999511 for Two-Term Exponential in his recession study of blue mussels dried in an oven and vacuum oven. Accordingly, the values are in agreement with the literature (Ozyalcin & Kipcak, 2021). The model fit of the data is plotted against the experimental and calculated rehydration rates, and their distribution around the 45-degree line is shown in Figure 6. By examining these graphs, it can be better understood to what extent the models fit the experimental data.

Table 4. Mathematical model constants and statistical parameters of rehydration data (R^2>0.92)

Model	Rehyd. Temp. - Drying Power	R^2	RMSE	χ^2	a	k_1	k_2	-
	20°C - 140 W	0.996719	0.000036	0.005285	0.00132	81.7178	2.67935	-
	20°C - 210 W	0.994973	0.000057	0.006827	0.00117	67.49381	2.4269	-
	20°C - 350 W	0.995153	0.00008	0.008075	0.00264	53.42592	2.01408	-
	30°C - 140 W	0.994721	0.000056	0.00667	0.00107	54.18193	2.59825	-
Peleg	30°C - 210 W	0.996199	0.000051	0.006505	0.00074	44.04461	2.16446	-
	30°C - 350 W	0.992476	0.000125	0.010164	0.00322	49.13646	1.95738	-
	40°C - 140 W	0.986341	0.000229	0.01373	0.00822	75.12399	1.96888	-
	40°C - 210 W	0.996075	0.000087	0.008471	0.00293	52.27594	1.69781	-
	40°C - 350 W	0.998672	0.000029	0.004968	0.00114	41.42198	1.67686	-
Model	Rehyd. Temp. - Drying Power	R^2	χ^2	RMSE	a	b	c	d
	20°C - 140 W	0.998261	0.000021	0.003848	0.272883	0.000757	-0.27209	-0.03671
	20°C - 210 W	0.999473	0.000006	0.002209	0.316287	0.000552	-0.31579	-0.03667
	20°C - 350 W	0.996226	0.000068	0.007125	0.382158	0.000564	-0.38028	-0.03931
	30°C - 140 W	0.998959	0.000012	0.002961	0.303981	0.000555	-0.30361	-0.04611
Two-Term Exponential	30°C - 210 W	0.999212	0.000011	0.002962	0.377677	0.000411	-0.37693	-0.04201
	30°C - 350 W	0.996246	0.000067	0.007179	0.395779	0.000544	-0.39404	-0.0423
	40°C - 140 W	0.991132	0.00016	0.011066	0.360543	0.000717	-0.35699	-0.0366
	40°C - 210 W	0.996724	0.000078	0.007739	0.450377	0.000525	-0.44794	-0.0339
	40°C - 350 W	0.997501	0.000061	0.006815	0.4812	0.000408	-0.47874	-0.03557

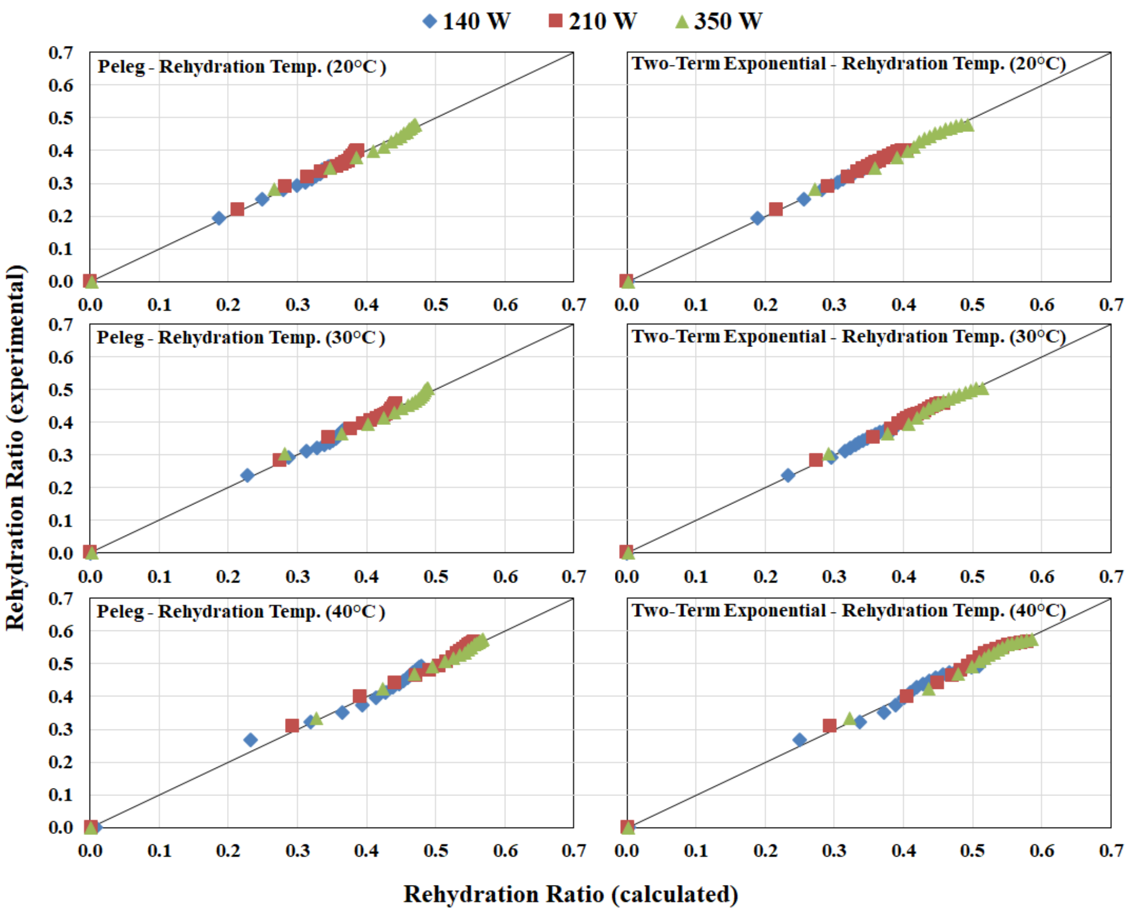

Figure 6. Experimental and calculated rehydration ratio values of Peleg and Two-Term Exponential models.

Conclusion

The blue mussels were subjected to MW drying at 140, 210, and 350 W power levels and subsequently rehydrated by immersion in water at various at 20, 30, and 40 °C. The drying experiments were conducted between 4.5 and 13 minutes. The D_{eff} values were found to be between 1.22 - 3.91×10^{-7} m^2/s, in an increasing trend with the increase in power level. While the rehydration process was continued for at least 360 minutes, it was observed that the increase in the temperature exhibited an enhancing impact on the rehydration rate and maintained this relationship even at the end of the process. Increased MW power levels have been observed to cause greater rehydration ratios and rates. The situation was suspected to be connected to the duration of heat exposure. Of the mathematical models applied, the Alibas model for drying and the Two-Term Exponential model for rehydration demonstrated higher agreement with the experimental data. In the continuation of the study, it is foreseen to examine the rehydration behavior of blue mussels in a rehydration medium with salinity rates compatible with the literature.

Ethical Statement

Not applicable.

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Author Contribution

Sema Sevim: Methodology, Formal Analysis, Data Curation

Zehra Ozden Ozyalcin: Visualization, Writing, Editing

Azmi Seyhun Kipcak: Supervision, Review, Editing

Conflict of Interest

The authors declare that they have no known competing financial or non-financial, professional, or personal conflicts that could have appeared to influence the work reported in this paper.

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