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ÇİMENTO ENDÜSTRİSİNDE ALTERNATİF YAKIT OLARAK KULLANILAN BELEDİYE ÇAMURU VE FINDIK KABUĞU KARIŞIMLARININ KURUMA KİNETİĞİ

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Özet: Bu çalışmada, çimento fabrikalarının yakma sistemlerinde alternatif yakıt olarak kullanılan arıtma çamuru ve karışımlarının kurutma karakteristiği sunuldu. Arıtma çamurunun ısıl değerini arttırmak ve nem miktarını düşürmek için fındık kabuğu gibi farklı tarımsal atık ilave edildi. Arıtma çamuru ve fındık kabuğu karışımlarının kurutma karakteristiği dört farklı kurutma metodu için belirlendi ve sonuçlar birbirleriyle karşılaştırıldı. Farklı oranlardaki numunelerin zamana bağlı nem oranı değerleri deneysel olarak elde edildi ve literatürdeki yarı ampirik modellerle karşılaştırıldı. İlaveten, farklı oranlardaki arıtma çamuru ve fındık kabuğu karışımlarının üst ısıl değerleri 3445 ile 4900 kcal/kg arasında değişmektedir.
Anahtar Kelimeler: Kurutma, Arıtma çamuru, Fındık kabuğu, Kurutma kinetiği.

DRYING KINETICS OF SEWAGE SLUDGE AND HAZELNUT SHELL MIXTURES USED AS AN ALTERNATIVE FUEL IN CEMENT INDUSTRY

Abstract: This study presents drying characteristics of sewage sludge and mixtures used as an alternative fuel in cement incineration systems. In order to increase calorific value and reduce moisture, content of sewage sludge, different agricultural waste substance like hazelnut shell is included in it. Drying characteristics of sewage sludge and hazelnut shell mixtures were evaluated for four drying methods with moisture content and results were compared with each other. Moisture rate as a function of time for different rates of samples were obtained experimentally and also compared with the semi-empirical models from literature. In addition, higher heating values (HHV) of sewage sludge and hazelnut shell mixtures ranged between 3445 and 4900 kcal/kg.
Keywords: Drying, Sewage sludge, Hazelnut shell, Drying kinetics.

INTRODUCTION

Over recent years, environmental and energy problems have been increasing around the world. Consequently , there is a growing interest in the use of combustible waste as an alternative energy source for that different types of waste materials like sewage sludge are used in energy recovery system. However one of the main problems with this kind of waste is its moisture content. Drying is an unavoidable part of the process that can lower its water content below 5% dry solids and, inconsequence reducing the cost for storage, handling and transport. According to census data, the population of Turkey is now over 75 million (Turkish Statistical Institute, 2014) and the environmental and energy problems have become current issues in especially western cities within Marmara region. The city of Sakarya has a population of 917,373 and is located on the coast of Black Sea in the Marmara Region, in Northwest Turkey . The city has a wastewater treatment plant which has sufficient capacity to treat an average waste flow of 235,370 m3 per a day. The dry sewage sludge has high heating value of 16–21 MJ/kg. The annual average relative humidity in the city is approximately 73.9%. Agriculture is a big activity in Sakarya and it has favorable weather conditions for especially hazelnut production.

The sewage sludge is considered as a special type of renewable fuel in the world due to the high quantity of organics of sufficiently high calorific value (Magdziarz and Werle, 2014) and there is an increased interest in thermal and chemical utilization methods of sewage sludge by researchers.

Generally, thermal and chemical utilization techniques of sewage sludge is categorized under seven headings such as 1) anaerobic digestion 2) incineration and co-incineration 3) gasification 4) pyrolysis 5) wet air oxidation 6) super critical wet oxidation and 7) hydro thermal treatment. In incineration and co-incineration process, the biosolids are burned in a combustion chamber supplied with excess air (oxygen) to form mainly carbon dioxide and water, leaving inert material (ash) (Tyagi and Lo, 2013). Implementation of incineration and co-incineration processes are usually began with the dewatering of the sludge. Dewatering is made by belt presses, decanter centrifuges and filter presses. The next step is the drying process and generally belt, drum and fluid bed dryers are used. After dried sewage sludge is fed to incinerator. Several different incineration technologies which include multiple hearths, fluidized bed, electric furnaces and co-incineration with refuse are mostly used for sewage sludge incineration (http://www.nacwa.org, 2010 and http://www.epa.gov, 2014). In addition there are several experimental studies on combustion of sewage sludge ; pyrolysis of sewage sludge using both raw sewage sludge and sludge sample (Fan et al. (2014), Hlavsová et al.(2014), Liu et al.(2014), Dai et al.(2014), Wallace et al.(2014)). Magdziarz and Werle (2014) investigated the combustion and pyrolysis processes of three sewage sludge came from three wastewater treatment plants. In their work TGA (burning profiles) and MS (gaseous products) data were used to determine the combustion and pyrolysis characteristics of three types of sludge, using coal as a reference fuel. Their analyses of the gaseous products of the combustion and pyrolysis processes showed that H2, CO, CO2, and CH4 are the main components. It is also observed that the composition of gaseous compounds changed by the temperature for combustion and for pyrolysis.

Other type experimental studies focus on air-steam gasification of sewage sludge and influence of several operating conditions on sewage sludge . Gil-Lalaguna et al.(2014) was used a lab-scale fluidized bed reactor in order to evaluate the feasibility of gasifying kind of char and in their other study on , Gil-Lalaguna et al.(2014) used fluidized bed with mixtures of air and steam. Furthermore Roche et al.(2014) used an atmospheric fluidized bed reactor using air and air + steam as gasifying agents whereas Ma et al.(2014) investigated the combustion efficiency of recovered organic matter and waste activated sludge (WAS) in the electro genesis process.

Dewatered sludge contains about 80 % (wetted base) moisture so that reduction of moisture content can be achieved by drying with an external heat supply. Energy consumption of the sludge drying process also strongly depends on the type of dryer . There are several drying techniques of wastewater sludge have been used, such as paddle dryer (Deng et al., 2009), fluidized bed dryer (Adamiec et al., 2002), pneumatic dryer (Jamaleddine et al., 2011a), cyclone dryer (Jamaleddine et al., 2011b). Deng et al. (2009) investigated the drying kinetics of sewage sludge in a Nara-type paddle dryer. In order to have a better understanding of the sewage sludge drying mechanism, a penetration model developed by Tsotsas and Schlunder is used in their studies to simulate the drying kinetics of the pasty, lumpy and granular phase where the sludge experiences during the drying process. Their result indicates that the penetration theory is able to describe the sludge drying kinetics of the three distinct phases. Experimental and calculated drying kinetics are in satisfactory agreement for different drying parameters. In addition Font et al. (2011) studied thermal drying of sewage sludge in the 30–65 ◦C temperature range with two types of sewage sludge in the convective dryer. They developed a mathematical model, based on mass and heat balances and kinetic laws. Also drying experiments were done by Ayol and Muslu (2013) using a contact drying oven, which can be operated at different temperatures ranging between 50 and 250 °C. They used a Box–Wilson response surface methodological approach to evaluate the drying performance of dewatered municipal sewage sludge under different operating conditions for optimization purposes. Their results indicate that the drying kinetics was primarily affected by the drying temperatures, which influenced the drying rate and times.

Drying of the municipal sludge is a field that requires more research due to the complexity of the process. Furthermore the drying abilities of municipal sludge can vary depending on the waste- activated sludge characteristics. Bennamoun et al. (2014) presented an experimental work done in a discontinuous cross-flow convective dryer. Determination of the diffusion coefficient during sludge drying was performed by comparing fitted drying curves, represented by Newton's model, and analytical solutions of the equation of diffusion represented by Fick's second law in their study and they reported that the values of the diffusion coefficient ranged from 42.35 E-9 m2.s-1 to 28.45 E-9 m2.s-1 . Their results showed the complex characteristics of sludge drying because samples from the same plant had different behavior. More work related to sludge origin is needed. Also in their study Bennamoun et al. (2013) dried wastewater sludge in a convective dryer using air temperatures varying from 80 °C to 200 °C, velocities changing from 1 m.s-1 to 2 m.s-1 and humidities ranging from 0.005 kg water.kg dry air-1 to 0.05 kg water/kg. dry air. The drying curves were modeled using several empirical models and they reported that the fourth-degree polynomial model gave best results with a correlation coefficient approaching unity and with lowest errors. On the other hand, flammability properties of sewage sludge, including ignition sensitivity, explosion severity, thermal sensitivity and thermal stability was studied by Fernandez-Anez et al.(2014). Yu et al.(2014) was used wet sewage Sludge and the pyrolysis experiments were performed in a laboratory-scale microwave heating apparatus. Microwave heating technology has already been used in waste treatment and considered as a cost-effective alternative way for preparing activated carbon from organic solid wastes. In comparison to conventional heating techniques, microwave heating has the advantages of interior heating; higher heating rates, saving energy, and greater control of the heating process (Lin et al., 2011). A comparison of the microwave method with conventional pyrolysis in an electrical furnace indicated that the former is more efficient and it gives rise to a slightly higher reduction in the volume of the solid residue (Menendez et al., 2005). Published research articles on the application of microwave irradiation in sludge treatment have increased during the last decade (Tyagi and Lo, 2013) to find better combination of incineration process. Kumar and Lo (2013) have emphasized other benefits of microwave irritation as follows; a) it is a rapid and efficient method to recover the heavy metals from sludge, b) solids produced in the microwave treatment are more resistant to leaching, i.e., are less porous and more resistant to the lixiviation of organic substances and heavy metals, c) microwave heating process with a few additives provides efficient heavy metal stabilization for industrial waste sludge, and also d) it provides enhancement in sludge solubilisation and subsequent anaerobic digestion.

The main objective of the current study was to investigate the drying characteristics of sewage sludge used as an alternative fuel in cement incineration systems. Sewage sludge samples were obtained from a wastewater treatment plant, Sakarya Municipality, Turkey. To increase calorific value and reduce moisture content of sewage sludge, hazelnut shell is included in it. Three different mixtures of hazelnut shell and sewage sludge were prepared. The mixtures were 20% and 30% hazelnut shell by mass, respectively. The sample with moisture content of 80% on wetted based dried to 6% using microwave and laboratory drying oven. Drying characteristics of sewage sludge were evaluated for two drying methods with moisture content and results were compared with each other. Experimental results of moisture ratio versus drying time were fitted to the most important semi-empirical models, which are widely used in the scientific literature to describe the kinetics of the drying process.

MATERIAL AND METHODS

The sewage sludge for the study was obtained from the municipal mechanical-biological sewage-treatment plant with population equivalent of nearly 1,000,000. In order to improve the properties of the sludge and to convert it into an alternative fuel, which is applicable in the clinker process, the sludge was blended with hazelnut shell. Several batches of sludge were sampled after thickening and dewatering (belt filter pressing). Prepared samples of sewage sludge and hazelnut shell mixture before (a) and after (b) drying are shown in Fig 1.

Samples consisted of 100 grams in total were taken and dried by two methods: laboratory oven (MMM Medcenter, ECOCELL 55, Germany) and microwave oven (FAKIR, Model MW70170) under various conditions. Experiments done in the study are listed in Table 1. The moisture content of the samples was measured by Sartorius moisture analyzer based on infrared drying and weighing of samples was determined manually using an electronic balance with a capacity of 0–3000 g and accuracy of 0.01 g. In addition proximate analysis carried was out on the samples of raw solid waste, hazelnut shell and their different mixtures, in the laboratory at the Sakarya University and Tubitak Marmara Reserch Center. Mean moisture content of laboratory samples were 12.84–79.06% wb (wet base) with ash contents of about 1.88–35.59 % db (dry base) and high volatile matter ranging 56.39–72.51 % db.

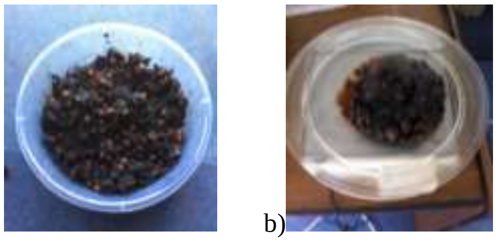
a) 

Figure 1 Prepared samples of sewage sludge and hazelnut shell mixtures (a) before drying (b) after drying

Table 1 Experiments

Test codes (P: microwave dryer) (O: Oven dryer)	Microwave oven Power [W]	Mixture mass rates, % sewage sludge, (ss)+hazelnut shell, (hs)
P1(70% SS)	336	70% ss+30% hs
P2(70% SS)	462	
P3(70% SS)	595	
P1(80% SS)	336	80% ss+20% hs
P2(80% SS)	462	
P3(80% SS)	595	
P1(100% SS)	336	100% ss
P2(100% SS)	462	
P3(100% SS)	595	
	Temperature (°C)	
O(70% SS)	105 °C	70% ss+30% hs
O(80% SS)	105 °C	80% ss+20% hs
O(100% SS)	105 °C	100% ss

Physical characteristics of the samples are presented in Table 2. The chemical characteristic of hazelnut shell and mixtures are also listed in Table 3. Also heavy metal concentrations of the samples are presented in Table 4.

Table 2 Physical characteristics of samples [* calculated]

	100 % ss			100% hs			80%ss+20%hs			70%ss+30%hs			60% ss+40%hs			Method
	As received	Air dried bases	Dry bases	As received	Air dried bases	Dry bases	As received	Air dried bases	Dry bases	As received	Air dried bases	Dry bases	As receviced	Air dried bases	Dry bases	
Moisture	58.7	7.02	_	5.7	_	_	48.34	6.92	_	43.11	6.83	_	37.68	6.46	_	ASTM D 7582
Ash	14.68	33.09	35.59	1.77	_	1.88	14.74	26.56	28.5	14.58	23.89	25.63	13.8	20.71	22.14	ASTM E 1755
Volatile	23.27	52.44	56.39	68.38	_	72.51	30.63	55.2	59.3	34.52	56.54	60.68	38.76	58.18	62.2	ASTM D 7582
Fixed C	3.31	7.46	8.02	24.15	_	25.62	6.29	11.33	12.17	7.79	12.75	13.68	9.76	14.65	15.66	*
Total S	0.45	1.01	1.09	0.04	_	0.05	0.44	0.8	0.86	0.43	0.7	0.76	0.41	0.62	0.66	ASTM D 4239

Table 3 Composition of chemical characteristic of samples [* calculated]

	100% ss	100% hs	80%ss+20%hs	70%ss+30%ss	60%ss+40%ss	Method
C	36.35	55.67	40.02	42.2	44.31	ASTM D 5373
H	4.34	4.97	4.14	4.34	4.48	ASTM D 5373
O	17.29	36.98	21.99	23.1	24.97	*
N	5.34	0.45	4.46	3.97	3.44	ASTM D 5373
S	1.09	0.05	0.86	0.76	0.66	ASTM D 4239

Drying kinetics is evaluated experimentally by measuring the weight of a drying sample as a function of time. Drying curves may be represented in different ways; moisture content (wet and dry base) versus time, drying rate versus time, or drying rate versus moisture content. Moisture content of sewage sludge samples in dry base (db) is used the following equation:

$$M_{db} = \frac{W_t - W_d}{W_d} \quad (1)$$

where W_t is the sample weight at a specific time; W_d is the sample dry weight (g). The moisture ratio (MR) of samples during the drying experiments is calculated by using the following equation;

$$MR = \frac{M_t - M_e}{M_0 - M_e} \quad (2)$$

where M_e is the equilibrium moisture and M_0 is the initial moisture content of materials. This equation also can be simplified to $MR = M/M_0$ because of the continuous fluctuation of the relative humidity of the drying air (Midilli et al., 2002). The drying rate of sewage sludge and mixture samples can be defined as the moisture content variation with time by using the following Eq. (3);

$$DR = \frac{M_{t+\Delta t} - M_t}{\Delta t} \quad (3)$$

where $M_t$and $M_{t+\Delta t}$are the moisture content at t and moisture content at $t + \Delta t$, respectively.

Mathematical Model

Simple mathematical models that enable prediction of the drying curves of two drying methods were used in the present study. In mathematical expressions given in Table 5, a, b, c, d, e and n are model constants and t is the drying time. Drying curves were experimentally obtained and fitted with different MR models using the MATLAB (R2012b) computer program. The goodness of fit between predicted and experimental data was determined by three parameters: higher values for coefficient of determination (R^2), summed square of residuals SSE and root mean square error (RMSE) using Eqs.(4-6), respectively.

$$R^2 = 1 - \left[\frac{\sum_{i=1}^{N}\left(MR_{pre,i} - MR_{exp,i}\right)^2}{\sum_{i=1}^{N}\left(\overline{MR}_{pre} - MR_{exp,i}\right)^2}\right] \quad (4)$$

$$SSE = \left[\sum_{i=1}^{N}\frac{\left(MR_{exp,i} - MR_{pre,i}\right)^2}{N-n}\right]^{1/2} \quad (5)$$

$$RMSE = \left[\frac{1}{N}\sum_{i=1}^{n}\left(MR_{exp,i} - MR_{pre,i}\right)^2\right]^{1/2} \quad (6)$$

Table 4 Heavy metal concentration of the samples

sample	Fe. %	Cu.mg/kg	Ni.mg/kg	Zn. %	Pb.mg/kg	Cr.%	Cd.mg/kg	Ash.%
100% hs	1.3	220	304	0.05	3	0.04	0.6	1.9
100% ss	4.6	360	347	0.35	111	0.09	2.7	36.5
%20hs+%80ss	4.6	360	390	0.36	111	0.09	2.2	29.5
%30hs+%70ss	4.6	360	395	0.36	108	0.09	4.8	25.8
%40hs+%60ss	4.4	340	404	0.35	111	0.09	2.6	22.5
Method	ASTM D 3683-04							

Table 5 Selected drying models applied for drying curves

Model no	Model name	Mathematical definition
1	Page (Akpınar et al., 2003)	$MR = exp(-kt^n)$
2	Logarithmic (Bennamoun et al., 2013 and 2014)	$MR = a\ exp(-kt) + b$
3	Midilli (Midilli et al., 2002)	$MR = a\ exp(-k\ t^n) + b\ t$
4	Fourth degree polynomial (Bennamoun et al., 2013 and 2014)	$MR = at^4 + bt^3 + ct^2 + dt + e$

RESULTS

In this study the effect of drying technique on moisture ratio was investigated. The mean moisture content of laboratory samples were 12.84–79.06% wb and dried by oven and microwave techniques to the final moisture content of about 4-5% (wb). The Fig. 2 represents experimental drying curves of sewage sludge and hazelnut shell mixtures dried in oven for the temperature of 100℃ by natural convection. Experimental drying curves show a linear behavior. Initially all MR values were close to each other. After 5th hour, MR values for 100 % sewage sludge (ss) decreased significantly compared to the others. The experiments were carried out by microwave dryer to examine the effects of power level and time.

Figs 3 and 4 indicate microwave drying characteristics of sewage sludge and hazelnut shell mixtures. Initially, MR values were obtained proportional to microwave power levels. The drying rates were improved with an increase in the power because drying at higher temperature provided a larger driving force for heat transfer, which is noticeably related to the rate of mass transfer. In addition when moisture content approached the equilibrium moisture content, drying rates were very low and overlapped with each other.

Fig 5 presents a comparison of the average drying rates of sewage sludge and mixtures for two drying methods. Initial moisture content of 100% sewage sludge changed between 197 and 428% (db), while for sewage sludge and hazelnut mixture (70% ss+30% hs) between 116 and 121 % (db). Drying rates of 100% sewage sludge oven dried ranged were between values 1.59 E-5 and 7.99 E-5. Although there were few unexpected values, the main drying periods were observed as initial, constant and falling rate periods. Once all the moisture on the surface was evaporated, the drying rate increases quickly. Moisture moves fast to keep the surface wet and constant rate drying continues. Later the material surface becomes dry and falling rate period which is controlled by internal diffusion starts. After reaching the final moisture of samples, drying rates almost remained constant. Similar observation was made by Deng et al. (2009). They used the paddle dryer for drying of sewage sludge and found three different drying periods; called as pasty, lumpy and granular periods. In addition the microwave drying rate of sewage sludge and hazelnut shell mixtures were found to be higher than oven drying rate values as shown in Fig 5.

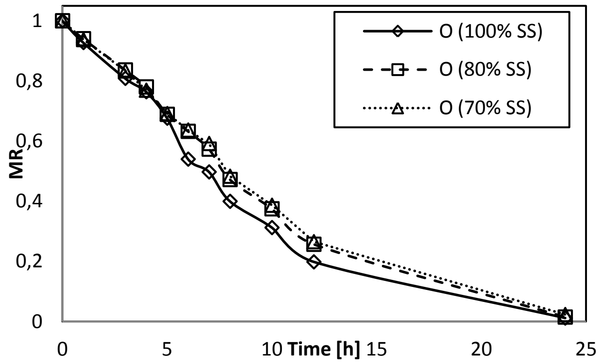


Figure 2 Oven drying characteristic of sewage sludge and hazelnut shell mixtures

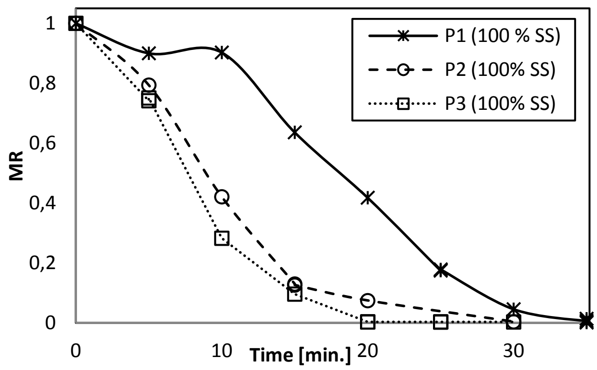


Figure 3 Microwave drying characteristic of sewage sludge at different power level (100% ss)

Oven drying was controlled by external conditions, in our experiment conditions (in 105℃ and atmospheric pressure) water transport to the material surface slowly. However in microwave oven drying, the drying rates increased when the water content of the samples decreased.

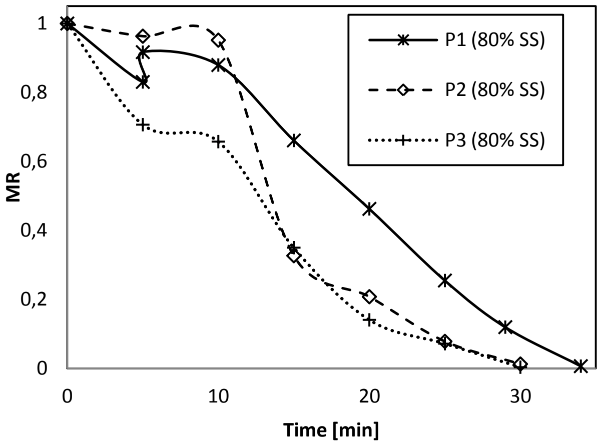


Figure 4 Microwave drying characteristic of sewage sludge and hazelnut shell mixtures at different power levels (80% ss).

After critical moisture content, falling rate period had started and lasted to equilibrium moisture content. Experimental results indicated that sludge samples were dried faster in microwave dryer than the oven. This also implied that the microwave dryer operated more efficiently during drying when compered total drying time of two methods. For mathematical model, drying experiments were categorized into twelve groups as shown in Table 1.The first nine groups belonged to microwave drying experiments with three mixture ratios which were conducted by a different power level. Next three groups were part of laboratory oven drying experiments. Drying process optimization requires knowledge of the drying kinetics. Therefore, drying data of both methods was put into four different drying models as presented in Table 5.Higher values of R2 and lower the values of SSE and RMSE were chosen as the criteria for goodness of fit. Table 6 shows all fitting results (R2, RMSE and SSE) of two drying techniques. The best model describing the drying kinetics was selected with the highest R2 average values, and the lowest RMSE and SSE average values. It was observed that R2 values ranged from 0.88 to 0.99 for the Page model, from 0.95 to 0.99 for the Midilli model and 0.95 to 0.99 for fourth degree polynomial model for all drying experiments. On the other hand, R2 values ranged from 0.71 to 0.98 for the Logarithmic model for drying data of microwave oven and satisfactory results could be obtained for laboratory oven drying data. It was seen that very close results obtained for both Midilli and fourth degree polynomial models. By comparing R2, RMSE and SSE average values, it is clear that the fourth degree polynomial model satisfactorily fits experimental data on drying kinetics and has better agreement with the experiments. Similar results have been reported by Bennamoun et al. (2013 and 2014).

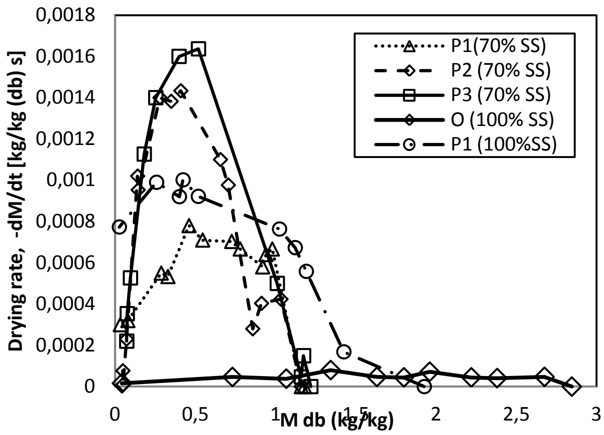


Figure 5 Comparison of drying rates of sewage sludge and hazelnut shell mixtures.

CONCLUSION

This study shows the drying characteristics of sewage sludge and hazelnut shell mixtures that were dried by oven and microwave techniques. Sewage sludge samples were obtained from a wastewater treatment plant, Sakarya Municipality, Turkey. To increase calorific value and reduce moisture content of sewage sludge, different agricultural waste substance like hazelnut shell is included in it. The sample with moisture content of about 80% on wetted based dried to 6% using microwave and laboratory drying oven. Drying characteristics of sewage sludge and hazelnut shell mixtures were evaluated for two drying methods with moisture content and results were compared with each other. Experimental results of moisture ratio versus drying time were put into the four empirical models. The best model describing the drying kinetics was selected the fourth degree polynomial model with the highest R2 (0,998) value. This study provided experimental data of two methods and showed that the microwave drying could significantly reduce the drying time and it could be used in municipality sludge sewage drying.

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Table 6 Model parameters, coefficient of determination (R2), root mean standard error (RMSE) and summed square of residuals (SSE) of drying models

Model	Test codes	Model constants	R^2	SSE	RMSE
	P1(70%SS)	k = 0.001949 n = 2.011	0.9444	0.03003	0.07750
Page	P2(70%SS)	k = 0.009515 n = 1.708	0.9830	0.01242	0.04984
	P3(70%SS)	k = 0.005517 n = 2.139	0.9945	0.00565	0.03362
	P1(80%SS)	k = 2.62e-07 n = 4.528	0.9545	0.01977	0.06288
MR = exp(-k*(t^n))	P2(80%SS)	k = 5.434e-06 n = 4.257	0.8865	0.1477	0.1719
	P3(80%SS)	k = 0.01785 n = 1.516	0.9637	0.02471	0.07029
	P1(100%SS)	k = 0.0002975 n = 2.424	0.9887	0.007769	0.04407
	P2(100%SS)	k = 0.0009301 n = 2.379	0.993	0.002767	0.0372
	P3(100%SS)	k = 0.001741 n = 2.231	0.9975	0.001016	0.02254
	O(70%SS)	k = 7.428e-05 n = 1.487	0.9979	0.001906	0.01455
	O(80%SS)	k = 7.961e-05 n = 1.476	0.9962	0.001801	0.01501
	O(100%SS)	k = 0.004378 n = 0.9309	0.9728	0.0184	0.0452
	P1(70%SS)	a = 169.1 k = 0.0001666 c = -168.1	0.9128	0.03767	0.09704
	P2(70%SS)	a = 2.354 k = 0.01982 c = -1.336	0.9852	0.008635	0.04646
Logarithmic	P3(70%SS)	a = 1.295 k = 0.06532 c = -0.223	0.9518	0.0491	0.1108
	P1(80%SS)	a = 548.8 k = 5.857e-05 c = -547.8	0.9057	0.06551	0.1145
MR = a*exp(-k*t)+c	P2(80%SS)	a = 486.6 k = 7.827e-05 c = -485.5	0.7196	0.2918	0.2701
	P3(80%SS)	a = 1.496 k = 0.03727 c = -0.4905	0.9533	0.02543	0.07974
	P1(100%SS)	a = 139.7 k = 0.0001639 c = -138.6	0.9434	0.02913	0.09853
	P2(100%SS)	a = 196.3 k = 0.0001685 c = 0.03013	0.9503	0.009843	0.09921
	P3(100%SS)	a = 23.14 k = 0.001524 c = -22.12	0.9557	0.008966	0.09469
	O(70%SS)	a = 0.4429 k = 0.3371 c = 0.5571	0.1981	0.7221	0.3004
	O(80%SS)	a = 0.4456 k = 0.6537 c = 0.5544	0.05328	0.5196	0.2725
	O(100%SS)	a = 0.6053 k = 0.9064 c = 0.3947	0.4428	0.4191	0.2289
	P1(70%SS)	a = 0.9996 b = -0.03451 k = -0.03963 n = 0.4003	0.9526	0.01494	0.07057
	P2(70%SS)	a = 0.992 b = -0.005326 k = 0.06891 n = 1.443	0.9863	0.005992	0.04469
Midilli	P3(70%SS)	a = 1.008 b = 0.001336 k = 0.004647 n = 2.243	0.9947	0.00269	0.02995
	P1(80%SS)	a = 0.994 b = -0.07918 k = -0.1242 n = 0.588	0.9826	0.01024	0.0506
MR = a*exp(-k*(t^n))+b*t	P2(80%SS)	a = 1.1 b = 0.004413 k = 2.338e-08 n = 6.53	0.9583	0.06515	0.1474
	P3(80%SS)	a = 0.994 b = -0.1052 k = -0.07328 n = 0.8132	0.9508	0.02006	0.08177
	P1(100%SS)	a = 0.9931 b = -0.0005574 k = 0.0005467 n = 2.225	0.9735	0.008628	0.06568
	P2(100%SS)	a = 1.004 b = 0.0005526 k = 0.01068 n = 2.05	0.997	0.001505	0.0224
	P3(100%SS)	a = 1 b = -0.01566 k = 0.05978 n = 0.742	0,998	0,000128	0,01125
	O(70%SS)	a = 0.978 b = 1.32e-05 k = 5.555e-05 n = 1.557	0.9948	0.02188	0.003351
	O(80%SS)	a = 0.9768 b = 0.0001234 k = 1.796e-05 n = 1.786	0.9933	0.003121	0.02281
	O(100%SS)	a = 0.9982 b = -0.0006278 k = 0.03128 n = 0.4716	0.9803	0.01036	0.03847
Polinom	P1(70%SS)	a = 1.918e-06 b = -0.0001169 c = 0.001696 d = -0.02665 e = 0.9979	0.9829	0.009855	0.03817
	P2(70%SS)	a = 2.631e-06 b = -0.0001238 c = 0.001765 d = -0.04592 e=1.002	0.99	0.002915	0.03663
	P3(70%SS)	a = -1.251e-05 b = 0.0007941 c = -0.01449 d = 0.02441 e =1.004	0.9988	0.001263	0.02513
	P1(80%SS)	a = 2.58e-06 b = -0.0001429 c = 0.001701 d = -0.02266 e =0.9868	0.9804	0.01087	0.05214
	P2(80%SS)	a = -6.857e-06 b = 0.0005539 c = -0.0139 d = 0.07153 e = 0.98	0.948	0.05037	0.1587
	P3(80%SS)	a = 2.797e-06 b =-0.0001333 c = 0.002137 d = -0.052 e = 0.9862	0.9827	0.01472	0.0858
	P1(100%SS)	a = 7.269e-06 b = -0.000316 c = 0.001914 d = -0.002265 e =0.9963	0.9939	0.002349	0.03427
	P2(100%SS)	a = -8.551e-06 b = 0.0005296 c = -0.00841 d = -0.02644 e = 1.009	0.9939	0.006119	0.05531
	P3(100%SS)	a = -1.028e-05 b = 0.0006264 c = -0.01025 d = -0.01109 e = 1.001	0.994	0.001798	0.02998
	O(70%SS)	a = -6.234e-13 b = 2.032e-09 c = -1.653e-06 d = -0.0006532 e = 0.9948	0.9989	0.00103	0.0131
	O(80%SS)	a = -2.203e-12 b = 4.202e-09 c = -2.499e-06 d = -0.0005878 e = 1	0.9949	0.0006999	0.01871
	O(100%SS)	a = 2.914e-11 b = -3.815e-08 c = 1.713e-05 d = -0.004234 e = 0.9828	0.9919	0.006089	0.03186

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