Influence of Different Parameters on the Drying Kinetics While Making Apple Snack with Microwave

[1]Banu Yokus, and *Alev Akpinar Borazan
*[1] Bilecik Seyh Edebali University, Engineering Faculty, Chemical and Process Engineering Department,
Bilecik, Turkey

Abstract

Dehydration is a very frequently used method of fruits preservation since it is responsible for the reduction of the product moisture content which greatly retards microbial and chemical deterioration. The objective of this work was investigated combined effect of the application of dip concentration ratio and apple skin on the drying kinetics during microwave drying. Lutz Golden apples were used as test material. Pretreated and non-pretreated samples were dried in a microwave oven at 350watt. The moisture content of the sample at intermediate drying stages was calculated from the weigh lost during drying. The shortest drying times were obtained from pre-treated samples with 1:6 dipping concentration ratios [ascorbic acid (0.3% w/v) and citric acid (0.1% w/v)] and without skin.

A mathematical relation was studied between the moisture content of pretreated and non-pretreated apple slices and time drying period. Different mathematical models were evaluated in the kinetics research.

Key words: Apple, moisture content, mathematical modeling, microwave, drying time

1. Introduction

Drying is a creative way to preserve foods and use home-grown fruit, extra produce (e.g., ripe bananas) and farmers' market specials. Every drying technique has its own advantages and disadvantages [1-3]. Depending on the specified physical or chemical characteristics of the final product different dryers operated at different thermal conditions may be needed even if the feed material is the same. Often different dryers yield similar product at comparable costs [4].

Heat-drying has become important in almost all areas of industrial processing. Apart from the popular conventional procedures based on conduction, convection, or infrared radiation, heat-drying utilizing microwave energy is an attractive solution to many problems in process technology. In microwave drying, heat is generated by directly transforming the electromagnetic energy into kinetic molecular energy, thus the heat is generated deep within the material to be dried. Drying is an interdisciplinary field comprised of both transport phenomena and material science. With 12 to 25 percent of the national industrial energy consumption devoted to thermal dehydration in developed countries, drying technologies have significant impact on both energy and environmental aspects of a country [4, 5].

One of the most important aspects of drying technology is the mathematical modeling of the

*Corresponding author: Address: Faculty of Engineering, Department of Chemical and Process Engineering Bilecik Seyh Edebali University, 11210, Bilecik TURKEY. E-mail address: alev.akpinar@bilecik.edu.tr, Phone: +902282141545 Fax: +902282141332

drying processes. The mathematical description of food moisture evolution during the process is also known as drying kinetics. Various empirical models have been used to simulate fruit-drying processes. Before drying accordingly to meet desired operating conditions, the most suitable operating conditions and treatments were chosen. The principle of modeling is based on having a set of mathematical equations that can adequately characterize the system[].

In this study, mathematical relationship of the drying rate and moisture ratio of dried apple slices upon pre-treatment were investigated using microwave dryer and were developed important parameters about basic information. Also, the empirical mathematical model was developed using modified parabolic model. Then, a made of control was made up to be decreased energy cost of drying time. The effect of presence of apple skin, the dip solution application and concentration ratio of the dip solution on the drying rate was studied.

Nomenclature

MR	:	Moisture Ratio, g water/g dry mass
D_R	:	Drying Rate(gH_2O/g dry mass*min)
$LG_S^{Contr.}$	:	Lutz Golden with skin; control sample
$LG_S^{(1:3)}$	:	Lutz Golden with skin; 1:3 Dipping sol. applied sample
$LG_S^{(1:6)}$	:	Lutz Golden with skin; 1:6 Dipping sol. applied sample
$LG_{S.less}^{Contr.}$	:	Lutz Golden, skinless; control sample
$LG_{S.less}^{(1:3)}$	:	Lutz Golden, skinless; 1:3 Dipping sol. applied sample
$LG_{S.less}^{(1:6)}$	:	Lutz Golden, skinless; 1:6 Dipping sol. applied sample

2. Materials and Method

2.1. Drying experiment

In this study, apples of Lutz golden varieties were used as a raw material. They were purchased from a local grocery store in Inegol, Turkey. They were stored in a refrigerator at 4°C prior to the experimental runs. Before, sample preparation, apples were equilibrated at room temperature before each pre-treatment and subsequent drying.

Experiments were designed for microwave drying of apple slice, with different pre-treatments. Drying process is given below step by step as the combination of parameters for the designed experiments.

a. supplied Lutz golden apple species,
b. cleaned and cored,
c. pared of apples (applied just for skinless samples in each apple species),
d. cut in slices 6 mm thick,
e. soaked into K_2CO_3 solution (3% w/v) for 1min.,

f. soaked in dipping mixture of ascorbic acid (0.3% w/v) and citric acid (0.1% w/v) solution for 5minutes (by 2 different alternative ratio of 1:3 and 1:6), control samples were untreated.
g. Pre-treated apples were removed from solution.
h. Dried apple slices in MW (350watt; 2450 MHz Altus ALMD 17 B,Turkey).

Moisture content was determined by the oven method [6]. At regular time intervals during the drying processes, samples were taken out and determined moisture content of apples by Sartorius Moisture Analyzer (Model MA150, Germany) at 70°C until a constant weight was achieved. Moisture content (wet basis and dry basis) was calculated. The tests were performed in duplicate.

2.2. Mathematical modeling

The experimental moisture loss data were fitted to selected semi-theoretical and empirical thin-layer drying models. These models are generally derived by simplifying general series solution of Fick's second law. These empirical models derive a direct relationship between average moisture content and drying time. Different equations are available in the literature. Many investigators have successfully used these equations to explain drying of several agricultural products. The mathematical models compared according to the coefficient of determination (R^2) between the observed and predicted moisture ratios.

The moisture ratio (MR) and drying rate of apple slices during drying experiments were calculated using the following equations:

$$MR = (M - M_e) / (M_0 - M_e) \qquad (1)$$

$$D_R = (M_{t+dt} - M_t) / d_t \qquad (2)$$

Where MR is the local moisture content (g water/g mass), t is the drying time (min), D_R is Drying Rate (gH_2O/g dry mass*min), M, M_0, M_e, M_t and M_{t+dt} are the moisture content at any time, initial moisture content, equilibrium moisture content, moisture content at t and moisture content at t + dt (kg water/kg dry matter), respectively. The following assumptions were made. (a) The food sample was one-dimensional (b) the initial moisture content was uniform throughout the solid.

To determine the drying characteristics of the chips, the experimental data were fitted into three different models as presented in Table 1. These models described the relationship between moisture loss and drying time with various coefficients attached to each model. Coefficient of determination (R^2) is the primary criterion for selecting the best equation to describe drying curve. In conclusion, the modified parabolic models satisfactorily described the drying in MW characteristics of apple slices.

Table 1. Mathematical drying models

Models	**Equation**	**References**
Henderson and Pabis	MR=a exp(-kt)	Chinnman, (1984), Zhang and Litchfield (1991)
Logarithms	MR=a exp(-kt) +c	Yagcioglu, Degirmencioglu and Cagatay (1999), Togrul and Pehlivan, (2003)
Parabolic	MR= 1+ at+ bt^2	Wang and Singh, (1978); Sharma and Prasad (2004)

a, *b*, *c*, *k*, *t* are coefficients.

3. Results

Analytical information must be obtained, assessed, and integrated with drying process to check quality control of dried apple sliced. The experiments were carried out either in triplicate or duplicate, and results were presented as mean values with standard deviations

Data's of the experimental moisture ratio are shown in Fig 1.a/b during drying of apple slices which were subjected to different pre-treatments.

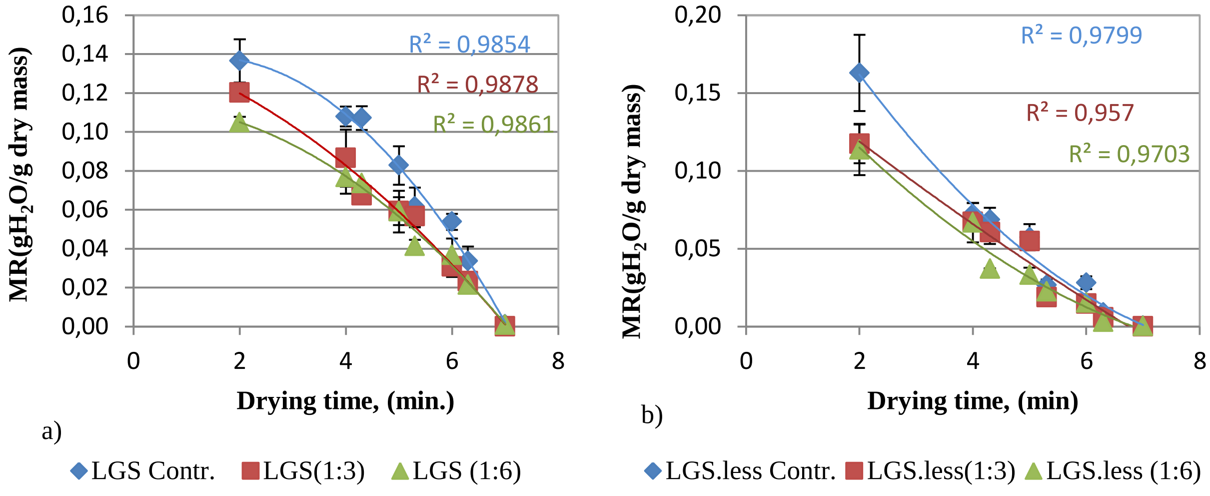

Figure 1. Moisture content profile of apple for drying by MW oven
a)Lutz.Golden with skin, b) Lutz. Golden, skinless

The drying rates of apples with pre-treated and untreated are given figure 2a/b. Moisture gradients were controlling the observed drying rates. These relations are shown in Figure 3.

The fit parameters and fit statistics (R^2) associated with the three models for the different apple slices investigated are presented in Tables 2.

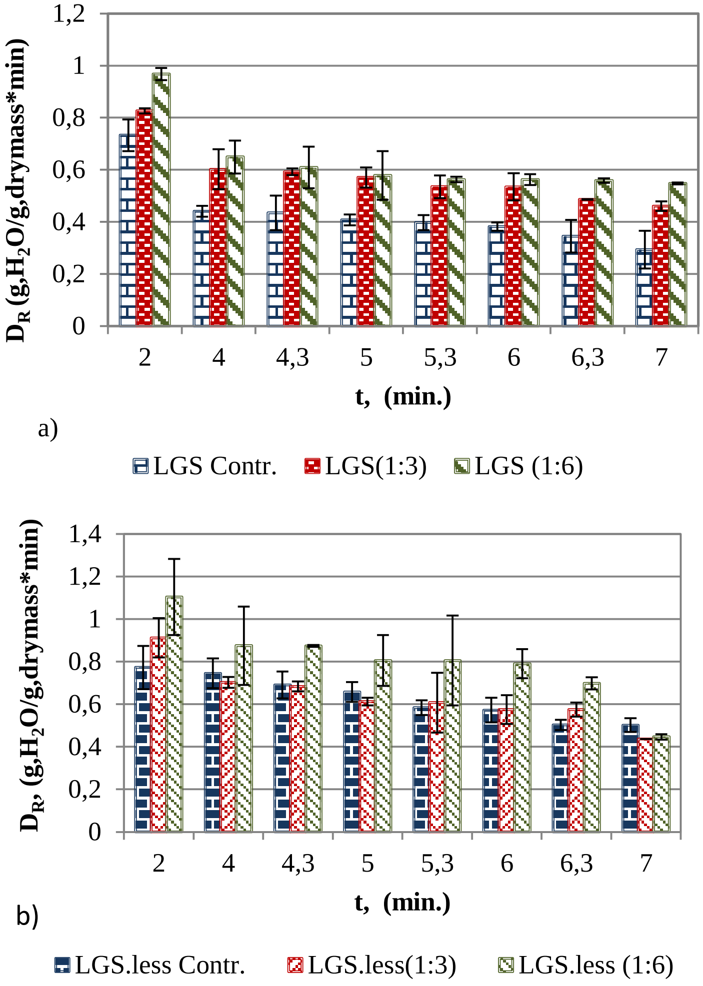

Figure 2. Drying profiles of apple by MW oven a)Lutz Golden with skin, b) Lutz Golden, skinless

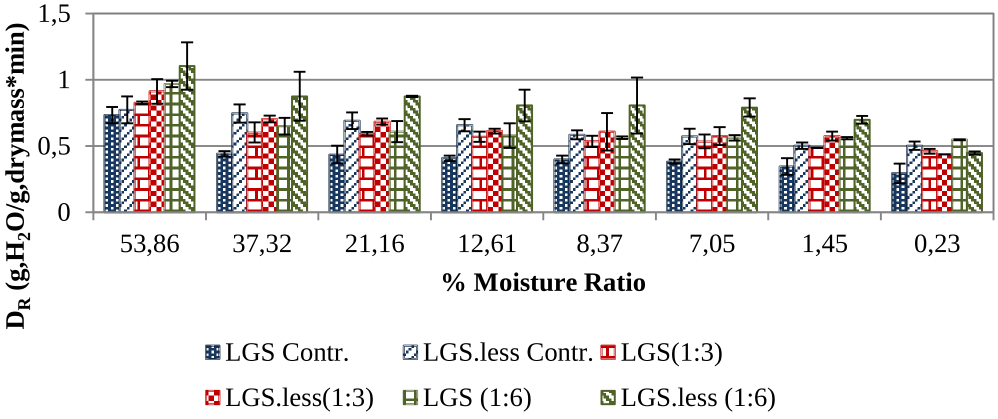

Figure3. Relation of rate & moisture of the Lutz Golden Apple slices during drying ratio

Table 2. Mathematical drying models

Sample & Dipping sol.	**Models**	**Equation**	**a**	**b**	**c**	**k**	**R^2**
LG_S $^{Contr.}$	Henderson and Pabis	MR=aexp(-kt)	1,5685			0,713	0,5159
	Logarithmic	MR=aexp(-kt) +c	-0,1		0,2278		0,7901
	Modified Parabolic	MR= c+ at+ bt^2	0,012	-0,0043	0,1301		0,9854
$LG_S{}^{(1:3)}$	Henderson and Pabis	MR=aexp(-kt)	4,6952			1,059	0,4566
	Logarithmic	MR=aexp(-kt) +c	-0,091		0,1961		0,8909
	Modified Parabolic	MR= c+ at+ bt^2	-0,081	-0,0017	0,1429		0,9878
LG_S $^{(1:6)}$	Henderson and Pabis	MR=aexp(-kt)	0,27			1,1836	0,5513
	Logarithmic	MR=aexp(-kt) +c	-0,078		0,1729		0,8498
	Modified Parabolic	MR= c+ at+ bt^2	-0,002	-0,0023	0,1146		0,9861
$LG_{S.less}$ $^{Contr.}$	Henderson and Pabis	MR=aexp(-kt)	0,941			2,7653	0,6914
	Logarithmic	MR=aexp(-kt) +c	0,13		0,2543		0,9709
	Modified Parabolic	MR= c+ at+ bt^2	-0,002	0,0033	0,2724		0,9793
$LG_{S.less}{}^{(1:3)}$	Henderson and Pabis	MR=aexp(-kt)	1,28			8,2147	0,5825
	Logarithmic	MR=aexp(-kt) +c	-0,098		0,1937		0,9267
	Modified Parabolic	MR= c+ at+ bt^2	-0,0297	0,0005	0,1761		0,957
$LG_{S.less}$ $^{(1:6)}$	Henderson and Pabis	MR=aexp(-kt)	1,038			2,7084	0,7261
	Logarithmic	MR=aexp(-kt) +c	-0,094		0,1822		0,9646
	Modified Parabolic	MR= c+ at+ bt^2	-0,0433	0,0022	0,1928		0,9703

4. Discussion

Drying rate is affected by many factors such as the size, composition, structure, treatments, dryers and the amount of food to be dried. Drying rate can be accelerated by analysing the effect of constant and variable conditions on the dehydration of the raw material. The apple species, presence of skin and concentration ratio of the dip solution were all affected on the drying rates of apple sliced in different ratios [7-10].

Two different alternative ratio of 1:3 and 1:6 of the dipping mixture solution were applied to prior to drying process. It was observed that the drying rate and the drying time were affected. The fastest drying were obtained from pre-treated samples with 1:6 dipping mix.solution.
Interestingly, dip mix sol. ratios were not significantly influenced to drying rate and time as expected. Skinless samples have higher moisture ratio than other samples in each dipping concentration ratios and control sample. This is the same for drying rate because of moisture flux gradient. Moisture gradients were controlling the observed drying rates. At low moisture contents the rates of drying become very low [5, 7, 11].

Conclusions

The rates of water removal for the sample without skin, especially pre-treated apples were better than the others. Consequently, the microwave drying technique can reduce drying time and produce a high quality end-product up to process conditions so as to offer a promising alternative and significant contribution to the apple.

The high temperatures and long time periods required for water removal from apple fruits may seriously affect their nutritional and organoleptic quality. For this reason, these technological parameters are considered as being critical variables [7, 10-12]
Next, dehydration processes should be investigated to minimize the impact on bioactive compounds.

Acknowledgements

The authors thank to Bilecik Seyh Edebali University to the financial support provided for Scientific Research Project Code No. 2013-01.BİL.03-02.

References

[1] Kendall, P. and Sofos, J., Food and Nutrition Series| Preparation, Fact Sheet No. 9.309 Colorado State University Extension, 8/94. Revised 6/12, 08.01.2014, http://www.ext.colostate.edu/pubs/foodnut/09309.pdf
[2] Huang, L., Zhang, M., Mujumdar, A.S., Lim, R. ,Comparison of four drying methods for re-structured mixed potato with apple chips, Journal of Food Engineering 103 (2011) 279–284
[3] Kitinoja, L, Gorny, J., Part II: Small-Scale Processing Technologies' for Horticultural Products, Chapter 13: Produce Drying, UC. Postharvest Outreach Program, p13.1-20, 1998, http://postharvest.ucdavis.edu/files/93620.pdf

[4] Mujumdar, A.S. , Recent developments in the drying technologies for the production of particulate materials, Handbook of Conveying and Handling of Particulate Solids, A. Levy and Kalman, H. (Editors), 2001 Elsevier Science B.V., pp: 533-547
[5] PUSCHNER, Mikrowellen Energie technik, Microwave Vacuum Drying for advanced Process Technology, File:pub_mw-vacuum-drying_engl.docSeite:1, Bremen, http://www.pueschner.com
[6] AOAC, Official Methods of Analysis of the Association of Official Analytical Chemists, 17th Ed., Editor; William Horwitz, 2002.
[7] Doymaz, İ., Effect of citric acid and blanching pre-treatments on drying and rehydration of Amasya red apples, Food Bioprod Process, 01/2010; 88(2):124-132, 2010.
[8] Andrés, A., Bilbao, C., Fito, P., Drying kinetics of apple cylinders under combined hot air–microwave dehydration, Journal of Food Engineering, Volume 63, Issue 1, June 2004, 71–78
[9] Doymaz, İ., The kinetics of forced convective air-drying of pumpkin slices, Journal of Food Engineering, 79, 243–248, 2007, http://www.aseanfood.info/Articles/11017482.pdf
[10] Grigoraş, C.G., Simion, A.I., Rusu, L.,Gavrilă, L., Mathematical Modeling Of Moisture Loss During Apple Cubes Dehydration, Annals. Food Science and Technology, 2011, http://www.afst.valahia.ro/docs/issues/2011/issue2/full/sectionv/2-CGrigoras-1.pdf
[11] Chong, C.H., Figiel, A., Law, C.L., Wojdyło, A., Combined Drying of Apple Cubes by Using of Heat Pump, Vacuum-Microwave, and Intermittent Techniques, Food and Bioprocess Technology, April 2014, Volume 7, Issue 4, pp 975-989, 2014.
[12] P. Fitob, P., Andrésb, A. , Lemusa, R., Mathematical modeling of hot-air drying kinetics of red bell pepper (var. Lamuyo), Journal of Food Engineering, Volume 79, Issue 4, April 2007, Pages 1460–1466