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Comparative Evaluation of Soaking Characteristics of Chickpea using Ambient water, Hot water and Microwave-assisted Heating

Gitanjali Behera[1*], Mitali Madhumita[1], Nayan Kumar Meher[1], Malay Ranjan Das[1] and Sarthak Pradhan[1]

[1]Department of Agricultural Engineering, SoABE, Centurion University of Technology & Management, Paralakhemundi, Gajapati-761211. India.

Authors' contributions

This work was carried out in collaboration among all authors. Author GB designed the study, performed the statistical analysis, wrote the protocol, and wrote the second draft of the manuscript. Author MM corrected the manuscript, check plagiarism, format the manuscript. Authors NKM, MRD and SP done the analysis, taken experimental observations. All authors read and approved the final manuscript.

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ABSTRACT

Aims: Soaking followed by cooking is the main aspect of chickpea processing which reduces the time consumption in the cooking process for achieving the desired cooking texture and nutritional qualities. But soaking chickpea in ambient water is very time-consuming. Therefore, the present investigation was carried out to study the soaking characteristics of chickpea in different soaking conditions.

Place and Duration of Study: Department of Agricultural Engineering, Centurion University of Technology & Management, between January 2021 to June 2021.

Methodology: The chickpea was soaked in ambient water, hot water, and microwave heating applications.

Results: The initial moisture content of the chickpea was found to be 14.39 % wet basis throughout the experiments. The moisture gain experimental was calculated and was found to be

**Corresponding author: E-mail: gitanjali.behera@cutm.ac.in;*

45.21 % dry basis (db) in ambient water soaking. In the hot water soaking, the moisture gain was estimated to be 50.74 % db, 53.28 % db, and 65.18 % db at 40°C, 50°C, and 60°C, respectively after 360 min (6h) of soaking period. The moisture gains in microwave-assisted soaking at 0.2 W/g, 0.4 W/g, 0.6 W/g, 0.8 W/g, and 1.0 W/g power densities levels were found to be 44.78 % db, 64.44 % db, 81.42 % db, 106.36 % db, and 115.95 % db, respectively after 10 min. The Peleg model was found to be suitable for describing the soaking characteristics of chickpea at all soaking conditions with higher R^2 values. The Peleg capacity constant and rate constant didn't show any particular trend in all the soaking methods.

Conclusion: Among all the soaking methods, microwave-assisted soaking showed the best soaking characteristics of chickpea with less time consumption and with more amount of moisture gain. Therefore, microwave-assisted may be recommended for soaking chickpea which is a less time-consuming and energy-saving process.

Keywords: Microwave-assisted soaking; hot water soaking; Peleg model; moisture gain.

1. INTRODUCTION

Chickpea (*Cicer arietinum* L.**)** is one of the most important legumes in the world which is commonly known as Bengal gram. It consists of an outer layer known as the seed coat and the inside cotyledons. They are of two types Kabuli chickpea which of large type and desi chickpea which is smaller, angular, and dark in color [1] [2]. The legume is grown in more than 50 countries. India ranks one in chickpea production and consumption in the world and also contributes about 68% of global chickpea production. Chickpea contains a high amount of protein, folate, dietary fiber, and some amount of minerals like phosphorous and iron [1] [3]. They also have a moderate amount of thiamine, zinc, magnesium, and vitamin B6 [4]. Chickpea is to be consumed in the raw form after soaking, some used it in the salad, ground into flour, some eat it like popcorn after popping and also can be cooked in the form of curries [5] [6] [7].

Soaking of chickpea followed by cooking is the two main steps of processing. Soaking chickpea overnight is an important step before cooking. Because it reduces the time consumption in the cooking process for achieving the desired cooking texture and nutritional qualities [8] Clemente et al., [3] Cooking of dry or previously soaked chickpea is generally done at a high temperature (above gelatinization temperature) to achieve starch gelatinization to convert it into the edible form [9] [10]. The major drawback in the traditional soaking process of chickpea is time consumption.

Now a day's microwave heating is being used in many industries for cooking, thawing, sterilization, and drying [4]. The electromagnetic waves in microwave heating are in the range of 300-3000 megahertz. Microwave causes volumetric heating whereas the traditional heating process does heating from the surface to the center [11]. The use of microwave in food processing has a lot of advantages like shorter heating time, retains better color, texture when compared with conventional heating methods [12] [13] [14]. The research on soaking chickpea using microwave heating is very much limited. Also, considering the energy and time consumption of traditional soaking and the benefits of microwave heating, the current research was carried out to study the water absorption characteristics of chickpea using microwave heating and to compare the soaking characteristics with ambient water, hot water soaking.

2. MATERIALS AND METHODS

2.1 Materials

Chickpea seed was brought from the local market of Paralakhemundi, Gajapati. It was washed properly using clean water. The surface moisture was removed by a hand towel. The initial moisture content was determined by keeping the sample in a hot air oven at 105± 2°C for 24 hr [15]. The initial moisture content of chickpea seed was measured using the following equation:

$$Moisture\ content\ (\%\ wb) = \frac{W_2 - W_1}{W_1} \times 100 \qquad (1)$$

Where W_1 is the initial weight of the sample (gram) and W_2 is the final weight of the sample after oven drying (gram).

2.2 Methods

2.2.1 Ambient water soaking

In the ambient water soaking method, the experiment was performed at room temperature in a glass beaker. The experiments were conducted in the Month of May 2021. The room temperatures were recorded by a thermometer and found to be in the range of 27°C to 29°C at the time of experiments and the temperature of the water used for soaking was found to be in the range of 24°C to 27°C. The sample to water ratio was maintained constant at 1: 4 and the experiment were conducted up to 6 h. Approximately one-two grams of sample was withdrawn from the glass beaker, wiped with tissue paper for surface moisture removal, and kept inside the hot air oven for estimation of moisture content. The samples were drawn at 10 min intervals up to 6 h.

2.2.2 Hot water soaking

The hot water soaking of chickpea was done at 40°C, 50°C, and 60°C temperature in a water bath fitted with heating coils. The temperature of the water bath was maintained at 3 different temperatures for 3 different experiments. The sample to water ratio was maintained constant at 1: 4. The sample with water was kept inside the water bath in a glass beaker and the experiment was conducted up to 6 h for all the 3 temperature ranges. The same procedure of sample drawing was followed as ambient water soaking for moisture content analysis at an interval of 10 min up to 6 h.

2.2.3 Microwave-assisted soaking of chickpea

A domestic microwave oven (Morphy Richards, 20MBG) available in the laboratory having a maximum power rating of 1000W was used throughout the experiments (Fig. 1). The height, width, and depth of the microwave oven were 280 mm, 300 mm, and 210 mm, respectively. Different parts like a 28 cm diameter of glass turntable, fan, grill arrangements, a control panel for controlling the power level, treatment time, etc are attached in the microwave oven within the microwave. The experiments were planned by taking 5 different power densities levels from 0.2 W/g, 0.4 W/g, 0.6 W/g, 0.8 W/g, and 1 W/g. The power density level was calculated by taking the microwave power level and weight of the sample and water. The power level was set first in the microwave control panel. The pre-measured weight of the sample with water was taken in a glass beaker and was kept inside the microwave oven to start the experiment. The microwave oven was paused after 1 min to draw approximately one gm of sample; the sample was kept in the hot air oven for measurement of moisture content [15]. The same process was continued up to 10 min (600 sec) and the same procedure was followed for all the microwave power density levels.

Fig. 1. Microwave oven

2.2.4 Modelling of soaking data

A two-parameter sorption equation proposed by Peleg [16] was used in the study to predict the moisture gain during ambient water, hot water, and microwave-assisted soaking. Peleg model has been also used by Turhan et al., [9] and Mehmet et al. [17] for studying the soaking characteristics of chickpea. The two-parameter equation is given below:

$$\frac{t}{M_t - M_0} = k_1 + k_2 t \quad \ldots \quad (2)$$

Where M_t is the moisture content at soaking time t (% db), M_0 is initial moisture content (% db), k_1 is a capacity constant dependent on the initial water absorption rate (min.%$^{-1}$) and k_2 is rate constant dependent on the equilibrium moisture content (%$^{-1}$).

2.2.5 Calculation of moisture gain

The moisture gain was calculated by taking initial dry basis moisture content using the following formula:

$$MG_t = MC_t - M_0 \quad (3)$$

Where, MG_t is the moisture gain at any time in % db, MC_t is the moisture content at any time % db, and M_0 is the initial moisture content in % db.

3. RESULTS AND DISCUSSION

3.1 Effect of Ambient water Soaking on Moisture Gain

The ambient water soaking was performed at room temperature for the chickpea. The moisture gain experimental data is given in Table 1. The initial moisture content was found to be 14.39 % wb for all the experimental samples. The soaking was done for 360 min and the dry basis moisture content was found to be 62.02 % db after 6 h. The moisture gain experimental was calculated and was found to be 45.21 % db after 360 min. The Peleg model was applied to the moisture gain experimental data and found to be the best in describing the soaking characteristics with an R^2 of 0.98 (Table 2). The Peleg rate constant and the capacity constant was found to be 0.7845 min. $\%^{-1}$ and 0.0208 $\%^{-1}$, respectively (Table 2). The moisture gain predicted was calculated from the values of k1 and k2 and the graph was plotted between moisture gain experimental and moisture gain predicted and is shown in Fig. 2.

3.2 Effect of Hot Water Soaking on Moisture Gain

The hot water soaking of chickpea was performed at 40°, 50°, and 60°C. The moisture content (% db) and moisture gain experimental and predicted data at different time interval is given in Table 3. The dry basis moisture content was found to be 67.56 % db, 70.09 % db, and 82.0 % db for 40°, 50°, and 60°C, respectively at the end of 360 min. The moisture gain experimental was 50.74 % db, 53.28 % db, and 65.18 % db for 40°, 50°, and 60°C, respectively at the end of 360 min. It can be observed from the above data that both the moisture content and moisture gain increased with an increase in temperature from 40°C to 60°C. This may be due to an increase in temperature increases the driving force for moisture migration. Similar results were also reported by Thakur and Gupta [18] for paddy. The Peleg model was applied to the moisture gain experimental data and found to be the best in describing the soaking characteristics with R^2 in the range of 0.95 to 0.96 for different temperature range (Table 2). The Peleg rate constant (k1) showed a decreasing trend from 4.4928 min.$\%^{-1}$ to 2.7078 min.$\%^{-1}$ and with an increase in temperature from 40°C to 60°C (Table 2). The Peleg rate constant (k2) didn't show any particular trend and was found to be in the range of 0.0073 $\%^{-1}$ to 0.0086 $\%^{-1}$. This may be due to Peleg model constants are not affected by the temperature of soaking water (Hung et al., 1993). The moisture gain predicted was calculated from the values of k1 and k2 and the graph was plotted between moisture gain experimental and moisture gain predicted for all the temperatures and is shown in Fig. 3.

3.3 Effect of Microwave Power Density on Product Temperature

The microwave-assisted soaking was performed at five microwave power density levels. i.e. 0.2 W/g to 1.0 W/g. The maximum temperature was found to be 41°C at 0.2 W/g, 48°C at 0.4 W/g, 70°C at 0.6 W/g, 89°C at 0.8 W/g, and 92°C at 1.0 W/g microwave power density level (Fig. 4).

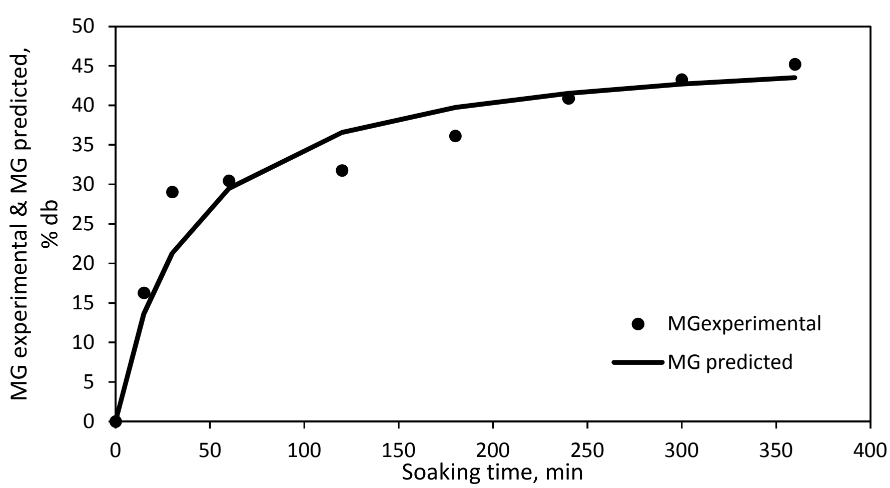

Fig. 2. MG experimental vs MG Predicted in ambient water soaking

Table 1. Moisture gains experimental data during ambient water soaking

Time (min)	MC % db	MG Experimental, % db	MG predicted, % db
0	16.84	0	0
15	33.09	16.27	13.67
30	45.85	29.04	21.29
60	47.28	30.46	29.52
120	48.59	31.77	36.57
180	52.95	36.13	39.74
240	57.70	40.89	41.54
300	60.07	43.26	42.70
360	62.02	45.21	43.51

Table 2. Peleg Model constants and R^2 values of all the soaking conditions

Soaking conditions	Peleg rate constant (k1, min.%$^{-1}$)	Peleg capacity constant (k2, %$^{-1}$	R^2
Ambient water soaking	0.7845	0.0208	0.98
Hot water soaking			
40°C	4.4928	0.0073	0.95
50°C	3.9799	0.0086	0.96
60°C	2.7078	0.0078	0.96
Microwave-assisted soaking			
0.2 W/g	9.5388	0.0064	0.92
0.4 W/g	6.959	0.0044	0.92
0.6 W/g	5.8038	0.0029	0.92
0.8 W/g	7.2667	0.0027	0.90
1.0 W/g	7.6012	0.0038	0.90

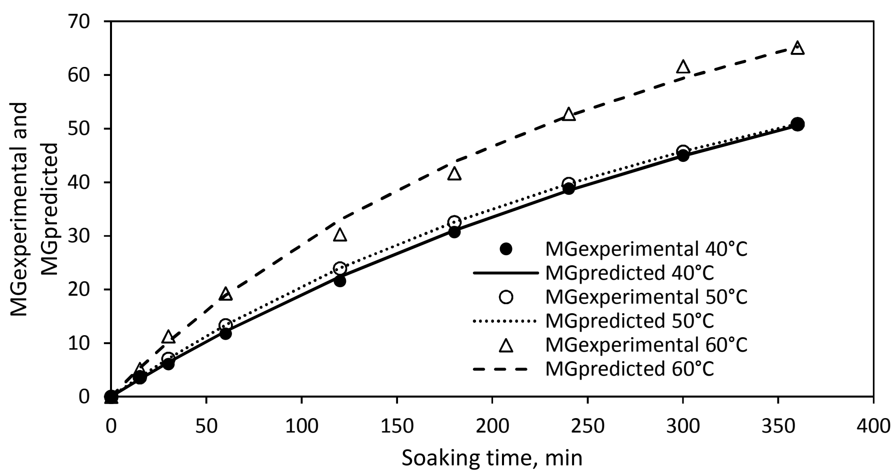

Fig. 3. MG experimental vs MG Predicted for hot water soaking at different temperature

The product temperature was increasing with an increase in the power density level. This may be due to the volumetric heating of the microwave with an increase in power density level. Similar results were also reported by Behera and Sutar [19] for microwave drying of steam gelatinized paddy.

3.4 Effect of Microwave-assisted Water Soaking on Moisture Gain

The microwave-assisted water soaking was performed at 5 different microwave power densities for 600 secs (10 min). The moisture gains experimental and predicted data at different time interval is given in Table 4. The dry basis moisture content was found to be 61.60 % db, 81.25 % db, 98.23 % db, 123.20 % db, 132.77 % db at 0.2 W/g, 0.4 W/g, 0.6 W/g, 0.8 W/g and 1.0 W/g, respectively after 10 min of soaking. Similarly, the moisture gain experimental was 44.78 % db, 64.44 % db, 81.42 % db, 106.36 % db and 115.95 % db at 0.2 W/g, 0.4 W/g, 0.6 W/g, 0.8 W/g and 1.0 W/g, respectively after 10 min of soaking. It can be seen that the moisture gain was increased from 44.78 % db to 115.95% db with an increase in the microwave power density from 0.2 W/g to 1.0 W/g. This may be due to the increase in microwave power density increases the product temperature and the increase in the product temperature ultimately increases the moisture gain. The increase in product temperature with an increase in power density can be also seen in Fig. 4. The results were in accordance with the result reported by Behera and Sutar [20] for microwave-assisted absorption of paddy grain. The Peleg model was applied to the moisture gain experimental data and found to be the best in describing the soaking characteristics with R^2 in the range of 0.90 to 0.92 for different microwave power density levels (Table 2). The Peleg rate constant (k1) and capacity constant (k2), both didn't show any particular trend and were found to be in the range of 5.8038 min.%$^{-1}$ to 9.5388 min.%$^{-1}$ and 0.0027 %$^{-1}$ to 0.0064 %$^{-1}$, respectively (Table 2). The moisture gain predicted was calculated from the values of k1 and k2 and the graph was plotted between moisture gain experimental and moisture gain predicted for all the microwave power density levels and is shown in Fig. 5.

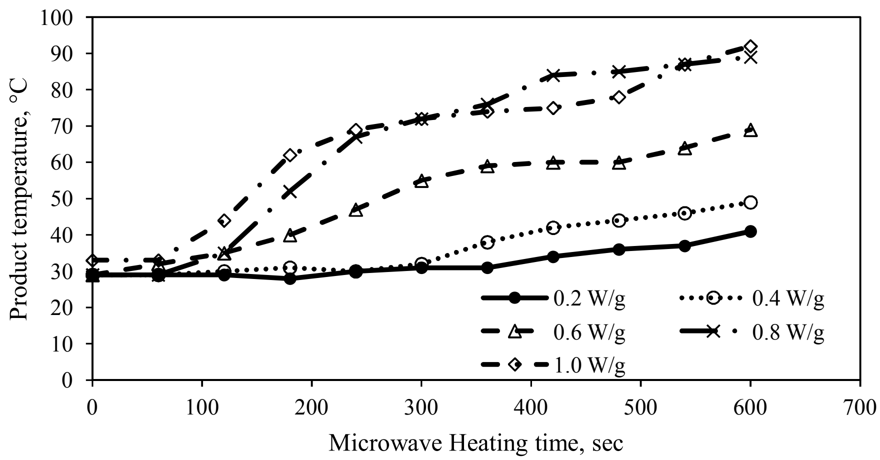

Fig. 4. Effect of Microwave power density level on product temperature

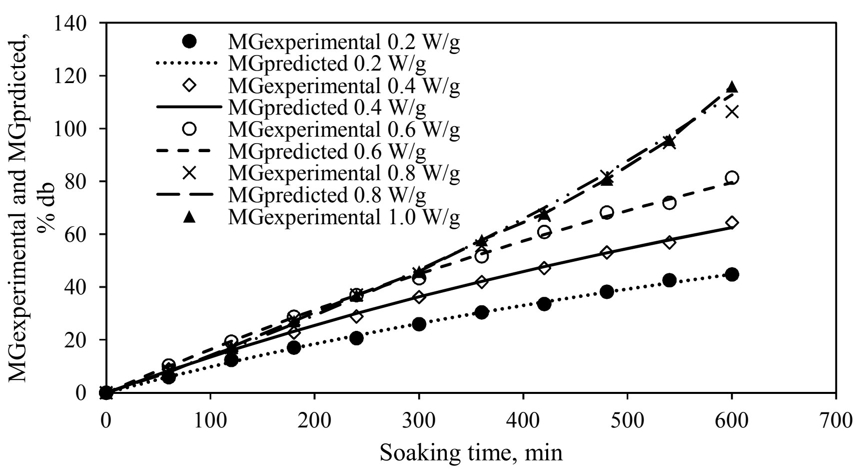

Fig. 5. MG experimental vs MG predicted for microwave-assisted soaking at different microwave power density levels

Table 3. Moisture gains experimental data during hot water soaking at different temperatures

	Soaking temperatures								
	40°C			**50°C**			**60°C**		
Soaking Time (min)	**MC % db**	**MG Experimental, % db**	**MG predicted, % db**	**MC % db**	**MG Experimental, % db**	**MG predicted, % db**	**MC % db**	**MG Experimental, % db**	**MG predicted, % db**
0	16.81	0	0	16.81	0	0	16.81	0	0
15	20.43	3.61	3.25	20.43	3.61	3.65	22.02	5.21	5.31
30	22.91	6.10	6.36	24.44	7.63	7.07	28.10	11.29	10.19
60	28.59	11.77	12.16	30.26	13.45	13.34	36.12	19.31	18.89
120	38.41	21.60	22.35	40.35	23.54	23.94	47.12	30.30	32.93
180	47.56	30.75	30.99	47.56	30.75	32.56	58.55	41.73	43.77
240	55.65	38.83	38.43	55.65	38.83	39.70	69.63	52.82	52.40
300	61.83	45.02	44.89	61.83	45.02	45.73	78.49	61.68	59.43
360	67.56	50.74	50.55	70.09	53.28	50.87	82.00	65.18	65.26

Table 4. Moisture gains experimental data during microwave-assisted water soaking at microwave-assisted soaking at different microwave power density levels

	Microwave power density levels									
	0.2 W/g		**0.4 W/g**		**0.6 W/g**		**0.8 W/g**		**1.0 W/g**	
Time (sec)	**MG Experimental, % db**	**MG predicted, % db**	**MG Experimental, % db**	**MG predicted, % db**	**MG Experimental, % db**	**MG predicted, % db**	**MG Experimental, % db**	**MG predicted, % db**	**MG Experimental, % db**	**MG predicted, % db**
0	0	15.88	0	0	0	0	0	0	0	0
60	5.90	21.93	8.86	8.30	10.31	10.03	8.38	8.07	7.69	7.66
120	12.42	27.52	15.81	16.02	19.35	19.50	17.10	15.80	17.34	14.89
180	17.09	32.72	22.73	23.22	28.75	28.45	27.76	23.21	27.09	21.72
240	20.67	37.55	28.87	29.94	36.95	36.92	37.01	30.32	36.88	28.19
300	25.95	42.06	36.20	36.23	43.35	44.95	44.98	37.14	45.84	34.32
360	30.42	46.28	41.94	42.13	51.65	52.57	55.63	43.69	57.79	40.13
420	33.57	50.23	47.17	47.68	60.86	59.81	67.16	49.99	67.82	45.66
480	38.22	53.94	53.10	52.91	68.24	66.70	81.89	56.05	80.76	50.92
540	42.58	57.43	56.88	57.84	71.89	73.27	94.63	61.89	95.77	55.93
600	44.78	60.73	64.44	62.50	81.42	79.53	106.36	67.51	115.95	60.72

3.5 Comparison between all the Soaking Methods

The moisture content gain in the ambient water soaking method was found to be 45.21 % db after 360 min (6 h). In the hot water soaking, the gain in moisture was estimated to be 50.74 % db, 53.28 % db, and 65.18 % db at 40°C, 50°C, and 60°C, respectively in the same soaking period (6 h). It was seen that the moisture gain has an increasing trend with an increase in temperature. Similarly, the moisture gains in microwave-assisted soaking at 0.2 W/g, 0.4 W/g, 0.6 W/g, 0.8 W/g, and 1.0 W/g power densities levels were 44.78 % db, 64.44 % db, 81.42 % db, 106.36 % db, and 115.95 % db, respectively after 10 min only. The increase in power density level showed an increasing trend of moisture gain from 44.78 % db to 115.95 % db. From all the soaking methods, if we compare the moisture gain data of microwave-assisted soaking with all other methods i.e ambient and hot water soaking (at 3 temperatures), the moisture content gain is very high in microwave-assisted soaking in 10 min only. This may be due to the volumetric heating of microwaves compared to the conventional heating process [11]. The time consumption in ambient water soaking was 6 h whereas, in microwave heating, the higher level of moisture gain was achieved in just 10 min.

4. CONCLUSIONS

The initial moisture content of the chickpea was found to be 14.39 % wb throughout the experiments. The moisture gain experiment was calculated and was found to be 45.21 % db in ambient water soaking. In ambient water soaking, the Peleg rate constant and the capacity constant was found to be 0.7845 min. $\%^{-1}$ and 0.0208 $\%^{-1}$, respectively. In the hot water soaking, the moisture gain was estimated to be 50.74 % db, 53.28 % db, and 65.18 % db at 40°C, 50°C, and 60°C, respectively after 360 min (6h) of soaking period. The moisture gains in microwave-assisted soaking at 0.2 W/g, 0.4 W/g, 0.6 W/g, 0.8 W/g, and 1.0 W/g power densities levels were found to be 44.78 % db, 64.44 % db, 81.42 % db, 106.36 % db, and 115.95 % db, respectively after 10 min. The Peleg model was found to be suitable for describing the soaking characteristics of chickpea at all soaking conditions with higher R^2 values. The Peleg capacity constant and rate constant didn’t show any particular trend in all the soaking methods. Among all the soaking methods, microwave-assisted soaking showed the best soaking characteristics of chickpea with less time consumption and with more amount of moisture gain. Therefore, microwave-assisted may be recommended for soaking chickpea which is a less time-consuming and energy-saving process.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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