Journal of Food Engineering and Technology 2019;8(2):55-64
https://doi.org/10.32732/jfet.2019.8.2.55

Optimized Extraction of Dietary Fiber from Defatted Rice Bran and Evaluation of the Fiber-fortified Drink Yogurt

Sara Rahbaran[1], Aazam Aarabi[1,2*], Mahsa Pourabedin[1]

1. Department of Food Science and Technology, Shahreza Branch, Islamic Azad University, Shahreza, Iran
2. Razi Chemistry Research Center (RCRC), Shahreza Branch, Islamic Azad University, Shahreza, Iran.
E-mail: aarabi@iaush.ac.ir (Corresponding author)

Received: 30 October 2018; Accepted: 23 November 2018; Available online: 1 May 2019

Abstract: The effects of time, temperature and concentration of hydrogen peroxide on the extraction yield of fiber from defatted rice bran, its color, water binding and oil binding capacity were investigated using the central composition design with three variables. Carboxymethyl cellulose (CMC) and extracted fiber were added to drink yogurt in different ratios (0-0, as blank sample, 0-0.05, 0-0.1, 0-0.2, 0.5-0.05 and 1-0.05) and rheological properties of the drink were analyzed weekly for 21 days. The results showed that temperature and hydrogen peroxide concentration significantly affected fiber extraction yield, and hydrogen peroxide concentration had the greatest impact on L*. The process temperature had the greatest impact on oil binding capacity of the fiber. However, water binding capacity was not affected by any parameter. Rheological tests indicated that blank sample was a Newtonian fluid while the drink yogurt fortified with the fiber showed a pseudo-plastic behavior.
Keywords: Dietary fiber; Drink yogurt; Rheological properties; Water binding capacity; Response surface methodology.

1. Introduction

Fibers are the structural and storage non-starch polysaccharides of the plants which are resistant to enzymatic hydrolysis. They cause increased satiety by reducing the energy density in the diet and therefore are effective in the weight control [1]. Due to the presence of fiber in the diet, blood glucose level increases slower after meals and weight loss occurs consequently [2]. Additionally, it has been identified that these compounds reduce the risk of colon cancer and type 2 diabetes and help to protect the heart and arteries by reducing bad cholesterol (LDL) up to 15%, without lowering good cholesterol (HDL) [3]. Studies have suggested that fiber intake also reduces the risk of breast cancer and is also beneficial in prevention and treatment of constipation, irritable bowel syndrome (IBS), high cholesterol, and obesity [4]. The recommended daily amount of fiber consumption is 38 g for men and 25 g for women aged 50 years or younger [5]. Studying the effect of alkaline hydrogen peroxide with the extrusion on the properties of the shell of oats demonstrated that temperature has been the most important factor influencing its water absorption characteristics [6].

Alkaline extraction of non-starch polysaccharides from wheat bran using hydrogen peroxide and the effects of time, temperature, and hydrogen peroxide concentration on extraction yield were investigated by Maes and Delcour [7]. They found the best conditions of wheat bran fiber as: 2% hydrogen peroxide at 60 °C for 4 h. Studying the concentrations and stability of the UHT (Ultra-high-temperature) drinks enriched with fiber showed positive relationship between fiber properties and stability of drinks [8]. In general, adding dietary fiber into some products improves physical properties, water binding capacity, oil-binding capacity, viscosity, texture, sensory properties and shelf life of the products [9].

Given the importance of dietary fiber on human health and due to the fact that no one has studied the effects of addition of dietary fiber extracted from rice bran to drink yogurt so far, in this study, we aimed to extract dietary fiber from rice bran using sodium hydroxide and add it to drink yogurt. Then, to study the effects of parameters (time, temperature, and concentration of hydrogen peroxide) on fiber extraction according to the tests designed by RSM (Response Surface Methodology) using Minitab Statistical Software (v. 16), and to identify the optimum level of each parameter in order to maximize the extraction yield. Additionally, knowing that drinks like drink yogurt are poor in fiber, the extracted fiber was added to drink yogurt and rheological properties of the drink were also evaluated.

2. Materials and methods

In this study, rice bran, Chamba cultivar, was prepared from local market of Isfahan. The chemicals used in the experiment were from Merck, Germany.

2.1. Chemical analysis of rice bran

The moisture content, fat, ash and fiber were measured according to the approved AOAC methods No. 925.10, 948.04, 923.03, and 962.09, respectively [10].

2.2. Designing the test with the response surface methodology (RSM)

Test design was conducted based on the Minitab 16 software and the response surface methodology (RSM) in order to evaluate the effect of three variables (time, temperature, and concentration of hydrogen peroxide) each at five levels (table 1) on extraction yield of fiber. Using fractional factorial design in the form of central composition design (CCD), 20 different treatments were determined (table 2) and the tests (extraction efficiency of fiber, water binding capacity and oil binding capacity) were then conducted on each treatment.

Table 1. Variables and measuring levels in order to extract fiber

Variables	Levels				
	+α=1.68	+1	0	-1	- α=1.68
Time (min)	70.00	60.00	45.00	30.00	20.00
Temperature (°C)	130.00	120.00	105.00	90.00	80.00
Concentration of hydrogen peroxide (%)	16.00	15.00	12.50	10.00	8.29

In order to extract fiber, bran oil extraction and hydrolysis procedures were performed. First, the amount of 6 g rice bran was added to 100 mL of 1 M NaOH. The obtained suspension was poured into a flask and covered with aluminum foil to prevent evaporation of alkaline solution. Then the resulting suspension was placed in the reaction vessel under pressure (in terms of temperature, time, and concentration of hydrogen peroxide in table 2 in accordance with the test design determined by the RSM). After reaction, the resulting suspensions were centrifuged at 5000 g for 20 min (Shimifann Centrifuge, model: C0401, Iran) and the obtained precipitate was filtered after washing. Then, hydrogen peroxide was used as a bleaching agent (table 2). In order to optimize bleaching process, hydrogen peroxide and the obtained sediments of the suspension was placed in vortex for 15 minutes, and then it was centrifuged at 5000 g for 10 min. The precipitate was isolated and washed several times with water to remove residual hydrogen peroxide. It was then flattened in tray and dried in vacuum at 40 °C for 24 hours [11]. The weight of sediments obtained from 20 treatments as well as features such as measurement of water and oil binding capacity were determined and the optimum conditions regarding reaction time, temperature and hydrogen peroxide concentration were analyzed by Minitab software.

2.3. Measurement of water binding capacity

To measure water binding capacity, 1 g dried fiber from each treatment was mixed with 20 ml distilled water and let for 18 hours. The samples were then centrifuged at 3000 g for 20 minutes and the precipitate was filtered using filter paper and funnel which were already weighed. Afterwards, the filter paper with isolated deposits was placed in the oven at 40 °C for 24 hours. Water binding capacity was calculated according the following equation [12]:

$$W_{H_2O} = \frac{m_1 - m_2}{m_2} \quad (1)$$

where m_1 and m_2 are sample's wet and dry weight in grams, respectively.

2.4. Measurement of oil binding capacity

In order to determine oil binding capacity of the fiber, 4 g of each sample was added to 20 ml corn oil in a 50 mL centrifuge tube, the content of the tube was then stirred for 30 seconds every 5 minutes. After 30 minutes, the tubes were centrifuged at 1600 g for 25 min. Finally, the supernatant was discarded and the bottom phase containing fiber and absorbed oil was filtered and weighed. Oil binding capacity (OBS) was reported according to the following equation [13]:

$$W_{OBC} = \frac{m_1 - m_2}{m_2} \quad (2)$$

where; m_1 is the weight of sample with oil in grams and m_2 is the weight of sample without oil in grams.

Table 2. The selected treatments according to central composition design in order to extract rice bran fiber, fiber extraction yield, water binding capacity and fat binding capacity of fiber

Treatments	Time (min) X1	Temperature (C°) X2	hydrogen peroxide (%) X3	fiber extraction (%) Y1	water binding capacity (%) Y2	Fat binding capacity (%) Y3
1	40.00	105.00	12.50	11.83 ± 0.01	7.42± 0.01	0.31 ± 0.01
2	60.00	90.00	15.00	12.67 ± 0.04	7.06± 0.04	0.40 ± 0.03
3	20.00	90.00	15.00	11.33 ± 0.06	6.69± 0.01	0.37 ± 0.05
4	40.00	105.00	12.50	12.83± 0.03	7.01± 0.01	0.29± 0.01
5	40.00	130.00	12.50	9.33 ± 0.04	6.57 ± 0.01	0.33 ± 0.08
6	40.00	105.00	12.50	11.00 ± 0.03	6.98± 0.02	0.33 ± 0.04
7	20.00	120.00	15.00	11.33 ± 0.06	6.87± 0.03	0.42 ± 0.02
8	60.00	105.00	12.50	9.50 ± 0.03	7.92± 0.04	0.32 ± 0.03
9	40.00	105.00	8.29	8.50 ± 0.06	6.74± 0.02	0.42 ± 0.06
10	20.00	120.00	10.00	7.50 ± 0.03	6.85± 0.03	0.40 ± 0.03
11	40.00	80.00	12.50	10.50 ± 0.07	6.82± 0.03	0.39 ± 0.02
12	20.00	90.00	10.00	11.67 ±0.03	5.04±0.01	0.37 ±0.01
13	40.00	105.00	12.50	13.17 ± 0.05	7.32 ± 0.01	0.29 ± 0.02
14	40.00	105.00	16.70	11.67 ± 0.01	7.57 ± 0.02	0.43 ± 0.03
15	60.00	120.00	10.00	7.17 ± 0.04	6.59 ± 0.02	0.29 ± 0.05
16	40.00	105.00	12.50	13.83 ± 0.04	7.87 ± 0.03	0.31 ± 0.04
17	60.00	120.00	15.00	8.50 ± 0.05	7.26 ± 0.03	0.33 ± 0.01
18	70.00	105.00	12.50	11.33 ± 0.01	6.47 ± 0.02	0.34 ± 0.01
19	40.00	105.00	12.50	13.83 ± 0.01	7.99 ± 0.04	0.30 ± 0.07
20	60.00	90.00	10.00	11.17 ± 0.04	6.98 ± 0.01	0.43 ± 0.05

2.5. Color measurement

Color meter instrument (manufactured by TES-135A Electrical Electronic Corp., Taiwan) was used and color indices, L*, a* and b*, of the samples were measured [14].

2.6. Fortifying drink yogurt with fiber

Considering the point that the drinks like drink yogurt are poor in fiber, the extracted fiber was added to drink yogurt and rheological changes were studied subsequently. For this purpose, drink yogurt was prepared from Apada company, Shiraz. Next, carboxymethyl cellulose (CMC) and extracted fiber was added to 100 mL of drink yogurt samples with different ratios (0-0, 0-0.05, 0-0.1, 0-0.2, 0.5-0.05 and 1-0.05), named C_0-C_5. The rheological properties of the samples were analyzed weekly for 21 days to obtain optimal concentration of the gum, regarding stability. Afterwards, specific ratio was added and the rheological properties of the drink were measured.

2.7. Measuring rheological properties

Viscometer device (RDVD-II, AMETEK Brookfield Co., USA) was used to determine the rheological properties of drink yogurt. Drink yogurt samples were poured in the sample container to the extent that the sample container was filled and placed in UL adapter. The measurements were performed at room temperature (20 °C) and rheological factors including shear stress, shear rate, flow consistency and behavior indices were measured. The samples were then transferred to and stored in a refrigerator at 4 °C in order to repeat weekly measurements for 21 days.

3. Results and discussion

3.1. Fiber extraction and its features

Chemical analysis of the rice bran used for fiber production is shown in Table 3. Based on the response surface methodology, a total of 20 trials were performed with 6 replications in the center point. The fiber extraction yield obtained from each treatment, water binding capacity, oil binding capacity and the measured fiber color indices (L*, a* and b*) are presented in table 2 and 4.

The mathematical model of the trials with 3 variables is as follows:

$$Y= B_0 + B_1X_1 + B_2X_2 + B_3X_3 + B_{12}X_1X_2 + B_{13}X_1X_3 + B_{23}X_2X_3 + B_{11}X_1^2 + B_{22}X_2^2 + B_{33}X_3^2 \quad (3)$$

where, B_0 is constant, B_1, B_2 and B_3 are coefficients of linear variables, B_{12}, B_{13} and B_{23} are coefficients of interaction parameters and B_{11}, B_{22} and B_{33} are coefficients of quadratic parameters.

Table 3. Chemical composition of rice bran

Property	Value
Moisture (% db)	6.20±0.14
Ash (%)	12.17±0.01
Fat (%)	20.32±0.55
Fiber (%)	21.77±0.67

Among the obtained results, the parameters with *P*-value less than 0.05 ($p<0.05$), had significant effects on the response. By eliminating the coefficients of the non-significant parameters, the final model of the proposed design obtained as follows:

$$Y_1= 0.745 - 0.121X_2 - 0.162X_2^2 - 0.147X_3^2 \quad (4)$$

According to the results, it is revealed that the extraction of fiber is significantly affected by two linear and quadratic parameters of temperature (X_2) and the concentration of hydrogen peroxide (X_3), respectively.

The effect of each parameter (time, temperature and hydrogen peroxide concentration) and interactions of them on fiber extraction are shown in contour plots (Fig. 1). Figure 1(a) indicates simultaneous effect of temperature and hydrogen peroxide concentration on fiber extraction. It was observed that with the increment of temperature to 100 °C, extraction of the fiber increased and the plot demonstrated the maximum height. However, it declined at temperatures higher than 100 °C (Fig. 1a). Additionally, increasing the concentration of hydrogen peroxide to 16%, increased the fiber extraction. Chemical reaction of rice bran with sodium hydroxide and hydrogen peroxide leads to fibers including cellulose and any cellulose derivatives destruction, depending on the reaction medium, configuration of cellulose, temperature, time and other factors such as mechanical stresses. Due to the alkaline reactions and the influence of alkaline molecules on the cellulose crystal layers and, consequently, breakdown of hydrogen bonds between them, free space develops and then cellulose structure is destroyed, which leads to its extraction [15].

In the figure 1(b), the interaction of time and hydrogen peroxide concentration on fiber extraction is depicted. Fiber extraction increased with increasing time to 40 minutes and decreased after 40 min. Similarly, the fiber extraction efficiency increased by increasing the concentration of hydrogen peroxide to 15%, while it decreased in the concentrations higher than 15%.

Figure 1(c) indicates the interaction of time and temperature on fiber extraction. The results demonstrate that the extraction rate decreased with increasing temperature. Moreover, increment of time interval to 60 minutes led to the maximum fiber extraction. However, it reduced in the case of time intervals greater than 60 minutes. Heat causes cells to rupture, resulting in destruction of polysaccharides including fiber. Moreover, the dissolution of the lignin in the cell wall cellulose by hydrogen peroxide under alkaline conditions and reduction of the crystallization, due to cutting the hydrogen bonds between and within branches, led to reduced amount of extracted fiber [16].

The maximum fiber extraction achieved at 100 °C, hydrogen peroxide concentration of 16% and 40 min process time.

Based on the results, water binding capacity of the fiber was significantly affected by time variable (X_1) of the second degree. By eliminating the coefficients of the parameters that were not significant, the final model of the proposed design was presented as follows:

$$Y_2 = 7.553 - 0.830X_1^2 \quad (5)$$

Figure 2 reveals the effect of each variable on the water binding capacity of the extracted fiber. According to the results, water binding capacity increased with increasing temperature to 110 °C and at temperatures higher than 110 °C, it declined (Fig. 2a). Additionally, by increasing the concentration of hydrogen peroxide to 13%, water binding capacity increased, while at the concentrations higher than 13%, it decreased (Fig. 2a). Lignocellulose combination treatment with hydrogen peroxide under alkaline conditions increases the solubility of the lignin in the cell wall and reduces the degree of crystallization of cellulose by cutting the hydrogen bonds

between and within branches. In the destroyed internal structure, free OH groups tend to bond with water molecules which in turn increases the water holding capacity [16].

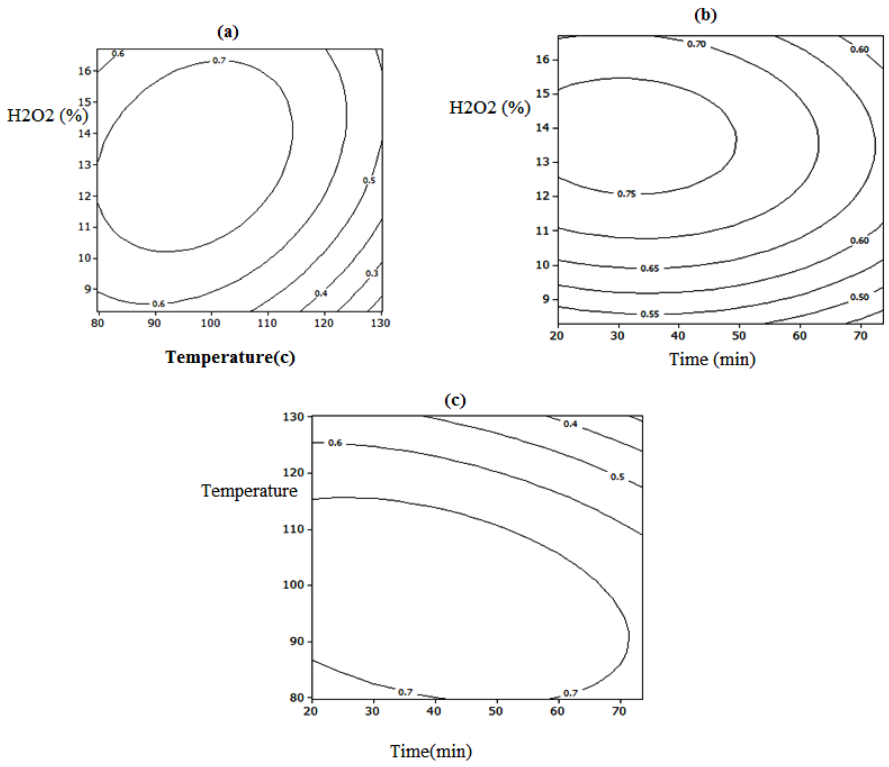

Figure 1. Two-dimensional contour plot of fiber extraction against: (a) Temperature (°C) and hydrogen peroxide concentration (%), (b) time and hydrogen peroxide concentration, and (c) time (min) and temperature.

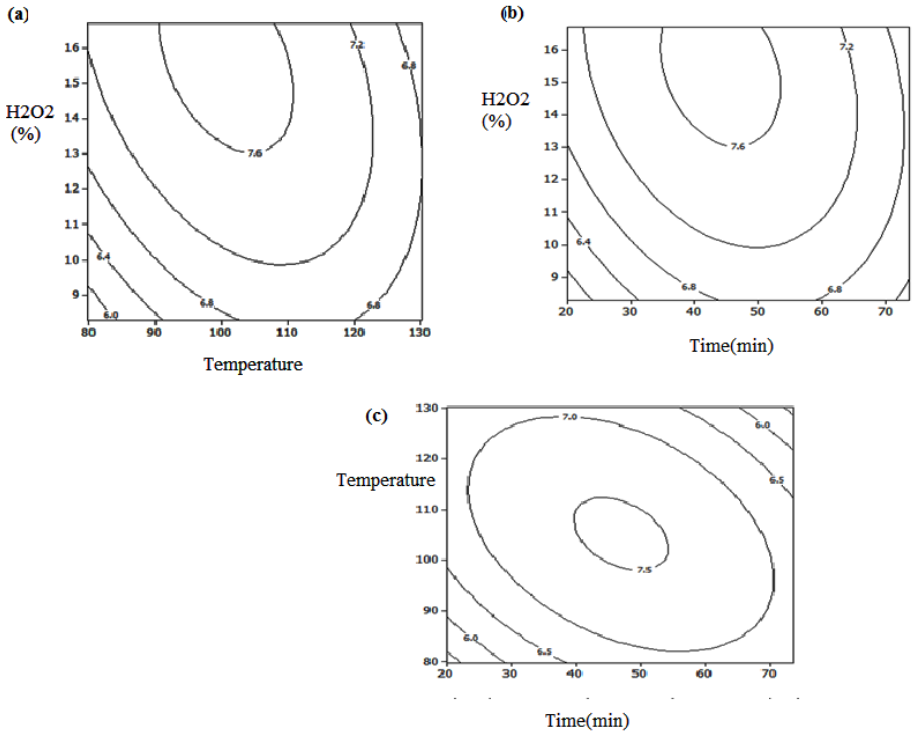

Figure 2. Two-dimensional contour plot of fiber water binding capacity against: (a) Temperature (°C) and hydrogen peroxide concentration (%), (b) Time and hydrogen peroxide concentration, and (c) Time (min) and temperature.

The interaction of time and hydrogen peroxide concentration on water binding capacity is shown in Fig. 2(b). As it can be seen, by increasing the process time to 50 minutes, and increasing the concentration of hydrogen peroxide to 13%, water binding capacity of the fiber increased and then it declined as the time passed 50 min and hydrogen peroxide percentage exceeded 13%.

Delignification and dissolution of hemicellulose under alkaline conditions (pH≥10.5) in the presence of hydrogen peroxide is enhanced and reaches its maximum at pH ≥ 11.5. In fact, once in the presence of hydrogen peroxide, fiber sources are exposed to pH = 10.5 or higher, insoluble hemicellulose content is significantly reduced and converts into soluble form. Indeed, increasing conversion of insoluble hemicellulose to the soluble form and alkaline hydrolysis of ester bond of lignocellulosic matrix and separating hemicellulose and lignin, due to considerably higher amounts of hemicellulose and its high tendency to absorb water, directly increased the water holding capacity of treated modified rice bran [17].

The simultaneous effect of time and temperature on water binding capacity of the fiber is plotted in figure 2(c). The results demonstrated that at temperatures up to 110 °C and process time of 50 min, the water-binding capacity increased, while its trend reversed at higher temperatures and times exceeding 50 min. In order to obtain maximum water binding capacity, optimum temperature of 110 °C, hydrogen peroxide concentration of 13% and process time of 50 min was selected.

The results suggested that the oil binding capacity of the extracted fiber is significantly affected by the temperature variable (X_2) by a first degree relation. By eliminating the coefficients of the parameters that were not significant, the final model of the proposed design obtained as follows:

$$Y_3 = 0.039 - 0.049X_2 + 0.030X_1^2 + 0.049X_2^2 + 0.114X_3^2 - 0.079X_1X_2 + 0.025X_2X_3 \quad (6)$$

The results showed the highest oil binding capacity of extracted fiber at 90 °C, hydrogen peroxide concentration of 9% and process time of 70 min (Figure 3). Oil binding is a physical phenomenon so that the sample compounds and biopolymers cause oil droplets trapped inside them. Due to water holding capacity of the fiber, it would affect the absorption of oil, because increased water holding capacity prevents loss of moisture and substituting lost water with oil [18].

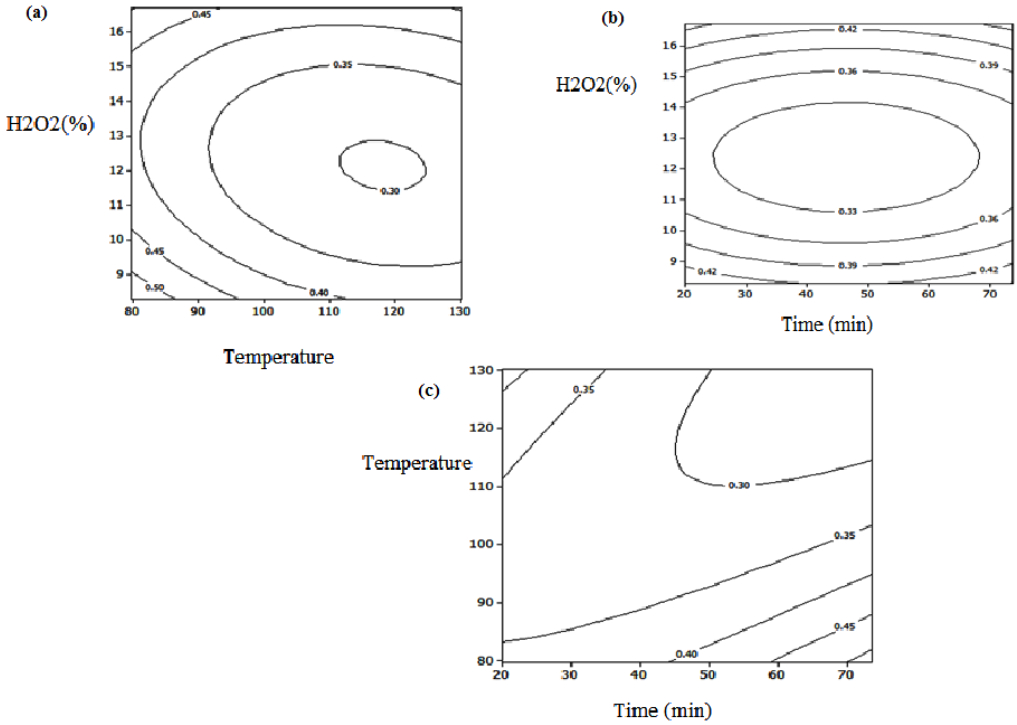

Figure 3. Two-dimensional contour plot for fat binding capacity against: (a) the temperature (°C) and hydrogen peroxide concentration (%), (b) the time and hydrogen peroxide concentration, and (c) time (min) and temperature.

3.2. Color measurement

The color indices (L*, a* and b*) of extracted fiber from each treatment are presented in table 4. By eliminating the coefficients of the parameters that were not significant, the final model of the proposed design was as follows:

$$Y_4 = 82.590 + 3.417X_2 + 9.889X_3 - 13.873X_2^2 - 18.736X_2X_3 \quad (7)$$

The results revealed that with increasing temperature up to 110 °C and time to 30 minutes, the maximum lightness was achieved whereas with increasing temperature and time, tendency to lightness reduced. By increasing the concentration of hydrogen peroxide to 16%, there was a tendency to maximum lightness and in lower concentrations the lightness of fiber reduced (Fig. 4).

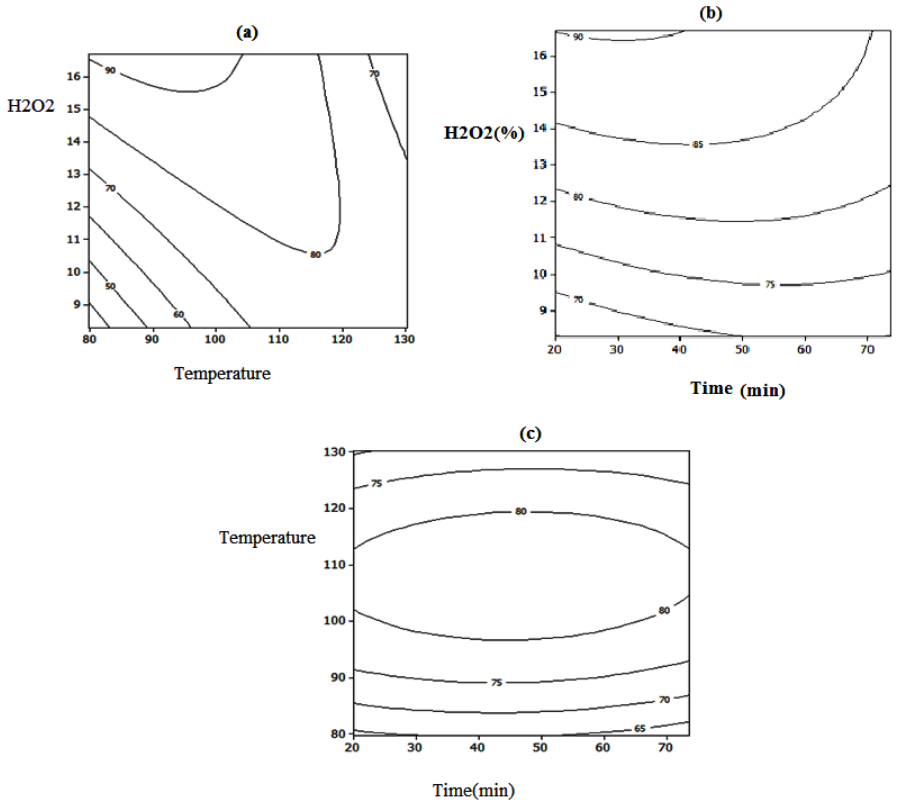

Figure 4. Two-dimensional contour diagram for fiber color (L*) against: (a) the temperature (°C) and concentration (%), (b) the time (min) and concentration, and (c) time and temperature.

It might be due to the bleaching effect of hydrogen peroxide and its effect on the pigments of rice bran. In fact, hydro peroxide anions, which form under alkaline conditions, are active and effective factors of bleaching in hydrogen peroxide. These anions are strongly nucleophile that preferably attack ethylene and carbonyl groups in the lignocellulosic complex, and consequently alter colored chromophore such as kinnons, cinnamaldehydes and ketones into colorless and non-chromophore groups. As the amount of hydrogen peroxide increases, lightness of the sample increases and redness decreases [6].

3.3. Rheological properties of the fortified drink yogurt

Studying the relationship between shear stress and shear rate can help us to properly interpret the Newtonian/Non-Newtonian behavior of a fluid. Figure 5 properly reveals such relationship.

According to the figure (5a), a linear relationship was observed between shear stress and shear rate of the drink yogurt. Thus, it was concluded that the drink was a Newtonian fluid.

The results demonstrated that with the addition of CMC, drink yogurt revealed non-Newtonian behavior, and by increasing CMC level, the stability of the drink yogurt increased. Added hydrocolloids, especially in high concentrations, develop a hydrocolloid network in the drink yogurt that straps water and therefore prevent separation of the serum. The mechanism is in fact the main mechanism of stabilizing using non-absorbent hydrocolloids which cause the stability of colloidal mixtures by developing such network and increasing the viscosity, when administered in appropriate concentrations [19]. According to the figures 5(e) and 5(f), it was demonstrated that by adding CMC and fiber, drink yogurt showed non-Newtonian behavior, in other words, the relationship between shear stress and shear rate was not linear.

Table 4. Experimental data for colorimetric test (L*, a*, b*)

Observations	L* Y_4	a* Y_5	b* Y_6
1	82.93 ± 0.01	-5.03 ± 0.01	20.75 ± 0.03
2	83.72 ± 0.04	2.52 ± 0.06	23.53 ± 0.01
3	87.97 ± 0.04	5.39± 0.04	21.29 ± 0.04
4	87.27± 0.05	0.80± 0.06	18.21± 0.01
5	70.80 ± 0.01	-3.13 ± 0.03	15.98 ± 0.01
6	85.11 ± 0.01	-2.11± 0.05	19.48 ± 0.03
7	75.17 ± 0.04	-1.19± 0.06	16.22 ± 0.02
8	79.00 ± 0.05	-1.05± 0.07	18.23 ± 0.01
9	67.41 ± 0.08	0.91± 0.02	18.61 ± 0.05
10	77.60 ± 0.01	-7.58± 0.03	16.54 ± 0.02
11	65.58 ± 0.02	0.18± 0.02	27.72 ± 0.04
12	57.26 ±0.03	-0.65±0.05	17.15 ±0.02
13	81.07 ± 0.01	-3.02 ± 0.03	19.76 ± 0.02
14	90.65 ± 0.08	1.07 ± 0.06	17.80 ± 0.05
15	79.40 ± 0.07	0.89 ± 0.03	15.27 ± 0.02
16	80.61 ± 0.06	-2.72 ± 0.01	20.07 ± 0.03
17	78.74 ± 0.01	-1.61 ± 0.04	13.51 ± 0.02
18	80.21 ± 0.04	4.64 ± 0.01	13.71 ± 0.02
19	79.99 ± 0.02	-1.98 ± 0.01	19.88 ± 0.03
20	64.53 ± 0.05	3.49 ± 0.03	23.09 ± 0.01

3.4. Coefficients of power law model

Regarding obtained coefficients of flow behavior index (n), the drink was shown to be a non-Newtonian fluid (table 5). Furthermore, $0<n<1$ suggested that the fortified drink yogurt was a pseudoplastic fluid. The results also indicated that for all samples, the flow behavior index and flow consistency index (k) increased and decreased during 3 weeks of storage, respectively. Adding CMC gum to drinks generally lead to increased consistency, however mechanical operations applied on the drinks resulted in decreased consistency index. Indeed, mechanical operation causes finer and more uniformly distributed particles which may affect and improve the reaction between proteins and absorbent gums. The low consistency and reduced viscosity observed after mechanical operation could be explained as a result of destruction of polysaccharide network during mechanical operation [20].

Table 5. Coefficients of power law model for different yogurt drink samples

Treatment	n	K (mp/s)
C_0	0.948	0.054
C_1	0.819	0.088
C_2	0.833	0.087
C_3	0.920	0.055
C_4	0.984	0.282
C_5	0.944	0.317

4. Conclusion

Studying the effect of three variables (time, temperature and concentration of hydrogen peroxide) on the quantity and properties of the extracted fiber (water binding capacity, oil binding capacity with fiber oil and Colorimetric L*, a* and b*) demonstrated that temperature was an effective parameter in the fiber extraction and the highest amount of fiber extraction was achieved at 100 °C, hydrogen peroxide concentration of 14% and process time of 40 minutes. In order to produce a fiber with the most acceptable color, hydrogen peroxide concentration of 16% was recommended. Adding different combinations of extracted fiber and CMC to drink yogurt revealed that the C_0 sample (drink yogurt without fiber and/or CMC) was a Newtonian fluid. However, other samples (C_1 to C_5) showed non-Newtonian fluid behavior. Since the *n* value in all drink yogurt samples containing CMC and fiber was lower than 1 ($0< n<1$), it was concluded that the fortified drinks were pseudoplastic fluids. Finally, flow behavior index and consistency index of all samples increased and declined, respectively, after 3 weeks.

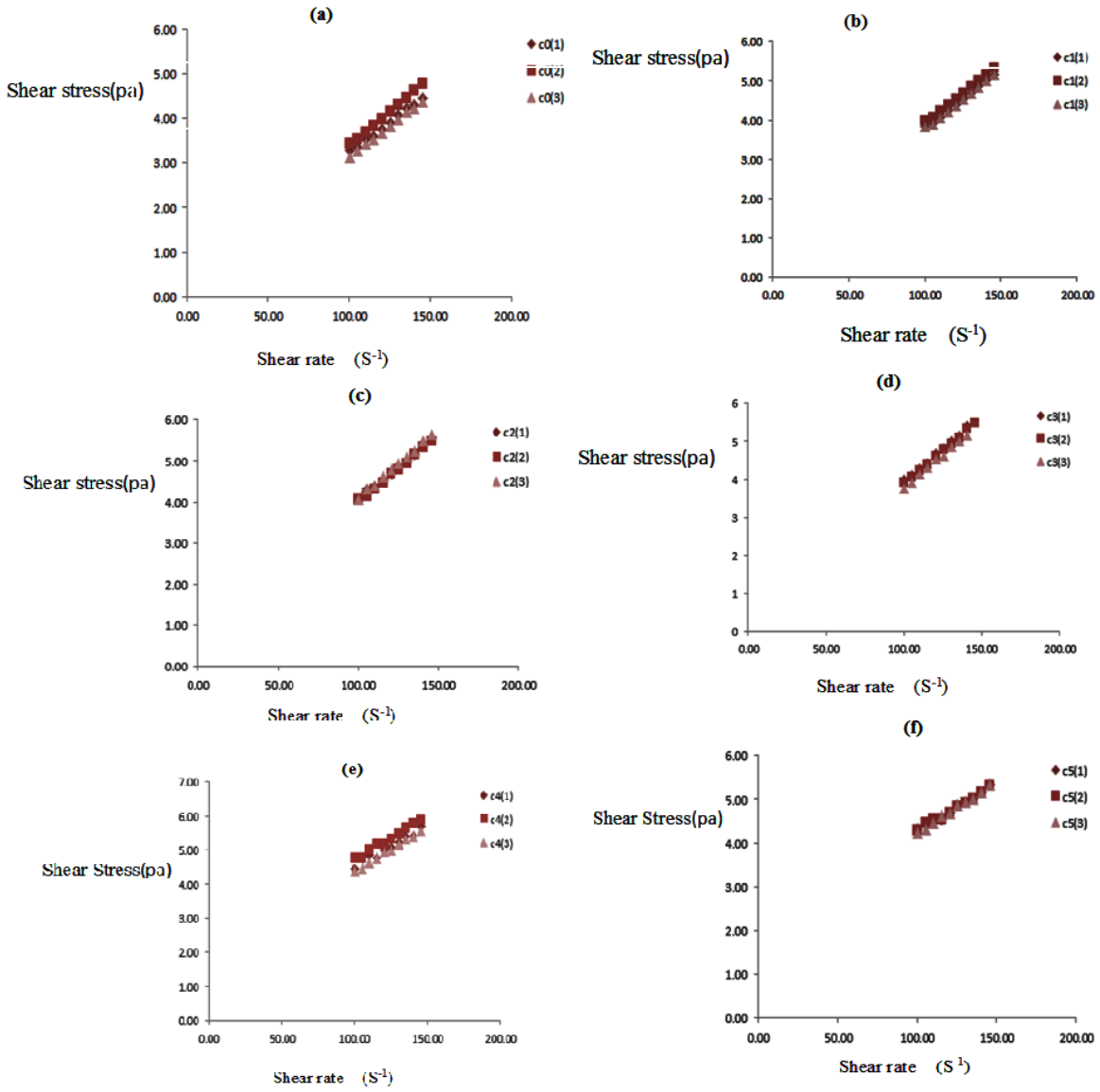

Figure 5. Shear stress (Pa) - shear rate (s^{-1}) graph, DY(C0) (a), DY+CMC 0.05% (C1) (b), DY+CMC 0.1% (C2) (c), DY+CMC 0.2% (C3) (d), DY+CMC 0.05% +DRBF 1% (C4) (e), DY +CMC 0.05%+DRBF0.5% (C4) (f) in 3 weeks. (DY= Drink yogurt, CMC =Carboxymethyl cellulose, DRBF= Defatted Rice Bran Fiber)

5. References

[1] Anonymous. Position of American Dietetic Association: Health Implications of Dietary Fiber A.D.A Reports. Journal of the American Dietetic Associations. 2002;102 (7): 993-1000.
[2] Marshall J. R. Nutrition and colon cancer prevention. Current Opinion in Clinical Nutrient ion & Metabolic Care.2009;12(5): 539-543.
[3] Park, Y., Hunter, D., Spiegelman, D. Dietary fiber intake and risk of colorectal cancer. Journal of the American Medical Association.2005;294(22): 2849-2857.
[4] Parisi, G.C., Zilli, M., Miani, M.P. High-fiber diet supplementation in patients with irritable bowel syndrome (IBS): a multicenter, randomized, open trial comparison between wheat bran diet and partially hydrolyzed guar gum (PHGG). Digestive Diseases and Sciences. 2002; 47 (8): 1697–1704.
[5] Labell, F. Designer food in cancer prevention. Food process.1990; 51: 23–32.
[6] Galdeano, M.C., Grossmann, M.V.E. Effect of treatment with alkaline hydrogen peroxide associated with extrusion on color and hydration properties of oat hulls. Brazilian Archives of Biology Technology.2005;48 (1): 63-72.

[7] Maes, C., Delcour, J.A. Alkaline hydrogen peroxide extraction of wheat bran non-starch polysaccharides. Journal of Cereal Science.2001; 34: 29-35.
[8] Alqahtani, k.N., Ashton, J., Katopo, L., Haque, E., Jones, O., Kasapis, S. Consistency of UHT beverages enriched with insoluble fibre during storage. Bioactive Carbohydrates and Dietary fibre.2014;4: 84-92.
[9] Elleuch, M., Bedigian, D., Roiseux, O., Besbes, S., Blecker, C., Attia, H. Dietary fibre and fibre-rich by-products of food processing: Characterization, technological functionality and commercial applications: A review. Food chemistry.2011;124: 411-421.
[10] AOCS. Official Methods and Recommended Practices. Champaign. Illinois: American oil Chemists' Society;2003.
[11] Inglett, G.E. Dietary fiber gels for calorie reduced foods and method for preparing the same. US patent 5, 666,662. 1998.
[12] Robertson, J. A., Monredon, F. D., Dysseler, P., Guillon, F., Amado, R., Thibault, J. F. Lebensm-wiss. Hydration properties of dietary fibre and resistant starch: a European collaborative study. LWT-Food Science and Technology. 2000;33(2):72-79.
[13] Abdul-Hamid A., and Luan S.Y. Functional properties of dietary fiber prepared from defatted rice bran. Food Chemistry.2000; 68: 15-19.
[14] Pourabedin, M., Aarabi. A., and Rahbaran, S. Effect of flaxseed flour on rheological properties, staling and total phenol of Iranian toast. Journal of Cereal Science. 2017; 76: 173-178.
[15] Gould, J. M. Studies on the mechanism of alkaline peroxide delignification of agricultural residues. Journal of Biotechnology and Bioengineering.1985; XXVII: 225-231.
[16] Gould, J. M., Jasber, B. K., Dexter, L.B., Hsu, J.T., Lewis, S.M., Fahey, G.C. High fiber, no caloric flour substitute for baked foods. properties of alkaline peroxide-treated lignocellulose. Cereal Chemistry.1989; 66(3): 201-205.
[17] Gould, J.M. Alkaline peroxide delignification of agricultural residues to enhance enzymatic Saccharification. Journal of Biotechnology and Bioengineering.1983; XXVI: 46-52.
[18] Singthong, J., Thongkaew, C. Using hydrocolloids to decrease oil absorption in banana chips, LWT. Food Science and Technology.2009; 42: 1199–1203.
[19] Syrbe, A., Bauer, W. J., Klostremeyer, H. Polymer science concepts in dairy system. A review of milk protein and food hydrocolloid interaction. International Dairy Journal.1998; 8: 179-193.
[20] Tamime, A. Y., and Robinson, R. K. Drink yogurt science and technology. Woodland publishing ltd and CRC press UK; 1999.