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Application of semi-continuous rotary separator in food industry fluids - a case study of pulp separation from fluid containing pectin

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ABSTRACT

Considering the importance and extent of industries related to food processing in human life and the key role of a raw material such as pectin in this industry, the use of innovative, more optimal and less expensive methods of extracting this material can be important. A semi-continuous rotary separator system for separating pulp from fluid containing pectin has been investigated in the present study. In this research, to evaluate the separation process with the help of semi-continuous separator by considering the rotational speed, fluid input flow rate and time in the separation process, on the efficiency (separation quality) and energy consumption at flow rates of 60, 90 and 120 ml/min and five levels of rotational speed 2000, 3000, 4000, 5000, 6000, rpm and time intervals 0-50, 51-100, 101-150, 151-200 and 201-250 seconds, according to the optimal energy consumption. The solution contains acid as a solvent for pectin and some solid fiber suspended in the fluid, in order to produce pectin, its solid particles must be separated first and a semi-continuous separator is used in this step. According to the obtained results, the input flow rate of 60 ml/min due to the longer retention time for better separation, the rotational speed of 6000 rpm due to the creation of the greatest rcf force, and finally the time interval of 0-50 seconds had the best separation quality. By considering the time and energy consumption and using the RSM, the optimal point with an efficiency of 99.12% in the conditions of a rotational speed of 3400 rpm, an input flow rate of 120 ml/min and a time of 50 seconds with a consumption of 6.48 W hours of energy consumption, by computer It was introduced that it was validated by testing the first 5 optimal points and with an error of 6% of the introduced optimal point.

1. Introduction

Today, various rotary separation methods are used in a wide range of industries, which are divided into three categories: continuous, semi-continuous and discontinuous. The separation process on a semi-industrial scale is generally done discontinuously] 1[. Continuous separators are usually used in large industries, for example, continuous separators are generally used in petrochemical, oil and gas industries.] 2[‹But semi-continuous separators are widely used in the medical, veterinary and food and beverage industries.] 3[.

The separation of materials from each other, especially the separation of two-phase and multi-phase fluids, has always been of particular importance in the field of processing equipment. The process of separation is done to achieve a phenomenon in which a mixture of several substances becomes two or more distinct products.] 4[. Separation is based on differences in chemical or physical properties such as size, shape, mass, density, or chemical interaction between the components of a mixture.] 5[. The rotary separator is used by researchers to separate solid particles from a liquid or to divide a mixture of liquids into its different components. Separation techniques are usually defined as operations that separate certain components from a mixture without chemical reaction] 6[.

In the rotary separation method, the multiphase fluid is placed in a container so that with the rotation of the rotary part of the separator, the heavier dissolved materials are pushed to the outside of the center of rotation and are pressed against the wall of the separator, and when the rotary separator stops moving, the materials are in a non-mixed state. It is observed. Fruit pulp, milk and other biological samples are separated in the food and beverage industry by a rotary separator.] 7[.

Separation based on fluid phases is one of the most important classification criteria for separation, which is divided into solid-liquid, solid-solid and liquid-liquid groups. Solid-liquid separation in food processing is one of the important and practical unit operations that is widely used in industrial processes and can play an important role in the production, quality and even preservation of many food products.] 8[. Separation techniques are involved in a large number of conversion industries. Solid-liquid separation is used in the food industry for many tasks, including changing the concentration and clarifying of fruit juices, separating coffee and tea slurry, de-sludging fish oil, recovering sugar crystals and similar things.] 9[.

Pectin is an acidic hydrocolloid compound that has many uses as a natural additive in industries, especially in the food, pharmaceutical and medical industries.] 10[. In the food industry, it is used for gelling, stabilizing, creating texture, emulsifying, thickening and replacing fat.] 11[. It is also used in medicine and pharmacy as a dietary fiber to treat digestive problems. The most common application of pectin in the food industry is its use in the production of jams and jellies as a gel-forming and thickening agent.] 12 and 13 [.

In recent years, in different countries, depending on the type of waste and sludge produced in the agricultural and food industries, research has been conducted in the field of extracting pectin from these wastes using different extraction methods and conditions. Pectin is found in the form of small to large particles, cream to brown and sometimes greenish yellow. On the other hand, pectin dissolves easily in water and produces a clear, colloidal liquid.] 14[. Fruits such as apples, plums, cherries, various vegetables and products such as carrots, potatoes, sugar beets, tomatoes and various vegetables contain pectin. According to the conducted researches, the best source for pectin can be considered the skin of vegetables] 15[.

In our country, about 30% of manufactured products are thrown away as waste [16], so it is very important to be able to reduce the amount of waste by providing solutions and return it to the consumption cycle. One of these solutions is the production of pectin from the waste of agricultural products, especially the waste of citrus fruits. Among the polysaccharides extracted from plant materials, pectin is a very complex polysaccharide that is found in the cell walls and middle layers of plants. Due to its gelling and stabilizing properties, it is used as an effective substance in the production of food products and medicinal applications. The annual consumption of pectin worldwide is approximately 50 thousand tons, which includes the value of the global market at least 400 million euros [3]. The normal level of pectin in different plants (fresh weight) is 1% apple, 1%

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apricot, 4% cherry, 1% tangerine, 1.5% carrot, and 71% citrus peel [17]. Currently, commercial pectin is almost exclusively derived from citrus peels or apple pomace, both of which are byproducts.are juice production units. Apple pomace contains 10% of dry matter. Citrus peels contain a relatively higher amount of pectin, about 67%, than apples. In terms of application, qualityCitrus and apple pectin are largely equivalent [18]. From the physical characteristics, citrus pectins are light creamy or light tan in color, while apple pectin is often darker. Alternative sources for pectin extraction include sugar beet waste, sunflower seeds and mango waste [19].The annual production of citrus fruits is more than 124 million tons, and about one third of citrus fruits are processed, which results in a large amount of residue every year. Pulp and juice are the edible parts of citrus, and peel, seeds, and internal dividing walls are considered waste.] 20[.

In the juice industry, centrifuge plays a very prominent role in different parts of the production of this product and its types are used. In a research, a decanter-type centrifuge device was used, which successfully separates suspended solids from liquids and slurry. The working principle of the decanter separator is based on buoyancy effects, that is, when water containing suspended solids is circulated, the components with higher density fall to the bottom of the liquid mixture, followed by the components with lower density. (Figure 1) explains the working of a modern decanter type centrifuge cylinder. These types of clarifiers are mostly used together with press systems to completely separate the juice from the pulp. A typical decanter consists of a cylindrical centrifuge of decreasing diameter covered with a permeable plate and enclosed in a blanket of inert gas inside a solid-walled conical bowl. Good quality and purity of this type of centrifuge was used in this research] 21[.

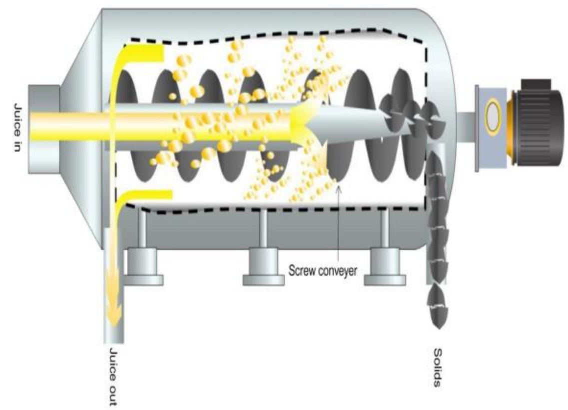


Fig 1 Schematic of decanter centrifuge machines.

In this study, centrifugation was reported to increase the separation. Centrifugation is an alternative auxiliary method to improve the efficiency of block freezing concentration. Concentrated solution was isolated from frozen fruit juice (cranberry and pineapple) in three freezing cycles. For forced separation of solutes from frozen samples, we used a centrifuge that worked for 10 min at 20 C and 4600 RPM. This technique performs well after the third cycle and reaches an increase of approximately 2.5 times the initial concentration of solids, values of nearly 0.74 kg of solutes per 1 kg of initial solutes. It reaches about 60% concentrate. The concentration performance of the centrifuge-assisted freezing block applied to the fruit juice was attributed to the ice matrix acting as a porous solid through which the concentrated solution permeates through ice drainage channels enhanced by centrifugal force.] 22[.

During World War II (1945-1939), the need to improve food production and distribution became important in order to ensure adequate nutrition and health for people around the world.] 23[. Agricultural production has more than tripled over the past 50 years due to population growth and the expansion of land for agricultural use, the technological contribution of the Green Revolution, which has affected productivity.] 24[.

As mentioned, detailed and comprehensive reports regarding the use of semi-continuous separation for multi-phase fluid separation in the food industry were not found, although discontinuous separation is widely available in research centers and can be easily used; But the very low time efficiency deprives them of the possibility of using them in industrial and semi-industrial processes; Therefore, in this research, the separation of multi-phase materials in the field of food industry has been addressed, which provides the basis for the extraction of the valuable substance pectin.

2- Materials and methods

The current research is in line with the application of semi-continuous separator in the field of food industry, that is, the separation of liquid solution containing pectin. This research was carried out using a semi-continuous rotary separator and a multi-phase fluid containing pectin, and the quality of the separated samples was measured by circulating the said fluid at different speeds and flow rates and monitoring the energy consumption in the process of conducting experiments and finally measuring the output dry matter. Less dry output indicates a better and more favorable separation quality.

Fig 2 Semi-continuous separator rotary separator vessel 1: fluid inlet containing pectin 2: fluid outlet 3: separated solid part stuck to the wall of the vessel due to rotational force (undesired part) 4: separated dilute fluid part leaving (desirable part)

Fig 3 Dissolved solid particles (pulp) stuck to the wall of the separator vessel used

2-1-Semi-continuous rotary separator

The semi-continuous rotary separator used in this research, using a rotary container set with the ability to adjust the speed, prostaltic pump[1] It works with the ability to adjust the flow rate and the inlet and outlet pipes for transferring fluid (Figure 4). When the fluid enters the separator, it causes separation by using the centrifugal force resulting from the rotation of the rotating container and the density difference of the liquid part and the solid parts suspended in the fluid.

The mechanism of the separator vessel is such that once the prostaltic pump pumps the liquid from the inlet part (Figure 2-1) into the rotating vessel at a certain rotational speed after a few minutes of the layer process (Figure 2-3 and Figure 3) It is formed from the pulp, which is the unfavorable part of our research, and a low-density (thin) layer is formed in the inner part (Figure 2-4) and finally exits from the outlet (Figure 2-2), which is the favorable part in the research. Present and contains pectin.

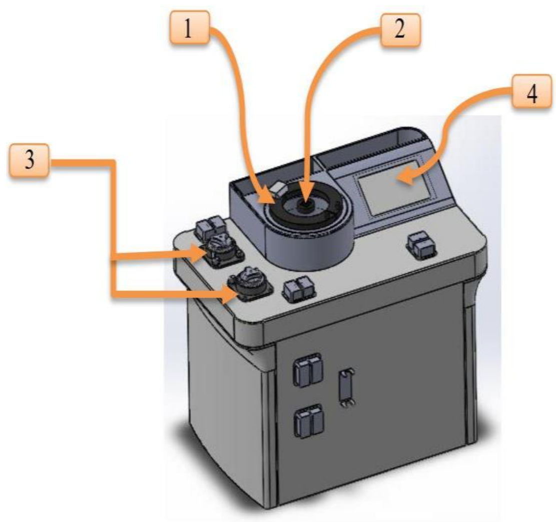


Fig 4 Schematic of the semi-continuous rotary separator 1: The location of the separator container 2: The location of the fluid inlet and outlet pipe 3: peristaltic pumps 4: The flow and flow control screen

1 Peristaltic pump

2-2- Fluid preparation method

In order to prepare orange peel powder, after preparing 30 kg of fresh oranges, the peel was separated for drying. The skin of the oranges was dried in a laboratory oven for 24 hours at a temperature of 45°C. The dried skins were powdered and passed through a sieve with mesh number 40 in order to equalize the particle size. In order to prepare the liquid, orange peel powder was mixed with distilled water at the desired ratio and the pH of the solution was adjusted using hydrochloric acid. The prepared solution was stirred for 50 min at a temperature of 82°C. The prepared solution contains acid as a solvent for pectin and some solid fiber suspended in the fluid, in order to separate the pectin, its solid particles must be separated first. A semi-continuous separator was employed at this stage.

In order to perform the test, as mentioned before, first, the inlet flow rate and rotational speed of the separator and one of the 17 treatments (five levels of speed, three levels of fluid inlet flow rate, and five time intervals) are adjusted, and then by injecting the fluid into the separator container after a period of time between 5 Up to 9 minutes (according to the rotational speed), the light phase of the fluid could be seen at the outlet of the container. In order to investigate the time process of isolation (checking the difference between the initial samples and the subsequent samples isolated in each treatment), sampling was done in containers with a capacity of 50 mL. This process continued until the separator container was saturated, and 5 samples were obtained in each step; Therefore, it was possible to separate 250 mL of fluid in each separation stage with the capacity of the container tested in this research.

It should be noted that in order to enter the uniform fluid into the separator container, the primary container (primary fluid tank) was continuously stirred during the test time by a low-speed stirrer.

2-3-Energy consumption

In order to measure the energy consumption of each experiment, with the help of a power analyzer (Figure 5) at different levels of the experiment, the amount of energy consumption related to each one was recorded. Finally, according to the duration recorded for each experiment, the energy consumption was calculated.

Fig 5 A view of the used Lutron DW-6090A power analyzer

2-4-how to evaluate the quality of separation

After receiving the output of each treatment in 5 samples (each with a volume of 50 mL) in order to measure the amount of solid material in each sample, all the test containers were numbered and knowing the weight of the empty container in each sample, the containers were carefully weighed.

The sample was centrifuged for 15 min and at a speed of 12,000 rpm until the remaining solids were separated at the end of the sampling container so that the liquid inside the container could be drained, then the falcons containing the remaining dry materials were kept at 50°C°C It was kept to ensure that no moisture remained in it (Figure 6). In this step, by weighing the sample after complete dehumidification, the weight of the dry matter of each sample was determined and with the help of equation 1, the percentage of solid matter in each sample was determined.

$$Dry\ matter\% = \frac{control\ dry\ sample\ of\ Mizan\ material - sample\ of\ each\ dry\ Mizan\ material}{control\ dry\ sample\ of\ Mizan\ material} * 100$$

Fig 6 The test container drying under standard conditions

2-5-Determining the degree of esterification

The degree of pectin esterification by titration according to the method of Santos et al] 25[With slight measurement changes in this method, 0.1 g of extracted pectin samples were added to 250 mL Erlenmeyer flasks. Pectin samples were moistened with 1 mL of ethanol and 40 mL of distilled water free of carbon dioxide was added to each of the flasks. Erlens were stirred with a shaker for 16 hours to completely dissolve the pectin. To start the titration, two drops of phenolphthalein were added to each of the erlenes and titrated with a gain of 0.1 N until the appearance of a pale pink color. The consumption volume of profit at this stage was recorded as V1. Then, 10 mL of 0.1 N soda was added to each of the neutralized solutions and stirred for 45 min until the pectin was saponified and the acid groups were released. Finally, the samples were removed and 10 mL of 0.1 N hydrochloric acid solution was added to each and again titrated with 0.1 N solution until a pale pink color appeared. The consumption benefit at this stage was considered as V2. It should be noted that an equal volume of 0.1 N hydrochloric acid can neutralize the benefit of 0.1 N. The degree of ester was calculated using equation (2).

$$DE\% = \frac{v_2}{v_2 + v_1} \times 100$$

In this regard:

DE% = degree of esterification (%)

$v_1 v_1$= volume of profit in the first stage (mL)

$v_2 v_2$= volume of profit consumed in the second stage (mL). Was.

6-2- Statistical analysis

The number of tests performed was 17, with 5 repetitions for the central point, as well as the recorded data, the average result of three observations was considered. Table 1 shows the treatments applied in the experiment for analysis using the response level method and the corresponding responses.

Table 1 Treatments applied in the experiment for analysis by RSM

test series	Q(mL/min)	RPM (rev/min)	Time step(S)
1	90	4000	150
2	90	4000	150
3	90	4000	150
4	90	4000	150
5	90	4000	150
6	60	2000	200
7	60	3000	100
8	120	5000	50
9	90	6000	200
10	60	2000	200
11	60	5000	150
12	120	3000	50
13	60	4000	50
14	120	5000	100

15	120	2000	250
16	120	3000	250
17	90	6000	250

In this research, in order to analyze the effect of independent variables related to dependent variables, Expert Design software has been used in the general response level method.

3. Results and Discussion

In this research, the aim is to investigate the behavior of the semi-continuous separator during the changes in the separation speed and the input flow rate along with the energy consumption calculation. In the obtained results, it was observed that the best rotational speed for separation is 6000 rpm; Because in all three input flow levels, the highest efficiency was achieved in this round. Based on the results of the tests, the flow rate of 60 mL/min had the best separation efficiency, this phenomenon is completely justified, because a lower flow rate means that the fluid has more time for separation, and therefore a more complete separation occurs. In this type of separation, the retention time is basically longer with the flow rate The relationship is opposite, and according to the results, it can be concluded that the best separation quality (less dry matter) was measured at the lowest flow rate.

To observe the effect of time on the process of separation quality, in each experiment, 5 samples were taken in chronological order from each experiment. It was observed that the passage of time had a negative effect on the quality of separation, which means that in each test treatment from sample number 1 to number 5, the amount of dry matter in the samples increased, the reason for this is the increase in the diameter of the outer layer formed inside the container of solid materials. which, over time, reduced the possibility of a thinner (more desirable) material to be released. In order to measure the energy consumed in the process of performing each test, the instantaneous energy consumption and the energy consumption in the whole process were observed and recorded. As expected, the instantaneous energy consumption increases with the increase in speed and flow rate, but in the overall energy consumption, considering that the flow rate takes most of the test time. makes less; Therefore, higher flow ultimately reduced energy consumption. With the help of the power analyzer used to measure the energy consumption in each round and specified flow rate and knowing the time of the entire process of each experiment, the amount of energy consumption was determined. The highest round and the lowest flow rate accounted for the most energy consumption.

3-1-Variance analysis for the efficiency of separated dry matter

The efficiency of the isolated dry matter is the ratio of the weight of the dry matter to the weight of the dry matter of the control sample. The results of variance analysis of the effect of variables on dry matter efficiency are listed in Table 2.

Table 2 Analysis of variance table of the parameters of the quadratic regression model for dry matter efficiency

Source	df	Sum of squares	Means of square	F-value	P-value
Model	9	3668.01	407.56	17.05^{*}	0.0001>
A(RPM)	1	1726.56	1726.56	72.24^{*}	0.0001>
B(Q)	1	37.33	37.33	1.56^{ns}	0.23996
C(TIME)	1	589.36	589.36	24.65^{*}	0.00056
AB	1	47.68	47.68	1.99^{ns}	0.1881
AC	1	640.99	640.99	26.81^{*}	0.0004
BC	1	28.01	28.01	1.17^{ns}	0.30440
A^2	1	467.32	467.31	19.55^{*}	0.001290
B^2	1	3.26	3.25	0.13^{ns}	0.7198
C^2	1	4.43	4.43	0.18^{ns}	0.6760

Residual	10	239.01	23.90		
Lack of Fit	4	174.29	43.57	4.039^{ns}	0.0633
Error	6	64.72	10.79		
total	19	3907.02			

** Significant at the 1% probability level

* Significant at the 5% probability level.

ns not significant

The results showed that the model was significant and the lack of fit was not significant. The effect of rotational speed and time factors is significant at the 1% probability level, also the interaction effect of rotational speed and time and the second power of rotational speed was significant at the 1% probability level. The significance of the mentioned effects indicates the importance and influence of the independent variables selected in this experiment. In Table 2, the effect of rotational speed is shown with (A), the effect of flow rate (B) and the effect of time with (C).

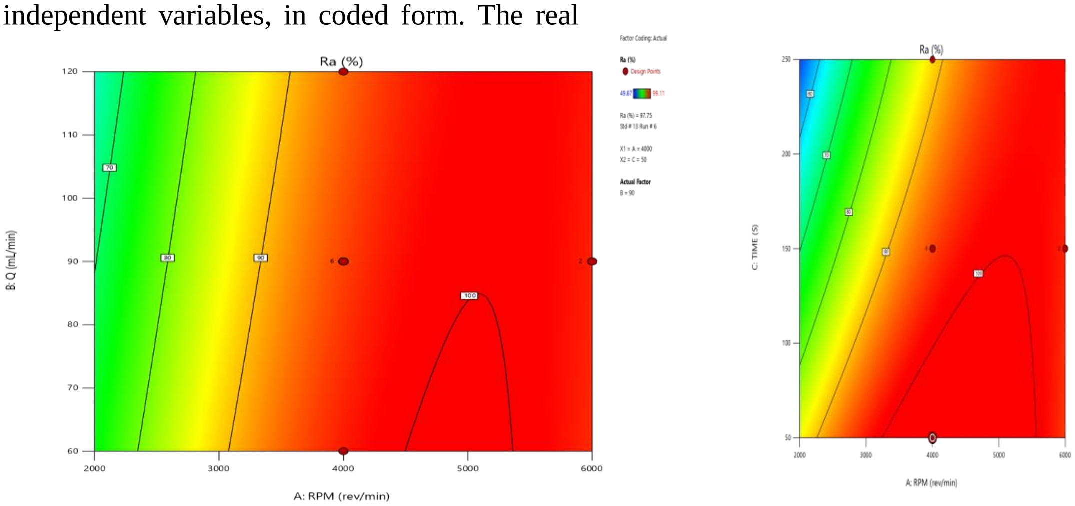
By using the response surface method, the complete quadratic polynomial model with the coefficient of determination of 91.66% was chosen to estimate the efficiency of the isolated dry matter, with a change in the amount of independent variables, in coded form. The real proposed model is a quadratic polynomial function in the form of equation 3 (R2 = 91.66%):

$$Ra_p = 95.99 + 13.9 * A - 7.68 * C + 8.95 * AC - 12.34 * A^2$$

The positive sign at the beginning of each sentence indicates the synergistic effect and the negative sign indicates the negative effect of the variable(s) on the answer.

2-3- The mutual effect of independent variables on the efficiency of separated dry matter

In Figure 7, the graph of the response level of the dependent variable (separated dry matter efficiency) for the changes of the independent variables can be seen in the form of horizontal lines.



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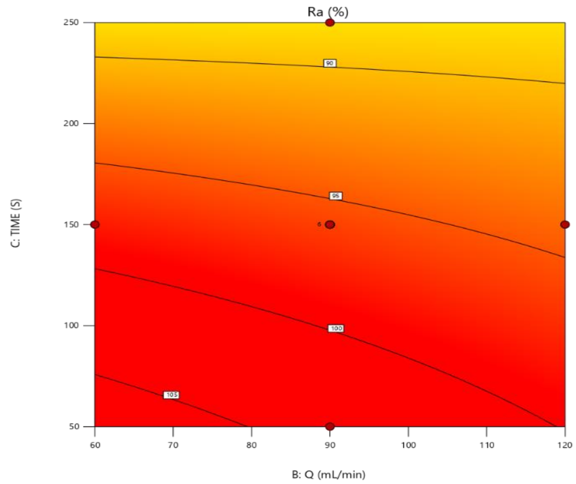

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Fig 7 The effect of independent variables on the efficiency of the separated dry matter a) changes in rotational speed and inlet flow rate b) changes in rotational speed and time c) changes in inlet flow rate and time

It can be seen in Figure A 7 that the relationship between the rotational speed and the input flow rate is such that the efficiency has increased with the increase of the rotational speed. In the case of the input flow rate, this relationship is less intense and vice versa; That is, it was observed that with a lower flow rate, the separation was of a higher quality (with a higher efficiency), which was completely justified; Because a lower flow rate causes the fluid to have more time for separation and therefore a more complete separation is achieved. In this type of separation, basically, the retention time is inversely related to the flow rate. According to Figure 7, it can be seen that the trend of changes in the dependent variable of the separation efficiency of dry matter containing pectin With the increase of time, the separation efficiency improved, which is due to the increase of the separated layer inside the separator container and the increase of the output concentration, and finally the negative effect of the passage of time on the separation efficiency. It can be attributed to the creation of more RCF force at higher rotational speed and the creation of more independent layers and finally better separation. In Figure C7, simultaneously with the increase of the input flow rate, the efficiency decreases at higher time points, which two phenomena simultaneously contribute to this decrease in efficiency. First, with a higher input flow rate, a two-phase layer is formed inside the container while rotating less accurately, and second, because at higher time points, the container is slowly filling up and the output liquid becomes thicker (lower efficiency).

3-3-Variance breakdown for energy consumption

Energy consumption, which includes two parts of energy consumption in pumps and rotor (Table 3). The results of variance analysis of the effect of offending variables on energy consumption are given in Table 4. The results of the analysis of variance table showed that the model is significant and the lack of fit is not significant, so the choice of model and analyzes can be cited and valid. The effect of rotational speed, input flow rate and square power of input flow rate is significant at the 1% probability level. The significance of the mentioned effects indicates the importance and influence of the independent variables selected in this experiment. In Table 4, the rotational speed is shown with (A), the effect of inlet flow (B) and the effect of time with (C).

Table 3 The amount of energy consumed by the rotary separator at different speeds and flow rates

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(rpm) rotational speed	2000			3000			4000			5000			6000		
Inlet flow rate (mL/min)	60	90	120	60	90	120	60	90	120	60	90	120	60	90	120
Test time (S)	972	559	421	932	536	375	857	501	381	821	591	340	816	517	310
Instant consumption(W)	43.6	47.6	50.1	53.4	56.7	59.1	64.9	67.5	69.5	72.1	74.3	77.2	80.4	82.1	84.3
Total energy (W.h)consumption	**11.77**	**7.39**	**5.86**	**13.84**	**8.44**	**6.16**	**15.45**	**9.39**	**7.36**	**16.44**	**12.20**	**7.29**	**18.22**	**11.79**	**7.26**

Table 4 Analysis of variance table of quadratic regression model for energy consumption

Source	df	Sum of squares	Means of square	F-value	P-value
Model	9	237.23	26.36	98.09*	< 0.0001
A(RPM)	1	35.62	35.62	132.54*	< 0.0001
B(Q)	1	174.97	174.97	651.14*	< 0.0001
C(TIME)	1	0.0000	0.0000	0.0000ns	1.0000
AB	1	12.75	12.75	47.45*	< 0.0001
AC	1	0.0000	0.0000	0.0000ns	1.0000
BC	1	0.0000	0.0000	0.0000ns	1.0000
A^2	1	0.0194	0.0194	0.0721ns	0.7937
B^2	1	8.16	8.16	30.35*	0.0003
C^2	1	0.1728	0.1728	0.6431ns	0.4412
Residual	10	2.69	0.2687		
Lack of Fit	4	1.36	0.3403	1.54ns	0.3028
Error	6	1.33	0.2210		
total	19	239.92			

**Significant at the 1% probability level

*Significant at the 5% probability level.

ns not significant

By using the response surface method, the complete quadratic polynomial model with a coefficient of determination of 98.81% was selected to estimate the amount of energy consumed, with a change in the amount of independent variables, in coded form. The actual proposed model is a quadratic polynomial function in the form of equation 4 (R2 = 98.81%):

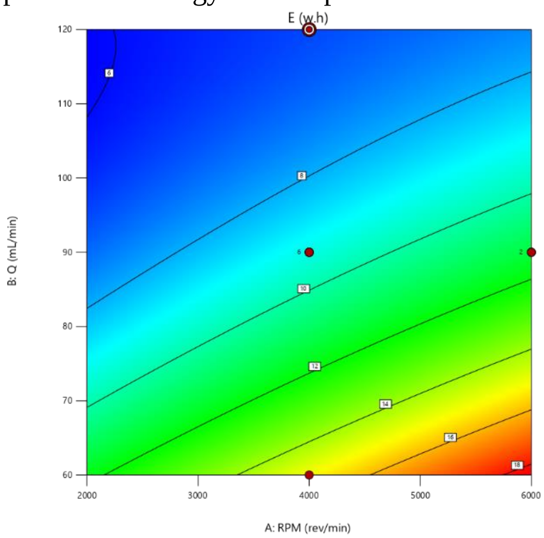
$$Ra_p = 9.24 + 2.08 * A - 4.18 * B - 1.26 * AB + 1.66 * B^2$$

The positive sign at the beginning of each sentence indicates the synergistic effect and the negative sign indicates the negative effect of the variable(s) on the answer.

3-4- The mutual effect of independent variables on energy consumption

In Figure A 8, we can see that two significant factors, i.e. rotational speed and input flow rate, each have an effect on the energy consumption of the separator. By observing the energy consumption trend of the input flow rate, it can be seen that the energy consumption decreases with the increase of the flow rate. Perhaps, at first glance, higher inlet flow rate means more energy consumption by inlet pumps; But by looking more closely at the whole process, we realize that the higher the input flow rate, the time to perform a test is reduced by a certain amount (one cycle), which automatically causes less energy consumption of the main rotor of the separator (a significant part of the energy is spent on the rotor) and As a result, the energy consumption of the whole rotary separator is less in one cycle. Regarding the rotational speed factor, it can be seen that the higher the rotational speed, the higher the energy consumption. Obviously, this happens due to the higher consumption of the rotor at higher speeds.

It can be seen in figure b 8 that the energy consumption directly increases with the increase in rotational speed, while the trend of the time periods on energy consumption is constant and has no effect on energy consumption, the reason for this phenomenon is that basically the time periods of S 50 are considered after It is a separation process and it is basically related to energy consumption and it only affects the separation efficiency. Similarly, it can be seen in Figure C8 that time has no effect on the energy consumption and it decreases with the increase in the flow rate of the energy consumption, which is because the input speed is higher as a result of the shorter cycle and, naturally, the energy consumption is less in the whole process.



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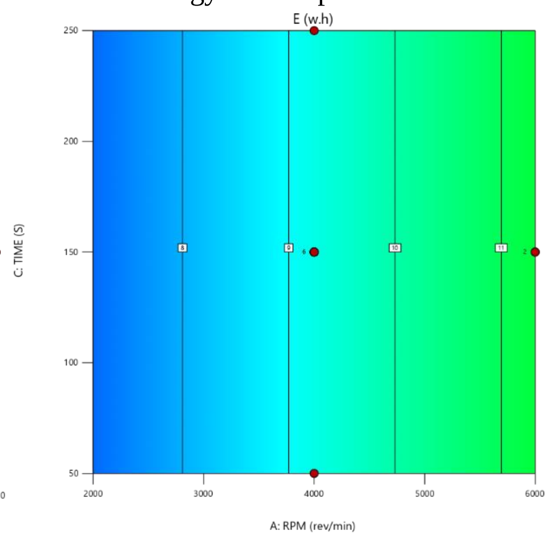

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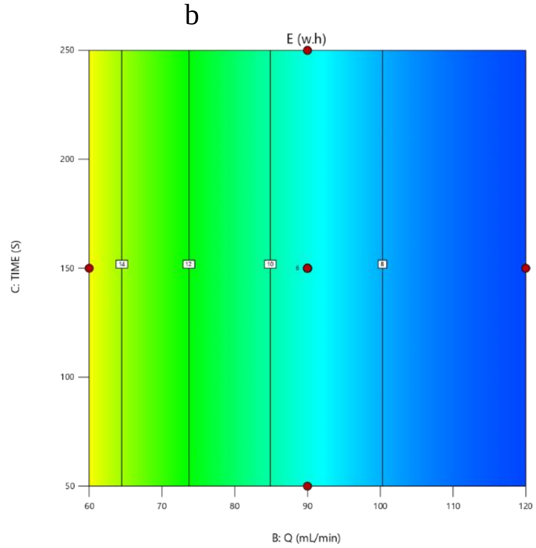

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Fig 8 The effect of independent variables on energy consumption a) changes in rotational speed and input flow rate b) changes in rotational speed and time c) changes in input flow rate and time

3-5- Checking the degree of ester

The process of changes in degree of ester is dependent on variables such as temperature, pH and starting material, which in the present research due to the same level of the above items in the experimentThere were no changes in ester level. The maximum rate of pectin deesterification occurs in alkaline conditions due to the saponification of ester groups, therefore, in the acidic conditions of this study, the protection rate of methoxyl groups is higher.] 26[. Abid et al] 27[In a study, they observed that the type of fruit from which pectin is extracted has a great influence on its ester degree. In this study, because the primary powder used was the same, as a result, the degree of ester is also expected to be the same. According to the evaluation, the degree of ester was equal to 70 ± 5%, and the extracted pectin is considered to have a high degree of ester, which has many applications.

6-3- Determining optimal points in the evaluation of pulp separation process in fluid containing pectin

In order to optimize the pulp separation process in pectin-containing fluid, the amount of energy consumed must be minimal and the efficiency of the dry material separator should be maximized. For this purpose, according to Table 5, the boundary conditions of the independent and target variables were determined. One of the important parts of optimization is weighting the variables of the objective function. Due to the equal importance of the variables, a weight equal to 1 was considered for them. It should also be noted that the optimal conditions in this research appear when the efficiency of separating dry materials (pulp) from pectin-containing fluid is at its maximum and energy consumption is at its minimum.

Table 5 Boundary conditions of independent and objective variables to optimize the separation process of dry matter from fluid containing pulp

Variable	Maximum weight	Minimum weight	upper limit	lower limit	target
rotational speed	1	1	6000	2000	in specified range
Inlet flow rate	1	1	120	60	in specified range
time	1	1	250	50	in specified range

Table 6 Introduction of the five optimal points of the pulp separation process from the liquid containing pectin

test series	rotational speed (RPM)	Inlet flow rate (mL/min)	time (S)	Total energy (W.h)consumption	Separation efficiency (%)
1	3400	120	50	6.47	99.12
2	3500	119	50	6.48	99.13
3	3500	120	51	6.48	99.23
4	3300	110	50	6.51	98.98
5	5500	120	200	6.69	97.54

At the end, the optimal point proposed by the computer was experimentally evaluated in 3 repetitions. The average of the obtained dependent variables was close to the value of the experimental relationship despite the sources of error. The values obtained by the experimental relationship show an acceptable error (6%) compared to the value predicted by the model (row 1 of Table 6), which indicates the correct choice of the model and its adaptation to the test data.

4 - Conclusion

The results of this research showed that due to the fact that the formation of layers in RCF is more, it is formed better; Therefore, it creates the best separation quality at the highest speed, i.e. high speeds. According to the results obtained from the separator, it can be predicted that low-quality separation takes place at low rotation speeds, regardless of the flow rate of the fluid input. Also, by comparing the five time samples taken in each experiment, a downward trend in the quality of separation was observed over time, so it can be concluded that if a mechanism is created to clean the pulp layer, it will be possible to receive bagged output in a longer period of time. Finally, due to the process of reducing the separation efficiency as the semi-continuous separator approaches its nominal capacity in order to receive a constant high-quality output, it is necessary to reduce the fluid input flow rate over time. The exact amount of this flow rate reduction requires separate experiments and calculations in this field. In the continuation of this research, it is possible to use software simulation in order to achieve the maximum quality of separation more accurately with the help of fluid analysis software, and also by using a system with larger dimensions than the current system and relying on the continuous flow structure, it is possible to make more progress. This method and its practical dimension helped.

5- Resources

[1] Appelt, J., Heschel, W. and Meyer, B. (2016) Catalytic Pyrolysis of Central German Lignite in a Semi-Continuous Rotary Kiln — Performance of Pulverized One-Way ZSM-5 Catalyst and ZSM-5-Coated Beads. Fuel Processing Technology, Elsevier, 144, 56–63. https://doi.org/10.1016/J.FUPROC.2015.12.004.

[2] Sikin, A.M. and Rizvi, S.S.H. Recent Patents on the Sterilization of Food and Biomaterials by Super-Critical Fluids. Bentham Science Publishers.

[3] Jaworski, A.J. and Meng, G. (2009) On-Line Measurement of Separation Dynamics in Primary Gas/Oil/Water Separators: Challenges and Technical Solutions—A Review. Journal of Petroleum Science and Engineering, Elsevier, 68, 47–59. https://doi.org/10.1016/J.PETROL.2009.06.007.

[4] Ishii, M. and Hibiki, T. (2010) Thermo-Fluid Dynamics of Two-Phase Flow. Springer Science & Business Media.

[5] Redelius, P. and Soenen, H. (2015) Relation between Bitumen Chemistry and Performance. Fuel, Elsevier, 140, 34–43.

[6] de Haan, A.B., Eral, H.B. and Schuur, B. (2020) Industrial Separation Processes. Industrial Separation Processes, De Gruyter.

[7] Tarleton, E.S. (2014) Progress in Filtration and Separation. Academic Press.

[8] Svarovsky, L. (2000) Solid-Liquid Separation. Elsevier.

[9] Kumar, C.G. and Takagi, H. (1999) Microbial Alkaline Proteases: From a Bioindustrial Viewpoint. Biotechnology advances, Elsevier, 17, 561–594.

[10] Milani, J. and Maleki, G. (2012) Hydrocolloids in Food Industry. Food industrial processes–Methods and equipment, InTech Rijeka, Croatia, 2, 2–37.

[11] Ngouémazong, E.D., Christiaens, S., Shpigelman, A., Van Loey, A. and Hendrickx, M. (2015) The Emulsifying and Emulsion-stabilizing Properties of Pectin: A Review. Comprehensive Reviews in Food Science and Food Safety, Wiley Online Library, 14, 705–718.

[12] Maran, J. P., Sivakumar, V., Thirugnanasambandham, K. and Sridhar, R. (2014) Microwave Assisted Extraction of Pectin from Waste Citrullus Lanatus Fruit Rinds. Carbohydrate Polymers, Elsevier, 101, 786–791. https://doi.org/10.1016/J.CARBPOL.2013.09.062.

[13] Grassino, A.N., Halambek, J., Djaković, S., Brnčić, S.R., Dent, M. and Grabarić, Z. (2016) Utilization of Tomato Peel Waste from Canning Factory as a Potential Source for Pectin Production and Application as Tin Corrosion Inhibitor. Food Hydrocolloids, Elsevier, 52, 265–274. https://doi.org/10.1016/J.FOODHYD.2015.06.020.

[14] Sun-Waterhouse, D. and Waterhouse, G.I.N. Spray-Drying of Green or Gold Kiwifruit Juice-Milk Mixtures; Novel Formulations and Processes to Retain Natural Fruit Colour and Antioxidants. https://doi.org/10.1007/s11947-014-1397-4.

[15] Cserjési, P., Bélafi-Bakó, K., Csanádi, Z., Beszédes, S. and Hodúr, C. (2012) Simultaneous Recovery of Pectin and Colorants from Solid Agro-Wastes Formed in Processing of Colorful Berries. Progress in Agricultural Engineering Sciences, Academic Publisher, 7, 65–80. https://doi.org/10.1556/PROGRESS.7.2011.5.

[16] Taghizadeh-Alisaraei, A., Hosseini, S.H., Ghobadian, B. and Motevali, A. (2017) Biofuel Production from Citrus Wastes: A Feasibility Study in Iran. Renewable and Sustainable Energy Reviews, Elsevier, 69, 1100–1112. https://doi.org/10.1016/j.rser.2016.09.102.

[17] Srivastava, Pranati, and Rishabha Malviya. 2011.... - Google Scholar. https://scholar.google.com/scholar?hl=en&as_sdt=0%2C5&q=Srivastava%2C+Pranati%2C+and+Rishabha+Malviya.+2011.+2+Indian+Journal+of+Natural+Products+ and+Resources+Sources+of+Pectin%2C+Extraction+and+Its+Applications+in+Pharmaceutical+Industry+-+An+Overview&b.

[18] May, C.D. (1990) Industrial Pectins: Sources, Production and Applications. Carbohydrate Polymers, Elsevier, 12, 79–99. https://doi.org/10.1016/0144-8617(90)90105-2.

[19] Thakur, B.R., Singh, R.K. and Handa, A.K. (2009) Chemistry and Uses of Pectin — A Review. http://dx.doi.org/10.1080/10408399709527767, Taylor & Francis Group, 37, 47–73. https://doi.org/10.1080/10408399709527767.

[20] Mahato, N., Sharma, K., Sinha, M. and Cho, M.H. (2018) Citrus Waste Derived Nutra-/Pharmaceuticals for Health Benefits: Current Trends and Future Perspectives. Journal of Functional Foods, Elsevier, 40, 307–316. https://doi.org/10.1016/J.JFF.2017.11.015.

[21] Sharma, H.P., Patel, H. and Sharma, S. (2016) Enzymatic Extraction and Clarification of Juice from Various Fruits. Trends in Post Harvest Technology Journal, 2, 00–00. www.jakraya.com/journal/tpht.

[22] Petzold, G., Moreno, J., Lastra, P., … K.R.-I.F.S.& and undefined 2015. Block Freeze Concentration Assisted by Centrifugation Applied to Blueberry and Pineapple Juices. Elsevier. https://www.sciencedirect.com/science/article/pii/S1466856415000569.

[23] FAO, 1948.

[24] FAO, 2017c; (FAO and OECD, 2019b).

[25] Santos, J.D.G., Espeleta, A.F., Branco, A. and De Assis, S.A. (2013) Aqueous Extraction of Pectin from Sisal Waste. Carbohydrate Polymers, Elsevier Ltd., 92, 1997–2001. https://doi.org/10.1016/j.carbpol.2012.11.089.

[26] Methacanon, P., Krongsin, J. and Gamonpilas, C. (2014) Pomelo (Citrus Maxima) Pectin: Effects of Extraction Parameters and Its Properties. Food Hydrocolloids, Elsevier, 35, 383–391.

[27] Abid, M., Cheikhrouhou, S., Renard, C.M.G.C., Bureau, S., Cuvelier, G., Attia, H. and Ayadi, M.A. (2017) Characterization of Pectins Extracted from Pomegranate Peel and Their Gelling Properties. Food Chemistry, Elsevier, 215, 318–325.

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کاربرد جداساز نیمه‌پیوسته دورانی در سیالات حوزه صنایع غذایی – مطالعه موردی جداسازی پالپ از سیال حاوی پکتین

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چکیده

با توجه به اهمیت و گستردگی صنایع مرتبط با فراوری مواد غذایی در زندگی بشر و نقش کلیدی ماده‌ی اولیه‌ای همانند پکتین در این صنعت، استفاده از روش‌های نوآورانه، بهینه‌تر و کم هزینه تر استخراج این ماده می‌تواند حائز اهمیت باشد. یک سامانه جداساز دورانی نیمه‌پیوسته برای جداسازی پالپ از سیال حاوی پکتین در پژوهش حاضر بررسی شده است. در این تحقیق به ارزیابی فرایند جداسازی به کمک جداساز نیمه‌پیوسته با درنظرگرفتن سرعت دورانی، دبی ورودی سیال و زمان در روند جداسازی، بر راندمان (کیفیت جداسازی) و انرژی مصرفی در دبی‌های ۶۰، ۹۰ و ۱۲۰ ml/min و پنج سطح سرعت دورانی ۲۰۰۰، ۳۰۰۰، ۴۰۰۰، ۵۰۰۰ ، ۶۰۰۰، rpm[2] و بازه‌های زمانی ۰-۵۰، ۵۱-۱۰۰، ۱۰۱-۱۵۰، ۱۵۱-۲۰۰ و ۲۰۱-۲۵۰ ثانیه، باتوجه‌به انرژی مصرفی بهینه پرداخته شده است. محلول حاوی اسید به‌عنوان حلال پکتین و مقداری فیبر جامد معلق در سیال است که به‌منظور تولید پکتین ابتدا می‌بایست ذرات جامد آن جدا شود و از جداساز نیمه‌پیوسته در این مرحله بهره برد. طبق نتایج حاصل شده دبی ورودی ۶۰ ml/min به علت زمان ماند بیشتر جهت جدایش بهتر، سرعت دورانی ۶۰۰۰ rpm به علت ایجاد بیشترین نیروی rcf و در نهایت بازه زمانی ۵۰-۰ ثانیه دارای بهترین کیفیت جداسازی بودند. با درنظرگرفتن زمان و انرژی مصرفی و با استفاده از روش سطح پاسخ RSM نقطه بهینه با بازدهی ۹۹/۱۲ درصد در شرایط سرعت دورانی ۳۴۰۰ rpm ، دبی ورودی ۱۲۰ ml/min و زمان ۵۰ثانیه با مصرف ۶/۴۸ وات ساعت مصرف انرژی، توسط رایانه معرفی شد که با آزمون ۵ نقطه بهینه اول و با خطای ۶ درصد نقطه بهینه معرفی شده صحت سنجی شد.

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