BENTONITE AS ENVIRONMENTAL FRIENDLY SORPTION MATERIAL FOR SUGAR BEET MOLASSES PURIFICATION

Miljana Djordjević[1], Zita Šereš [1], Marijana Djordjević [1], Dragana Šoronja Simović[1], Nikola Maravić[1], Tatjana Došenović[2]

[1]Department of Carbohydrate Food Engineering, Faculty of Technology,University of Novi Sad, bul. cara Lazara 1, Novi Sad, Serbia
[2]Department of Basic Engineering Disciplines, Faculty of Technology,University of Novi Sad, bul. cara Lazara 1, Novi Sad, Serbia
e-mail: zitas@tf.uns.ac.rs

Abstract

Search for efficient, inexpensive and environmental friendly sorption material for application in the sugar industry was always been in the research focus. Bentonite as natural material with great affinity for binding inorganic and organic compounds could fulfill the previous requirements. This study investigates application of two different sodium-calcium bentonites (Claris p30 and Claris p50) as adsorbents in the purification of sugar beet molasses. Box-Behnken experimental design was employed and the effect of 3 independent variables pH (3, 5, 7), molasses dry substance (30, 40, 50°Bx) and bentonite suspension concentration (9, 15, 21 g/L) on the sugar beet molasses color and turbidity reduction were studied. Positive results regarding color reduction (22% with Claris p30 and 48% with Claris p50) and turbidity reduction (90% with Claris p30 and 99% with Claris p50) of sugar beet molasses were obtained upon treatment with corresponding bentonites indicating their applicability as environmental friendly adsorbents of non-sugars from the sugar industry.

Introduction

Sugar beet molasses as the final residue from the sugar crystallization unit represents a stream in which all non-sugars including colorants are concentrated. Reduction of non-sugars in sugar beet molasses is desirable in order to facilitate sugar recovery from molasses by chromatographic process and minimize changes that may occur during storage and further industrial. Decrease in sugar beet molasses non-sugars content could be achieved through treatment with different adsorbents. Application of activated carbon for juice and sugar beet molasses purification was well established but inevitable problem represents his regeneration and disposal. Adsorbents disposal problems could be diminished with the application of bentonite since he is applicable in soil fertilization [1]. Bentonite application is widespread since represents a natural material with large specific surface area and high cation exchange capacity which provides exceptional adsorption capacity for various inorganic and organic compounds [2]. Presence of dominant exchangeable ion in bentonite structure determines bentonite type and among most commonly used in the industry are sodium (Na) and calcium (Ca) bentonites [1]. Enhancement of desired bentonite properties could be obtained through bentonite modification. Combined sodium-calcium bentonite (Na-Ca bentonite) is obtained after treatment of Ca bentonite with sodium carbonate as a result of calcium ions substitution with sodium ions. This way exceptional swelling and water absorption capabilities of Na bentonite can contribute to overall expanding ability of produced Na-Ca bentonite. Another way to enhance adsorption capacity of bentonite is hydration treatment prior to application which is highly recommended [3]. Previous studies on sugar beet juice purification with bentonite alone or in combination with other materials, reported great improvement in the juice quality [3-5]. Nevertheless, literary data concerning bentonite application in molasses treatment are scarcely. Therefore, the objective of this study was to determine the effects of Na-Ca bentonite treatement on changes in sugar beet molasses color and turbidity.

Experimental

Molasses purification treatment was conducted according to the Box-Behnken experimental design (Table 1) with independent variables: pH (3, 5, 7), molasses dry substance (30, 40, 50°Bx) and bentonite suspension concentration (9, 15, 21 g/L).

Molasses used in this research was sampled from the sugar beet factory "Šajkaška" (Žabalj, Serbia) during the sugar beet campaign in 2016. Two different types of fine powder formulated Na-Ca bentonite, Claris p30 and Claris p50 (montmorillonite content 88-92%, moisture content 9-10%, Bentoproduct, Bosnia and Herzegovina) were used for molasses treatment. For the purpose of corresponding experiments and experimental design, molasses samples were adjusted to 30, 40 and 50°Bx using distilled water. Measurements of color and turbidity in samples were conducted prior to every set of experimental runs.

Bentonite suspensions were prepared according to the producer's recommendations Claris p30: 100 g in 5 L of water, Claris p50: 100 g in 1 for L of water. Hydration is achieved through steeping of bentonite into distilled water heated at 40°C-50°C with intense mixing in the initial stage of hydration until uniform suspension is obtained. Bentonite suspension were stored for 12 hours at room temperature (25°C) in order to reach the best effectiveness [3].

Bentonite suspension was added to 200 ml of diluted molasses (30, 40 and 50°Bx) in order to achieve the selected concentration (9, 15 and 21 g/L). Selected pH was adjusted with citric acid (50 g/100 mL) (Lach-Ner s.r.o., Neratovice, Czech Republic) upon bentonite addition. Erlenmeyer flasks containing prepared blends were closed and placed into the water bath (VelpScientifica®, Italy) heated at 60°C and mixed for 30 min. Cooled blends (25°C) were filtered through filter paper (Selecta faltenfilter) and the obtained filtrate was used for color and turbidity measurements.

Color of samples was quantified by the absorbance measured on a spectrophotometer (Spectrophotometer MA 9522-Spekol 220, Iskra, Slovenia) at the wavelength of 420 nm according to the method given by the International Commission for Uniform Methods of Sugar Analysis (ICUMSA) and calculated using equation:

$$Color\ [IU] = \frac{A \times 1000}{c \times b} \qquad (1)$$

where C is the colour in ICUMSA unit (IU), A is the absorbance of the solution at 420 nm, b is the cuvette length or path length in cm (1 cm cuvette for molasses) and c is dry substance content in g/cm^3 calculated by using brix-density tables for sugar solutions. The turbidity of the samples was directly measured using turbidimeter WTW Turb 550IR (Germany) and given in NTU units.

Changes in molasses colour and turbidity were calculated using following equation:

$$Reduction\ [\%] = [(QP_i - QP_f)/QP_i] \times 100 \qquad (2)$$

where QPi is the value of initial quality parameter of diluted molasses and QPf is the value of final quality parameter of the molasses sample after treatment.

Results and discussion

In Table 1 are presented experimentally obtained values for each response under different experimental conditions according to the Box-Behnken experimental design.

Influence of bentonite treatment on colour reduction

Increase in molasses color reduction is observed at low pH values regardless of applied bentonite and his concentration (Figure 1). In samples treated at pH 3 when Claris p30 was applied (runs 1, 3, 5, and 7, Table 1) molasses color reduction percentage was three to four times higher than in samples treated with same bentonite at pH 7. Similar trend in molasses color reduction was noticed upon Claris p50 application where reduction percentage was about two times higher in samples treated at pH 3 in comparison to samples treated at pH 7. It could be concluded that pH is one of the main factors that affect bentonite adsorption capacity due to the modification of its charge [6] and the ionisation equilibrium of non-sugar compounds dissolved in the diluted molasses in acidic environment. As a result, strong electrostatic interaction between bentonite and non-sugars is enabled and molasses color reduction is more pronounced.

Table 1 Box-Behnken design with three independent variables at three levels and responses

				Color reduction [%]		**Turbidity reduction [%]**	
Standard run	pH	DS [°Bx]	BC [g/L]	Claris p30	Claris p50	Claris p30	Claris p50
1	3.0	40	9	21.75	40.57	0	0.63
2	7.0	40	9	7.92	26.53	66.97	48.90
3	3.0	40	21	17.51	42.86	0	55.04
4	7.0	40	21	6.66	24.92	90.20	92.65
5	3.0	30	15	22.34	48.93	30.87	97.45
6	7.0	30	15	1.51	31.62	67.65	99.08
7	3.0	50	15	19.34	38.29	0	0.50
8	7.0	50	15	0.22	14.06	80.31	52.77
9	5.0	30	9	0.12	24.31	0	97.08
10	5.0	30	21	11.54	20.6	57.32	98.37
11	5.0	50	9	10.18	25.68	25.46	1.12
12	5.0	50	21	18.14	38.17	54.59	63.27
13	5.0	40	15	5.14	33.02	47.75	54.73
14	5.0	40	15	2.38	19.25	63.35	73.34
15	5.0	40	15	3.22	27.23	45.88	64.40

DS-dry substance; BC-bentonite concentration;

Influence of bentonite concentration on molasses color reduction is not strongly expressed but still in samples treated with larger amount of bentonites increase in molasses colour reduction was recorded.

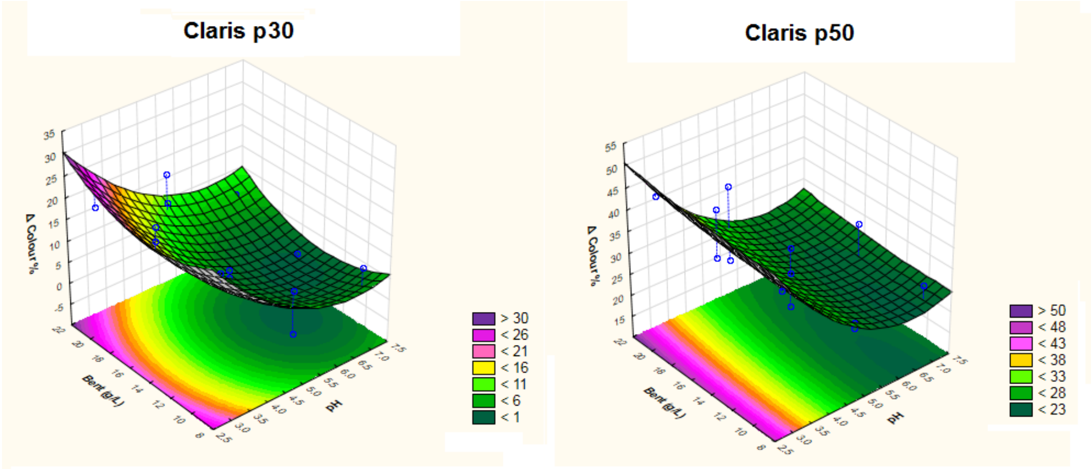

Figure 1. Influence of pH and bentonite concentration on molasses color reduction

In molasses samples with dry substance content 30°Bx and 40°Bx higher percentage in molasses color reduction was reached upon both bentonite addition probably because increase in molasses dry substance led to increase in non-sugars content.

In general, obtained results indicate that with Claris p50 application higher percentage in molasses color reduction is reached regardless of bentonite concentration and molasses dry substance.

Influence of bentonite treatment on turbidity reduction

Bentonite concentration and pH were the main factors which affect the molasses turbidity reduction. As presented in Figure 2 with increase in bentonite concentration and pH value reduction of molasses turbidity also increased regardless of applied bentonite. In samples treated at pH 3 (runs 1, 3, 5, and 7, Table 1) molasses turbidity reduction was almost 100% lower than in samples treated at pH 7 regardless of applied bentonite. Nevertheless, considerable molasses reduction percentage was also recorded in all samples treated at pH 5 upon both bentonites addition. Furthermore, molasses turbidity reduction increased with the increase in bentonite concentration at constant pH and molasses dry substance (runs 1 and 3; 2 and 4; 9 and 10, Table 1).

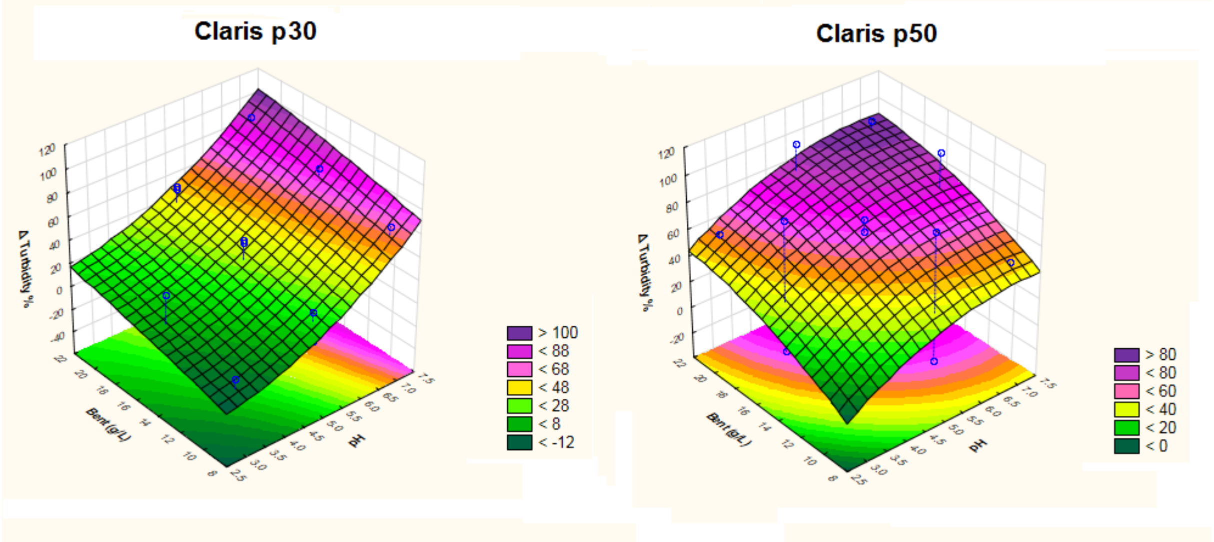

Figure 2. Influence of pH and bentonite concentration on molasses turbidity reduction

Highest molasses turbidity reduction percentage is observed when treated molasses had lowest dry substance content (30°Bx) indicating that increase in molasses dry substance content contributes to turbidity increasement.

Conclusion

This study showed that bentonite adsorption potential could be utilized for sugar beet molasses treatment since reduction of non-sugar compounds content, particularly colorants, is achieved upon his application. Based on the obtained results of molasses colour and turbidity reduction it can be stated that bentonite concentration and pH greatly affected the aforementioned parameters. Maximal molasses color reduction was obtained in acidic environment (pH 3-5) with the increase of bentonite concentration while the highest molasses turbidity reduction was observed at pH 7 with medium (15 g/L) and high (21 g/L) bentonite concentrations. The obtained results also drive on to conclude that Claris p50 was more efficient in molasses color and turbidity reduction in comparison to Claris p30. Therefore, corresponding bentonites can be successfully applied in the purification treatments in sugar industry without concerning of possible environmental problems.

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