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Effect of Different Treatments on Heavy Metal Concentration in Sugar Cane Molasses

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***Abstract*—**Cane molasses is used as a raw material for the production of baker's yeast (*Saccharomyces cerevisiae*) in Egypt. The high levels of heavy metals in molasses cause a critical problem during fermentation and cause various kinds of technological difficulties (yield and quality of yeast become lower). The aim of the present study was to determine heavy metal concentrations (cadmium, nickel, lead, and copper) in crude and treated molasses obtained from the storage tanks of the baker's yeast factory through four seasons. Also, the effect of crude molasses treatment by different methods (at laboratory scale) on heavy metals reduction and its comparison with factory treated molasses were conducted. The molasses samples obtained at autumn season had the highest values of all the studied heavy metals. The molasses treated by cation exchange resin then sulfuric acid had the lowest concentrations of heavy metals compared with other treatments.

***Keywords*—**Molasses, baker's yeast, heavy metals, treatment.

I. Introduction

CANE molasses, a byproduct of sugar industry is readily available at relatively low cost. Initially, the term molasses referred specifically to the final effluent obtained from the preparation of sucrose by repeated evaporation, crystallization and centrifugation of juices from sugarcane [1]. Cane molasses is used as a raw material for the production of baker's and feed yeast [2]. Beside its high sugar content, molasses contains minerals, organic compounds, and vitamins, which are valuable nutrients in fermentation processes [3]. In this respect, [4] studied the minerals concentration of molasses. He confirmed the presence of copper, iron, manganese, and zinc in cane molasses at concentrations ranged from 6.6 to 68.4 ppm (mean value 14.0 ppm), from 145 to 640 ppm (mean value 297 ppm), from 2.1 to 67.1 ppm (mean value 28.3 ppm), and from 7.5 to 37.3 ppm (mean value 13.1 ppm), respectively. Moreover, [5] studied the metals concentration of Egyptian cane molasses. He confirmed the presence of copper, lead, cadmium, and nickel in cane molasses and found that the metals concentrations (in ppm) ranged from 7.35 to 22.81 (mean value 12.86 ppm) for copper, from 1.55 to 9.46 (mean value 5.12 ppm) for lead, from 0.14 to 0.82 (mean value 0.40 ppm) for cadmium, and from 1.07 to 1.85 (mean value 1.31 ppm) for nickel.

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The variations in heavy metals concentrations in soil of different areas as well as sugarcane plant cause variations in heavy metals concentrations in molasses. Moreover, [6] stated that the trace elements concentration in sugarcane plant as well as in juice, sugar, and molasses was depended on the concentration of the available trace elements in the soil, fertilizers, and irrigation water, in addition to permissibility, selectivity, and absorbability of the plants for the uptake of certain trace elements from the soil. Also, [7] revealed that sugarcane requires not only irrigation but also needs a high input of different fertilizers including phosphatic fertilizers which contain significant amounts of heavy metals such as cadmium. Furthermore, [8] concluded that variations of heavy metals in molasses may be related to different compositions of sugarcane plants, season of production, ecological changes in soil, the addition of fertilizers to sugarcane plant, the irrigation water, the additives to cane sugar juice during cane sugar production stages, and the corrosion effects on containers due to passage of CO_2 and SO_2. Also, [9], [10] reported that heavy metal accumulation in soils was influenced by many factors such as type and amount of clay, soil organic matter content, phosphatic fertilizers, crop residues, and soil pH.

Cane molasses contains a number of organic and inorganic inhibitors, which may impede the metabolism of yeast cells. Before the fermentation process, cane molasses used to be pretreated to reduce the level of various inhibitors. Common pretreatment using acids could bring down the concentration of excessive metallic ions and raise the quality of fermentation [11]. In this respect, [12] studied the different pretreatment techniques for molasses to remove undesirable metals. The tested pretreatment techniques were sulfuric acid, potassium ferrocyanide, tricalcium phosphate, and tricalcium phosphate with hydrochloric acid treatment. The potassium ferrocyanide treatment considerably reduced the metal ion concentration compared to the other treatment techniques and untreated molasses. Moreover, [13] studied the effect of pretreatment of molasses with cation exchange resin, sulfuric acid, tricalcium phosphate, potassium ferrocyanide, and EDTA. He reported that the sulfuric acid gave the better results as a technique can be efficiently used for the removal of heavy metals from molasses, compared with other techniques. The purpose of the current study is to evaluate the heavy metals concentration (lead, cadmium, copper, and nickel) in crude and treated molasses obtained from the storage tanks of the yeast factory at four seasons. In addition, the study aims to test the treatment of molasses by different suggested methods and study their decreasing effects for the heavy metals content, as well as comparing the suggested methods of treatments at the present study with the applied treatment in the factory.

II. Materials and Methods

A. Sampling

Egyptian sugarcane molasses (crude and treated molasses) was obtained from baker's yeast factory. A total of 72 samples of crude molasses and treated molasses were collected during the four investigated seasons (winter, spring, summer, and autumn, 2013). The crude sugarcane molasses reached the baker's yeast factory from different sources (Deshna, Kous, Armant, Edfu, Gerga, and Naga Hammady) and mixed together, then kept in the storage tanks. Thirty-six samples of mixed crude molasses were taken from storage tanks of the factory. In addition, thirty-six samples of molasses treated with phosphoric acid (85%) were collected from the factory tanks and were kept at 5°C until analysis. Molasses samples were analyzed for the lead, cadmium, copper, and nickel concentrations.

B. Treatment of Molasses as Described by Baker's Yeast Factory

The crude sugarcane molasses (Brix 80) was diluted (1:1) with distilled water to Brix 40. One mL of phosphoric acid (85%) was added to one liter of diluted molasses. The mixture was heated to 92 °C for 2 h. with continuous mixing. The molasses was centrifuged at 4500 rpm for 20 min. The treated molasses was analyzed for its concentrations of heavy metals (cadmium, nickel, lead, and copper).

C. Treatment of Molasses as Described in the Present Study

The diluted molasses (Brix 40) was subjected to treatment at two stages. The first stage was achieved by cation exchange resin as physical treatment as follows: Twenty grams of cation exchange resin (Amberlite IR 120) were added to 100 ml diluted molasses and the mixture was shaken for 6 h. at 250 rpm and under 30 °C using a rotary shaker incubator. The resin was removed by filtration. Meanwhile, the second stage was achieved by one of the chemical treatments *i.e.* sulfuric acid, tricalcium phosphate, potassium ferrocyanide, EDTA or phosphoric acid. The treated molasses from the first stage was treated by sulfuric acid (1 ml/l), tricalcium phosphate (0.03 M), potassium ferrocyanide (100 ppm), EDTA (100 ppm) or phosphoric acid (1 ml/l). The mixture was heated to 92 °C for 2 h. with continuous mixing. The molasses was centrifuged at 4500 rpm for 20 min. The treated molasses was analyzed for its concentration of heavy metals [13].

D. Determination of Brix Degree

Brix degree of molasses was determined by using Brix hydrometer according to [14].

E. Heavy Metals Assay

Cadmium, nickel, lead, and copper were determined according to the method described in [15]. The molasses sample (2 g) was dried in an oven (105 °C). The dried material was ashed in a muffle furnace at 450-500 °C until the sample was completely combusted (ash turned to white / gray or slightly colored). The obtained ash was dissolved using 1 ml concentrated HCl at crucible walls. Dissolved samples were transferred to a 50 ml volumetric flask and de-ionized water was added to complete the volume. The solution was filtered through ashless filter paper (Whatman No. 42) and stored in a refrigerator until metals' determination by Atomic Absorption Spectrophotometer (PG-990). The maximum absorbance was obtained by adjusting the specific hollow cathode lamps for each element at specific wave length for the element as 228.8, 232.0, 217.0, and 327.4 nm for Cadmium, nickel, lead, and copper, respectively. Concentration (K) of a metal in sample was calculated according to: $K = [(a - b) \times V] / m$ where K = concentration of metal in sample (mg/kg); a = concentration in sample solutions (mg/l); b = mean concentration in blank solutions (mg/l); V = volume of sample solution (ml); m = weight of sample (g).

F. Statistical Analysis

Results were subjected to one-way analysis of variance (ANOVA) of the general linear model (GLM) using SAS statistical package [16]. The results were the average of three replicates ($p \leq 0.05$).

III. Results and Discussion

A. Concentration of Heavy Metals in Crude and Treated Molasses

Concentrations of lead, copper, nickel, and cadmium of crude and treated molasses (with phosphoric acid, 85%) through the four investigated seasons (2013) were determined and the obtained results are presented in Tables I-V. Also, the reduction in heavy metals concentration as a result of molasses treatment at the four seasons was calculated and expressed as percentages.

Concerning lead concentration in the different crude molasses samples, results in Table I show that the lowest value being 4.58 ppm was recorded in winter molasses, while the highest concentration of lead (13.95 ppm) was recorded for autumn molasses. With regard to the treated molasses samples obtained at different tested seasons, data in the same table indicate that lead concentrations of different treated molasses samples ranged from 2.09 ppm for winter molasses to 7.38 ppm for autumn samples.

Data in Table I show clearly that, lead concentrations decreased in all treated molasses samples compared to the corresponding untreated molasses. The percentage of reduction in lead concentration was varied. Results reveal that the highest percent of lead reduction was 57.03% at autumn. Meanwhile, the lowest percent of lead reduction was 44.82% at summer. These results were in accordance with those obtained by [5], who stated that the lead concentration of crude molasses ranged between 1.55 and 9.46 ppm, while differed considerably the percentage of decrease in lead concentration of treated molasses ranged from 43.17 to 54.98%. Meanwhile, the obtained values are relatively higher than those recorded by [17], who revealed that the lead concentration of crude molasses was 3.5 ppm. Moreover, [18] noticed that lead concentration of crude molasses was 3.19 ppm. The presence of lead in molasses may be referred to the absorption of lead from the soil to sugarcane plant [19].

With regard to the copper concentration of the untreated molasses, data presented in Table II indicate that copper concentrations ranged from 7.99 ppm in winter molasses to 22.93 ppm in autumn molasses. Moreover, copper concentrations decreased in all treated molasses samples. The copper concentrations in treated molasses samples ranged between 3.26 and 12.45 ppm for samples of winter and autumn seasons, respectively. The percentage of reduction in copper ranged from 44.42% in spring to 59.20% in winter samples. These results were in agreement with those obtained by [20], who reported that the copper concentrations of crude molasses samples was found to be in the range from 9.1 to 36.8 ppm (average value 18.6 ppm). Furthermore, [21] stated that the copper concentration in crude molasses ranged between 12.7 and 22.5 ppm. Also, [5] reported that the copper concentrations ranged from 7.35 to 22.81 ppm for crude molasses and from 4.40 to 11.80 for treated molasses. On the other hand, [18], [22] recorded lower copper concentrations for crude molasses; being 5.34 and 4.90 ppm, respectively. Meanwhile, [1] recorded higher copper concentration for crude molasses; being 36 ppm. Also, [4] stated that the copper concentration in crude molasses ranged from 6.6 to 68.4 ppm (mean value 14.0 ppm). The variation in copper concentration of molasses may be return to the concentration of copper in the soil, fertilizers, and water of irrigation [6].

TABLE I
LEAD CONCENTRATION OF CRUDE AND PHOSPHORIC ACID TREATED MOLASSES AT DIFFERENT SEASONS

Season	Molasses sample	Lead concentration (ppm) * of sample replicates								
Winter	Crude	5.42	4.75	4.62	4.58	5.27	4.93	5.06	5.16	4.84
	Treated	2.93	2.25	2.19	2.09	2.83	2.48	2.57	2.69	2.33
	Reduction (%)	45.94	52.63	52.60	54.37	46.30	49.70	49.21	47.87	51.86
Spring	Crude	5.88	4.73	5.45	5.07	5.68	5.24	5.56	5.25	5.72
	Treated	3.21	2.18	2.77	2.32	2.94	2.63	2.96	2.64	3.07
	Reduction (%)	45.41	53.91	49.17	54.24	48.24	49.81	46.76	49.71	46.33
Summer	Crude	10.82	8.73	9.05	9.57	10.34	10.18	9.13	9.72	8.97
	Treated	5.97	3.92	4.28	4.71	5.56	5.33	4.38	4.88	4.14
	Reduction (%)	44.82	55.10	52.71	50.78	46.23	47.64	52.03	49.79	53.85
Autumn	Crude	13.95	12.74	11.52	13.08	12.16	13.78	13.55	12.42	12.65
	Treated	7.38	6.12	4.95	6.56	5.52	7.13	6.97	5.83	6.08
	Reduction (%)	47.10	51.96	57.03	49.85	54.61	48.26	48.56	53.06	51.94

* Determined on dry weight basis.

TABLE II
COPPER CONCENTRATION OF CRUDE AND PHOSPHORIC ACID TREATED MOLASSES AT DIFFERENT SEASONS

Season	Molasses sample	Copper concentration (ppm) * of sample replicates								
Winter	Crude	8.13	8.38	8.86	9.03	7.99	9.93	8.67	10.24	9.37
	Treated	3.43	3.65	4.14	4.37	3.26	5.22	3.98	5.55	4.68
	Reduction (%)	57.81	56.44	53.27	51.61	59.20	47.43	54.09	45.80	50.05
Spring	Crude	11.86	12.17	11.63	12.45	10.64	9.86	10.45	10.86	11.22
	Treated	6.43	6.78	6.31	6.92	5.25	4.67	4.96	5.57	5.76
	Reduction (%)	45.78	44.29	45.74	44.42	50.66	52.64	52.54	48.71	48.66
Summer	Crude	15.23	16.42	16.89	14.85	15.68	16.14	14.87	16.38	14.07
	Treated	8.44	7.37	8.93	6.87	7.74	8.22	6.99	8.48	6.19
	Reduction (%)	44.58	55.12	47.13	53.74	50.64	49.07	52.99	48.23	56.01
Autumn	Crude	22.35	21.72	22.93	20.57	19.89	20.33	22.08	21.15	18.94
	Treated	11.92	11.17	12.45	10.14	9.56	9.81	11.58	10.66	8.51
	Reduction (%)	46.67	48.57	45.70	50.70	51.94	51.75	47.55	49.60	55.07

* Determined on dry weight basis.

Regarding cadmium concentration in crude molasses under investigation, results in Table III reveal that the cadmium concentration in different molasses samples through the four tested seasons fluctuated between 2.84 and 6.08 ppm in winter and autumn samples, respectively. Moreover, the cadmium concentration was decreased in treated molasses and ranged from 1.57 ppm in winter samples to 3.38 ppm in autumn samples. The percentage of reduction in cadmium ranged from

42.03 to 50.21(%) in the same order. These results were in accordance with those obtained by [18], who reported that crude molasses contained 2.73 ppm of cadmium. On the contrary, the cadmium concentrations of different molasses samples under investigation were found to be higher than those obtained by [5], who revealed that the concentrations of cadmium ranged from 0.143 to 0.815 ppm in crude molasses.

TABLE III
CADMIUM CONCENTRATION OF CRUDE AND PHOSPHORIC ACID TREATED MOLASSES AT DIFFERENT SEASONS

Season	Molasses sample	Cadmium concentration (ppm) * of sample replicates								
Winter	Crude	3.62	3.33	2.95	3.37	2.84	3.81	3.56	3.18	3.06
	Treated	2.09	1.85	1.71	1.92	1.63	2.16	2.06	1.62	1.57
	Reduction (%)	42.27	44.44	42.03	43.03	42.61	43.31	42.13	49.06	48.69
Spring	Crude	4.03	3.26	3.85	3.47	3.61	3.65	4.19	3.32	3.14
	Treated	2.24	1.72	2.11	1.87	1.94	2.05	2.41	1.83	1.75
	Reduction (%)	44.42	47.24	45.19	46.11	46.26	43.84	42.48	44.88	44.27
Summer	Crude	5.43	4.98	5.65	5.22	4.75	5.38	4.59	5.72	4.88
	Treated	2.92	2.58	3.04	2.81	2.74	2.85	2.31	3.12	2.66
	Reduction (%)	46.22	48.19	46.19	46.17	42.32	47.03	49.67	45.45	45.49
Autumn	Crude	5.72	5.45	5.93	5.61	5.14	5.66	4.76	6.08	5.25
	Treated	3.18	2.93	3.25	2.93	2.81	3.06	2.37	3.38	2.74
	Reduction (%)	44.41	46.24	45.19	47.77	45.33	45.94	50.21	44.41	47.81

* Determined on dry weight basis.

The variation in cadmium concentration of molasses samples might be due to the different amounts of applied fertilizers (which contain significant amount of cadmium) added to the sugarcane plants [7]. Furthermore, [8] concluded that variations of heavy metals in molasses may be related to differences in compositions of sugarcane plants, ecological changes in soil, the addition of fertilizers to sugarcane plant, the irrigation water, and the additives applied to syrup during cane sugar processing stages.

Concerning the nickel concentration of the crude molasses samples, results in Table IV reveal that the lowest value being 5.68 ppm was found in winter molasses, while the highest concentration of nickel (12.57 ppm) was recorded for autumn molasses. Meanwhile, the treated molasses samples obtained at different seasons indicate that the nickel concentration of different treated molasses samples ranged from 3.04 ppm in winter molasses to 7.57 ppm in autumn samples. Results also reveal that the highest reduction in nickel was 52.57% in summer samples. Meanwhile, the lowest reduction in nickel was 36.59% in spring samples.

TABLE IV
NICKEL CONCENTRATION OF CRUDE AND PHOSPHORIC ACID TREATED MOLASSES AT DIFFERENT SEASONS

Season	Molasses sample	Nickel concentration (ppm) * of sample replicates								
Winter	Crude	7.34	6.62	5.87	6.69	5.68	7.65	7.14	6.12	5.92
	Treated	4.42	3.76	3.04	3.85	3.07	4.68	4.23	3.26	3.16
	Reduction (%)	39.78	43.2	48.21	42.45	45.95	38.82	40.76	46.73	46.62
Spring	Crude	8.02	6.40	7.75	6.84	7.32	7.39	8.39	6.62	6.28
	Treated	4.95	3.31	4.68	3.82	4.25	4.36	5.32	3.67	3.43
	Reduction (%)	38.28	48.28	39.61	44.15	41.94	41.00	36.59	44.56	45.38
Summer	Crude	10.89	9.98	11.23	10.52	9.59	10.66	9.15	11.72	9.77
	Treated	6.08	5.23	6.19	5.76	4.75	5.88	4.34	6.65	4.97
	Reduction (%)	44.17	47.6	44.88	45.25	50.47	44.84	52.57	43.26	49.13
Autumn	Crude	11.58	10.82	11.96	11.23	10.23	11.37	9.46	12.57	10.55
	Treated	6.62	5.87	6.98	6.26	5.21	6.33	4.84	7.57	5.46
	Reduction (%)	42.83	45.75	41.64	44.26	49.07	44.33	48.84	39.78	48.25

* Determined on dry weight basis.

Nickel concentrations of crude molasses samples were found to be higher than those obtained by [5], who reported that the concentrations of nickel in crude molasses ranged from 0.87 to 1.85 ppm. Moreover, [20] reported that nickel concentrations in crude molasses ranged from 0.7 to 3.2 ppm (average value 1.8 ppm). Also, [18] reported that molasses contained 1.28 ppm of nickel.

Comparing the effect of seasons on the heavy metals concentrations in crude molasses, presented data in Table V reveal that molasses samples at autumn recorded the highest average concentration of lead (12.87 ppm), followed by those obtained at summer (9.61 ppm) with significant differences between the two seasons. Meanwhile, winter and spring samples had the lowest averages of lead content; being 4.96 and 5.40 ppm, respectively with no significant differences between them. Data in the same table also reveal that the lead concentration of treated molasses samples ranged from 2.48 ppm for winter molasses to 6.28 ppm for autumn sample with significant differences between the obtained values.

TABLE V
MEANS VALUES OF HEAVY METALS OF CRUDE AND PHOSPHORIC ACID TREATED MOLASSES AT DIFFERENT SEASONS

Metals	Molasses sample	Metals concentration (ppm)* at different seasons				LSD
		Winter	Spring	Summer	Autumn	
Lead	Crude	$4.96^{c} \pm 0.10$	$5.40^{c} \pm 0.12$	$9.61^{b} \pm 0.24$	$12.87^{a} \pm 0.27$	0.56
	Treated	$2.48^{c} \pm 0.10$	$2.75^{c} \pm 0.11$	$4.80^{b} \pm 0.23$	$6.28^{a} \pm 0.27$	0.55
Copper	Crude	$8.96^{d} \pm 0.26$	$11.24^{c} \pm 0.29$	$15.61^{b} \pm 0.31$	$21.11^{a} \pm 0.43$	0.94
	Treated	$4.25^{d} \pm 0.26$	$5.85^{c} \pm 0.27$	$7.69^{b} \pm 0.30$	$10.64^{a} \pm 0.42$	0.92
Nickel	Crude	$6.56^{b} \pm 0.24$	$7.22^{b} \pm 0.25$	$10.39^{a} \pm 0.28$	$11.09^{a} \pm 0.31$	0.78
	Treated	$3.72^{b} \pm 0.21$	$4.20^{b} \pm 0.23$	$5.54^{a} \pm 0.25$	$6.13^{a} \pm 0.29$	0.71
Cadmium	Crude	$3.30^{b} \pm 0.11$	$3.61^{b} \pm 0.12$	$5.18^{a} \pm 0.13$	$5.51^{a} \pm 0.14$	0.36
	Treated	$1.85^{b} \pm 0.07$	$1.99^{b} \pm 0.08$	$2.78^{a} \pm 0.08$	$2.96^{a} \pm 0.10$	0.24

* Determined on dry weight basis.
Means followed by different subscripts within the row are significantly different at the 5% level.

Regarding the average values of copper concentration in molasses, data in Table V shows that copper concentration of the crude molasses during the four tested seasons fluctuated between 8.96 and 21.11 ppm. Meanwhile, the copper concentration of the treated molasses ranged from 4.25 to 10.64 ppm. The highest value in this respect was recorded for molasses samples obtained at autumn, followed in descending order by those obtained at summer then at spring season, while molasses samples of winter recorded the lowest means with significant differences between the obtained values. In addition, the average values of nickel and cadmium concentrations in the crude molasses during the four tested seasons fluctuated from 6.56 to 11.09 and from 3.30 to 5.51 ppm, respectively (Table V). Meanwhile, the average values of nickel and cadmium concentrations in the treated molasses ranged from 3.72 to 6.13 and from 1.85 to 2.96 (ppm), respectively. The highest values in this respect were recorded for untreated (crude) and treated molasses samples obtained at autumn and summer, while molasses samples of winter and spring recorded the lowest values with significant differences between the obtained values.

Generally, it could be noticed that for all tested molasses, heavy metals concentration was significantly different at the studied seasons (Table V). These results were in accordance with [20], who reported that the quantity of the metals and the quality of molasses varied from season to season. The high concentrations of heavy metals in the autumn treated molasses might be due to their high contents in the autumn untreated molasses. In addition, data in the same table appear clearly that regardless the season, the heavy metals concentrations evidently decreased in all the treated molasses samples compared to the corresponding untreated samples. This decrease might be attributed to the removal of the precipitated minerals during the acid treatment [13].

B. Effect of Different Treatments on Heavy Metals Concentration of Molasses

The crude molasses (autumn molasses) was subjected to the treatment at two stages. The first stage was achieved by cation exchange resin as physical treatment, while the second stage was achieved by one of the chemical treatments *i.e.* sulfuric acid, tricalcium phosphate, potassium ferrocyanide, EDTA or phosphoric acid. Also, the previously mentioned treatments were compared with treatment of baker's yeast factory (phosphoric acid). Data presented in Table VI reveal that copper, nickel, lead, and cadmium concentrations of treated molasses were decreased as affected by the different treatments. It is worthy to conclude that all studied treatments gave the highest removal effect for heavy metals compared with the traditional molasses treatment at baker's yeast factory. Also, data in the same table reveal that the molasses treated by cation exchange resin then sulfuric acid had the lowest concentrations of heavy metals compared with other treatments with significant differences between the obtained values. The superiority of cation exchange resin then sulfuric acid over other molasses treatment may be due to the efficiency of sulfuric acid for the removal of heavy metals [13]. However, no significant differences were found between cation exchange resin then sulfuric acid and cation exchange resin then phosphoric acid treatments. These results were in agreement with those obtained by [13] who reported that sulfuric acid treatment gave the better results as a used technique for the removal of heavy metals from molasses. Also, [23] indicated that the molasses treated by sulfuric acid with activated carbon had the preferable effect compared with other techniques. Meanwhile, [12] reported that the potassium ferrocyanide treatment reduces the metal ion concentration considerably compared to the sulfuric acid, tricalcium phosphate, and tricalcium phosphate with hydrochloric acid treatments.

TABLE VI
EFFECT OF DIFFERENT TREATMENTS ON HEAVY METALS CONCENTRATIONS IN TREATED MOLASSES

Molasses treatments	Metals concentration (ppm)*			
	Copper	Nickel	Lead	Cadmium
Untreated molasses	22.45 ± 0.25	12.04 ± 0.29	13.76 ± 0.12	5.91 ± 0.10
Phosphoric acid (factory treatment)	11.98 ^{a} ± 0.25	7.06 ^{a} ± 0.28	7.16 ^{a} ± 0.12	3.27 ^{a} ± 0.06
Cation exchange resin then sulfuric acid	5.91 ^{d} ± 0.26	2.08 ^{c} ± 0.10	1.99 ^{d} ± 0.20	0.87 ^{c} ± 0.05
Cation exchange resin then tricalcium phosphate	10.22 ^{b} ± 0.20	4.76 ^{b} ± 0.15	5.24 ^{b} ± 0.24	2.17 ^{b} ± 0.06
Cation exchange resin then potassium ferrocyanide	10.03 ^{b} ± 0.17	4.72 ^{b} ± 0.14	5.32 ^{b} ± 0.31	2.14 ^{b} ± 0.10
Cation exchange resin then EDTA	7.76 ^{c} ± 0.26	4.62 ^{b} ± 0.16	3.94 ^{c} ± 0.25	2.08 ^{b} ± 0.08
Cation exchange resin then phosphoric acid	6.06 ^{d} ± 0.24	2.20 ^{c} ± 0.09	2.14 ^{d} ± 0.16	0.93 ^{c} ± 0.05
LSD	0.72	0.50	0.69	0.20

* Determined on dry weight basis.
Means followed by different subscripts within the column are significantly different at the 5% level.

IV. CONCLUSION

The heavy metals concentrations of crude and treated molasses obtained from storage tanks through the four investigated seasons (2013) varied considerably. The heavy metals concentration of the different crude molasses samples ranged from 4.58 to 13.95 (ppm) for lead, from 7.99 to 22.93 (ppm) for copper, from 2.84 to 6.08 (ppm) for cadmium, and from 5.68 to 12.57 (ppm) for nickel. Meanwhile, heavy metals concentrations in factory treated molasses reached from 2.09 to 7.38 (ppm) for lead, from 3.26 to 12.45 (ppm) for copper, from 1.57 to 3.38 (ppm) for cadmium, and from 3.04 to 7.57 (ppm) for nickel. The molasses samples collected at autumn recorded the highest average values of all studied heavy metals, followed by those obtained at summer. Meanwhile, winter and spring samples had the lowest average values. Regarding the effect of different treatments on heavy metals concentrations of molasses, it could be concluded that all studied treatments of molasses gave higher removal of heavy metals than the traditional molasses treatment at baker's yeast factory. Also, the molasses treated by cation exchange resin then sulfuric acid followed by cation exchange resin then phosphoric acid had the lowest concentrations of heavy metals compared with other treatments.

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