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Optimization of Molasses Desugarization Process Using Steffen Method in Sugar Beet Factories

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***Abstract*—**Molasses is one of the most important by-products in sugar industry, which contains a large amount of sucrose. The routine way to separate the sucrose from molasses is using steffen method. Whereas this method is very usual in sugar factories, the aim of this research is optimization of this method. Mentioned optimization depends to three factors of reactor alkality, reactor temperature and diluted molasses brix. Accordingly, three different stages must be done:

1. Construction of a pilot plant similar to actual steffen system in sugar factories
2. Experimenting using the pilot plant
3. Laboratory analysis

These experiences included 27 treatments in three replications. In each replication, brix, polarization and purity characters in Saccharate syrup and hot and cold waste were measured. The results showed that diluted molasses brix, reactor alkality and reactor temperature had many significant effects on Saccharate purity and efficiency of molasses desugarization. This research was performed in "randomize complete design" form & was analyzed with "duncan multiple range test". The significant difference in the level of $\alpha = 5\%$ is observed between the treatments. The results indicated that the optimal conditions for molasses desugarization by steffen method are: diluted molasses brix= 10, reactor alkality= 10 and reactor temperature=8˚C.

***Keywords*—**Molasses desugarization, Saccharate purity, Steffen process.

I. Introduction

MOLASSES desugarization process using Steffen method is based on CaO links with sucrose. Different stages of molasses desugarization process using Steffen method is as follows: first molasses is deluted by water until its brix reduces to about 10 to12; then lime is added to diluted molasses under cold conditions. In this stage, calcium and sucrose in the molasses will create Saccharate. In these interactions, di- and tri-Saccharate calcium will be made. Di-Saccharate calcium is soluble and tri-Saccharate Calcium is not soluble, therefore, first the resulting solution must be filtered for separating the tri-Saccharate calcium. Tri-Saccharate calcium obtained will be diluted with water and will be sent to section of syrup filtering by particular pumps to be used with lime milk [3]-[5].

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Because some soluble Saccharate still exists in wastewater of molasses desugarization, and because lime is sensitive to temperature and will thus create deposits, so, sugar use this property and by increasing the wastewater temperature from 90 to 80°C, it transforms the remaining soluble Saccharate into nonsoluble Saccharate. After filtering, the resulting Saccharate will be mixed with previous one and will be used in the process. The resulting wastewater, which is called hot wastewater and is obtained after neutralization with gas, will be used instead of molasses in residuum dryer [1], [2].

If appropriate conditions in molasses desugarization are considered, in this case, 90 to 85% sugars in the molasses can be obtained, otherwise, lack of attention to effective factors cause reduction of molasses desugarization efficiency [1], [4]-[7].

The most important factors in molasses desugarization efficiency are diluted molasses brix, reactor temperature and reactor alkalinity (in this case, reactor means the place where reaction between lime and sucrose available in diluted molasses will be performed and diluted molasses means the molasses which is diluted by water) and this research works on these three factors [6].

II. Materials and Methods

Doing this project includes three stages:

1. Construction of a pilot plant similar to actual steffen system in sugar factories
2. Experimenting using the pilot plant
3. Laboratory analysis

Regarding the test results obtained from the system can be extended to sugar characteristic, so design and construction of a small size separator of sugar from continuous molasses was started. The mentioned pilot plant includes all parts of the separator of sugar from continuous molasses in terms of principles and includes the following sections:

1) Diluted molasses tank
2) Reactor I
3) Reactor II
4) Lime producer machine
5) Water cooler
6) Circulation pump
7) Cool water circulation pump
8) Compressor
9) Connection hoses
10) Mixer
11) Büchner funnel
12) Thermometer

All of the tanks applied in this device are made of tin and are double; therefore, circulation of cold water and cooling of the tanks contents is possible. The required cold water is provided by a water cooler which sends the cool water to the tanks and turns it back using some hoses. The circulation of cold water into the tank wall and water cooler is done by a pump which is an air conditioner pump in this device. All input and output pipes are made of copper and the mentioned hoses by connecting to these pipes, lead the flow direction. In order to mix the contents of the three tanks, three air conditioner pumps with the spin of 3000 turn in minute was used and the rotation of its wings mixes the tank contents. The tanks height is designed so that the contents of each tank can go to other one just due to weight and height difference. The act of vacuum filter in a separator of sugar from continuous molasses means separating the Saccharate residuum from cooled waste. This type of filter is done in this device using Büchner funnel and the required vacuum is provided by a compressor. Since the main reaction between limestone and diluted molasses is done in reactor I, a lime distributer was made for uniform spraying of lime. The lime distributer is installed on reactor I; its building is relatively simple and includes the following sections:

1) Lime storage tank in shape of cube rectangle (made of tin)
2) Fixed perforated sliding door
3) Moving sliding door
4) Driving force (in this case a hair dryer engine is used)
5) Ball bearing to create a route for sliding door
6) Ramp

First the lime is poured into the storage tank. When the machine is switched on, the ball bearing moves and transfers the force produced from engine for moving sliding door and during each trip, a certain amount of lime will be poured in reactor I tank. The advantage of using the hair dryer engine is creating the fast or slow spins, so we can adjust the amount of poured lime into reactor I in each minute.

A. Test

In the beginning, prepared diluted molasses with desired brix is poured into diluted molasses tank, reactor I and reactor II. Cool water using the cool water circulation pump cools the contents of three tanks. When the diluted molasses existing in three tanks becomes so cold that its temperature arrives to about 2 to 4 degrees below the desired temperature, the lime distributer device will start to work. This time, circulation pump which connects reactor I to reactor II also starts to work and in result of reaction between the lime and diluted molasses, alkalinity of two reactors goes up until it arrives to desired amount. During pouring lime into the reactor I, alkalinity of two reactors is measured several times to ensure that the optimal alkalinity is created.

In result of entering the lime into the reactor and creating the calorific reaction, reactors temperature arrive slowly to desired amount and when the thermometer inside the tank of reactor I shows the desired temperature, device is ready for tests by continuous method. In this stage, lime is weighted and poured into lime distributer tank. Amount of lime used in each test is determined considering diluted molasses entered into reactor I. After flowing of diluted molasses and starting the lime distributor device, a steady flow of lime and diluted molasses will be obtained in reactor I. In this case, after a while, volume of reactor I contents will be elevated and will overflow into reactor II by means of relevant pipes. Due to limited volume of the two reactors, after a while, contents of the reactor II will also overflow and will be leaded to a Büchner funnel by a hose connected to the reactor II. There is a vacuum place in this funnel created by a compressor which is connected to it. By means of this vacuum, the Saccharate milk obtained from system will be separated to two phase of Saccharate residuum and cold waste in Büchner funnel. The temperature of cold waste will be increased to 80-90°C and will be filtered another time by Büchner funnel. The produced waste called hot waste. After this stage, the total Saccharate, cold waste and hot waste, which are the operation products, must be analyzed in the lab and the brix, pol and Q must be determined.

B. Statistical Design

The statistical society in this study is molasses of all sugar beet factories that are equipped with Steffen system. The statistical sample is molasses of sweet sugar factory which is selected using a regular sampling. Scheme used, was a completely randomized one included three replicates of 27 treatments. Treatments include full factorial of three factors: temperature, reactor alkalinity and diluted molasses brix. The average results of treatments were compared at 5% level using Duncan's multiple range tests.

III. Results

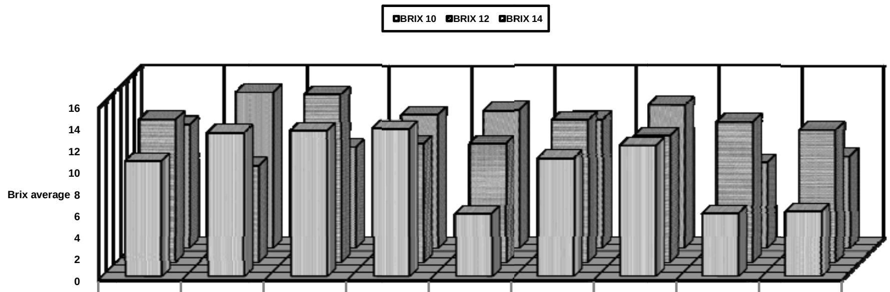
A. Saccharate Syrup

1. Interaction between Reactor Alkality, Diluted Molasses Brix and Reactor Temperature on Saccharate Syrup Brix

There were significant differences in all experimental treatments done for examination of brix characteristic in Saccharate syrup at 1% level.

Explanation: The main effect of reactor alkalinity and diluted molasses brix on this characteristic was nonsignificant, in other words, between the three levels of each of these characteristics, there is no significant difference. But reactor temperature characteristic effects on amounts of Saccharate syrup brix and is significant at 5% level. The interaction between reactor alkality and diluted molasses brix, reactor alkality and reactor temperature, also diluted molasses brix and reactor temperature on Saccharate syrup brix is not significant. But the interaction between second level reactor alkality and diluted molasses brix and reactor temperature on Saccharate syrup brix is significant at 5% level.

As specified in Fig. 1, when alkality is 12, brix is 12 and temperature is 8˚C, brix exists at maximum level, and when alkality is 10, brix is 10 and temperature is 16, and also when alkality is 10 and temperature is 12, brix exists in minimum level without any significant difference. Fig. 1 presents interaction between reactor alkality, diluted molasses brix and reactor temperature on Saccharate syrup brix



	8	10	12	8	10	12	8	10	12
BRIX 10	10.7	13.333	13.5	13.761	5.867	10.967	12.133	5.867	6.067
BRIX 12	13.267	8.967	15.567	11.067	11.067	13.2	11.767	13.033	12.367
BRIX 14	11.467	14.433	9.367	12.433	12.833	11.933	13.3	7.967	8.567

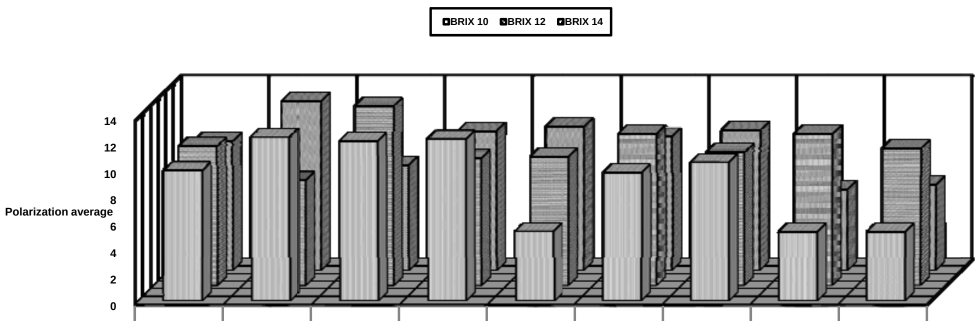
Fig. 1 The effects of reactor alkality, brix of diluted molasses & reactor temperature on brix of saccharate syrup

2. Interaction between Reactor Alkality, Diluted Molasses Brix and Reactor Temperature on Saccharate Syrup Polarization

There were significant differences in all experimental treatments done for examination of polarization characteristic in Saccharate syrup at 1% level.

Explanation: The main effect of reactor alkality and diluted molasses brix on this characteristic is nonsignificant, in other words, between the three levels of each of these characteristics, there is no significant difference. But reactor temperature characteristic effects on amounts of Saccharate syrup polarization and is significant at 1% level. The interaction between reactor alkality and reactor temperature, also, interaction between diluted molasses brix and reactor temperature on the amount of Saccharate syrup polarization is not considerable. Butinter action between reactor and diluted molasses brix, also, interaction between second level reactor alkality and diluted molasses brix and reactor temperature on saccharate syrup polarization at 5% level is significant.

Fig. 2 presents interaction between reactor alkality, diluted molasses brix and reactor temperature on Saccharate syrup polarization.



	8	10	12	8	10	12	8	10	12
BRIX 10	9.933	12.5	12.167	12.333	5.3	9.767	10.567	5.267	5.267
BRIX 12	10.633	8.033	13.7	9.7	9.833	11.567	10.167	11.567	10.467
BRIX 14	9.867	12.9	8.033	10.633	10.967	10.2	10.7	6.167	6.533

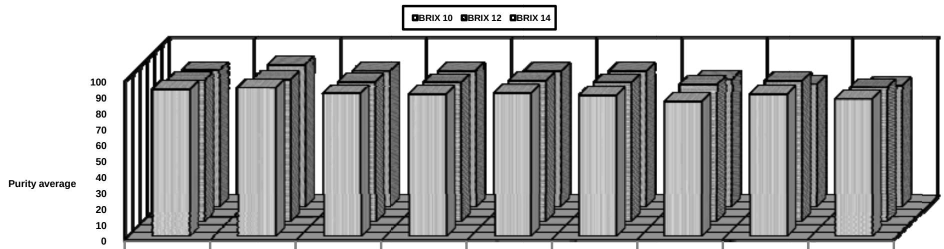
Fig. 2 The effects of reactor alkality, brix of diluted molasses & reactor temperature on polarization of saccharate syrup

3. Interaction between Reactor Alkality, Diluted Molasses Brix and Reactor Temperature on Saccharate Syrup Purity

There were significant differences in all experimental treatments done for examination of purity characteristic in Saccharate syrup at 1% level. Explanation: the interaction between reactor alkalinity, diluted molasses brix and reactor temperature on this characteristic is significant at 1% level. This means that changes on each of the mentioned characteristics are effective on Saccharate syrup purity. Interaction between reactor alkality and diluted molasses brix, also, interaction between diluted molasses brix and reactor temperature is significant at 1% level. It means that effect of reactor alkality is a function of changes occurred in diluted molasses brix and effect of diluted molasses brix is a function of changes occurred in reactor temperature and vice versa.

International Journal of Biological, Life and Agricultural Sciences
ISSN: 2415-6612
Vol:7, No:11, 2013

Interaction between reactor alkality and reactor temperature at 5% level is significant. Fig. 3 presents interaction between reactor alkality, diluted molasses brix and reactor temperature on Saccharate syrup purity.



	8	10	12	8	10	12	8	10	12
BRIX 10	92.83	93.75	90.12	89.62	90.33	89.05	85.09	89.77	86.81
BRIX 12	89.14	89.58	88	87.64	88.84	87.62	86.4	88.75	84.63
BRIX 14	86.04	89.37	85.75	85.52	85.45	85.47	80.45	77.407	76.25

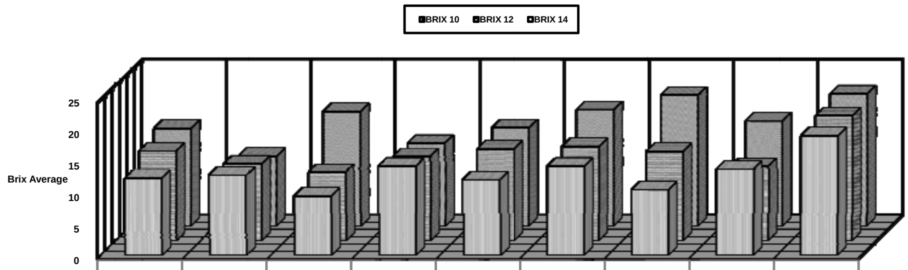
Fig. 3 Interaction between reactor alkality, diluted molasses brix and reactor temperature on Saccharate syrup purity

4. Interaction between Reactor Alkality, Diluted Molasses Brix and Reactor Temperature on Cold Waste Brix

There are significant differences in all experimental treatments done for examination of brix characteristic in waste. The main effect of reactor alkality, diluted molasses brix and reactor temperature at 1% level is significant. Interaction between reactor alkalinity and diluted molasses brix, also, reactor alkality and reactor temperature on cold waste brix is significant with 99% confidence. But interaction between diluted molasses brix and reactor temperature on waste brix is nonsignificant. Interaction between second level reactor alkality and diluted molasses brix and reactor temperature is significant with 99% confidence.

B. Cold Waste

Fig. 4 presents interaction between reactor alkality, diluted molasses brix and reactor temperature on cold waste brix.



	8	10	12	8	10	12	8	10	12
BRIX 10	12.367	12.867	9.5	14.3	12.1	14.3	10.5	13.8	19.167
BRIX 12	14.4	12.333	10.967	13.5	14.733	15.1	14.333	11.933	20.067
BRIX 14	15.675	11.2	18.367	13.3	15.767	18.667	21.033	16.867	21.233

Fig. 4 Interaction between reactor alkality, diluted molasses brix and reactor temperature on cold waste brix

1. Interaction between Reactor Alkalinity, Diluted Molasses Brix and Reactor Temperature on Polarization of Cold Waste

There is no significant difference in all experimental tests done for examination of polarization characteristic in cold wasteat 1% level. So that: the main effect of reactor alkality, diluted molasses brix and reactor temperature on polarization of cold waste is significant at 1% level. Interaction between reactor alkality and reactor temperature, also, the interaction between diluted molasses brix and reactor temperature is significant with 99% confidence. Interaction indiluted molasses brix at 5% level is significant and interaction between second level of reactor alkality and diluted molasses brix and reactor temperature on polarization of cold waste is nonsignificant.

Fig. 5 presents interaction between reactor alkality, diluted molasses brix and reactor temperature on cold waste polarization.

International Journal of Biological, Life and Agricultural Sciences
ISSN: 2415-6612
Vol:7, No:11, 2013

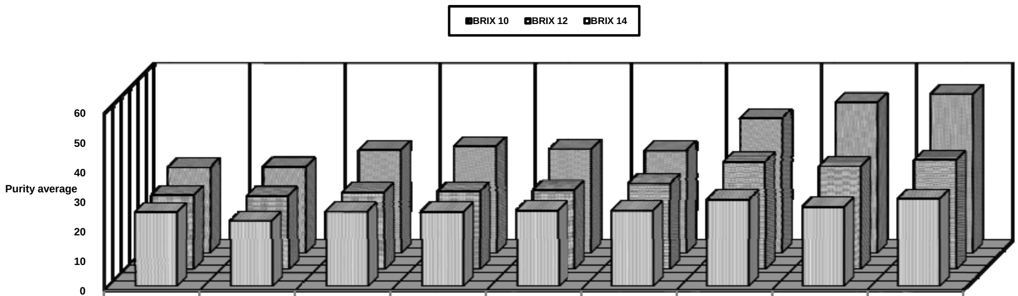
	8	10	12	8	10	12	8	10	12
BRIX 10	3.1	2.833	2.5	3.6	3.1	3.767	3.5	3.7	5.667
BRIX 12	3.633	3.067	2.867	3.567	3.967	4.4	5.233	4.167	7.433
BRIX 14	4.533	3.267	6.5	4.8	5.533	6.467	8.567	8.6	11.4

Fig. 5 Interaction between reactor alkality, diluted molasses brix and reactor temperature on cold wastepolarization

2. Interaction between Reactor Alkality, Diluted Molasses Brix and Reactor Temperature on Cold Waste Purity

There are significant differences in all experimental treatments done for examination of purity characteristic in cold waste at 1% level. The main effect of reactor alkality, diluted molasses brix and reactor temperature on cold waste purity is significant at 1% level. Interaction between reactor alkality and diluted molasses brix, also, reactor alkality and reactor temperature on cold waste purity is nonsignificant, but interaction between diluted molasses brix and reactor temperature is significant with 99% confidence. Interaction between second level reactor alkality and diluted molasses brix and reactor temperature on purity is nonsignificant.

Fig. 6 presents interaction between reactor alkality, diluted molasses brix and reactor temperature on cold waste purity.



	8	10	12	8	10	12	8	10	12
BRIX 10	25.06	22.01	25.26	25.17	25.62	25.64	29.33	26.81	29.56
BRIX 12	25.22	24.86	26.14	26.42	26.92	29.13	36.51	34.91	37.04
BRIX 14	28.91	29.16	34.82	36.09	35.09	34.64	45.48	50.98	53.69

Fig. 6 Interaction between reactor alkalinity, diluted molasses brix and reactor temperature on cold waste purity

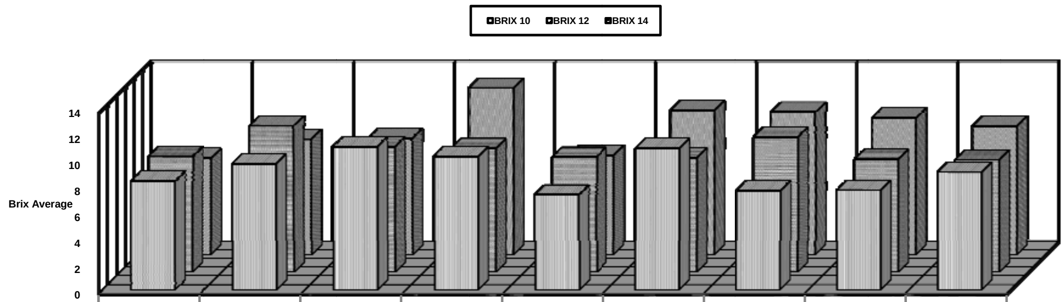
3. Interaction between Reactor Alkality, Diluted Molasses Brix and Reactor Temperature on Hot Waste Brix

There are significant differences in all experimental treatments done for examination of brix characteristic in hot waste at 5% level. The main effect of reactor alkality, diluted molasses brix and reactor temperature on hot waste brix is nonsignificant. Interaction between reactor alkality and diluted molasses brix on hot waste is nonsignificant, it means that among the three levels of reactor temperature there is no significant difference. Interaction between reactor alkality and reactor temperature on hot waste is significant at 1% level and interaction between diluted molasses brix and reactor temperature on hot waste is also significant at 5% level. Interaction between second level of reactor alkality and diluted molasses brix and reactor temperature is nonsignificant.

C. Hot Waste

Fig 7 presents interaction between reactor alkality, diluted molasses brix and reactor temperature on hot waste brix.

International Journal of Biological, Life and Agricultural Sciences
ISSN: 2415-6612
Vol:7, No:11, 2013



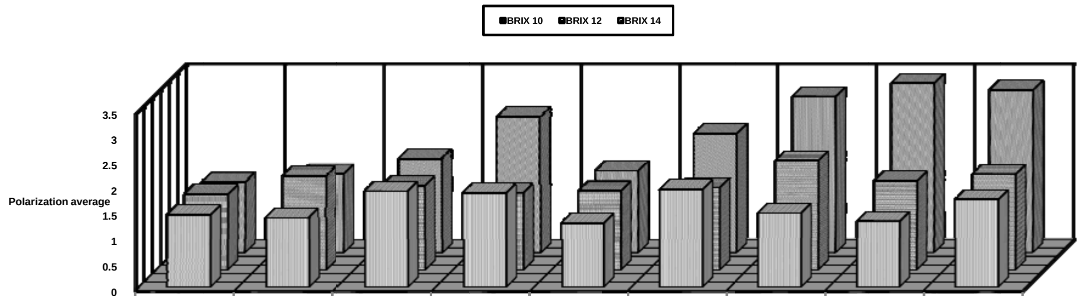
	8	10	12	8	10	12	8	10	12
BRIX 10	8.4	9.733	11.067	10.3	7.333	10.933	7.667	7.7	9.1
BRIX 12	8.967	11.333	9.7	9.567	8.9	8.867	10.467	8.733	8.7
BRIX 14	7.467	8.933	9	12.9	7.7	11.167	11.033	10.567	9.967

Fig. 7 Interaction between reactor alkality, diluted molasses brix and reactor temperature on hot waste brix

1. Interaction between Reactor Alkality, Diluted Molasses Brix and Reactor Temperature on Hot Waste Polarization

There are significant differences in all experimental treatments done for examination of polarization characteristic in hot waste at 1% level. The main effect of diluted molasses brix and reactor temperature on hot waste polarization and the main effect of reactor alkality on hot waste polarization are significant at 5% level. Interaction between diluted molasses brix and reactor temperature on polarization of hot waste at 1% level is significant, but the interaction between reactor alkalinity and diluted molasses brix, and the interaction between reactor alkality and reactor temperature on polarization of hot waste is nonsignificant. Interaction between second level of reactor alkality, diluted molasses brix and reactor temperature on this characteristic in nonsignificant.

Fig. 8 presents interaction between reactor alkality, diluted molasses brix and reactor temperature on hot waste polarization.



	8	10	12	8	10	12	8	10	12
BRIX 10	1.433	1.367	1.9	1.867	1.267	1.933	1.467	1.3	1.733
BRIX 12	1.5	1.867	1.667	1.533	1.567	1.633	2.167	1.767	1.9
BRIX 14	1.4	1.567	1.867	2.7	1.633	2.367	3.1	3.367	3.233

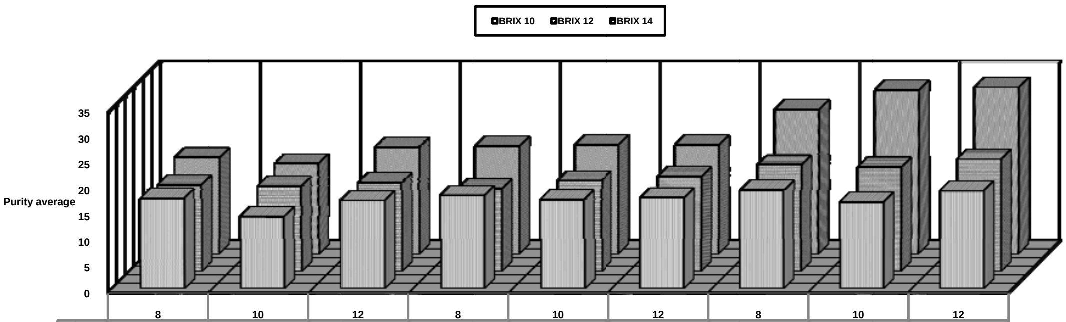
Fig. 8 Interaction between reactor alkality, diluted molasses brix and reactor temperature on hot wastepolarization

2. Interaction between Reactor Alkality, Diluted Molasses Brix and Reactor Temperature on Hot Waste Purity

There are significant differences in all experimental treatments done for examination of purity characteristic in hot waste at 1% level. The main effect of reactor alkality, diluted molasses brix and reactor temperature on hot waste purity is significant with 99% confidence. Interaction between reactor alkality and diluted molasses brix on hot waste purity at 5% level is significant. Interaction between reactor alkality and reactor temperature on hot waste purity is nonsignificant and interaction between diluted molasses brix and reactor temperature is significant with 99% confidence. Interaction between second level reactor alkality and diluted molasses brix and reactor temperature is nonsignificant.

Fig. 9 presents interaction between reactor alkality, diluted molasses brix and reactor temperature on hot waste purity.

International Journal of Biological, Life and Agricultural Sciences
ISSN: 2415-6612
Vol:7, No:11, 2013



	8	10	12	8	10	12	8	10	12
BRIX 10	17.5	14.04	17.16	18.12	17.27	17.68	19.13	16.88	19.04
BRIX 12	16.72	16.47	17.18	16.02	17.6	18.41	20.7	20.23	21.83
BRIX 14	18.74	17.54	20.74	20.93	21.2	21.19	28.09	31.86	32.43

Fig. 9 Interaction between reactor alkality, diluted molasses brix and reactor temperature on hot waste purity

IV. Discussion

The results show that these three factors have many effects on Saccharate purity and on the efficiency of molasses desugarization. The interactions of results show that when diluted molasses brix is 10, reactor alkalinity is 10 and reactor temperature is 8°C, we will have maximum efficiency in molasses desugarization.

This research is about the optimization of molasses desugarization, but cannot be considered a new phenomenon. The final purpose of this study is to improve this process and to increase efficiency of extraction of sugar from molasses. From the economic point of view, the importance of this project is more obvious. Efficiency of molasses desugarization depends directly to level of Saccharate purity. Considering the results of this study, Saccharate purity has increased to 93/7%, therefore, the possibility of increasing the efficiency of molasses desugarization surely exists.

References

[1] Groom, David R. Terry D. Mcgillivray, James H. Heggeness, Indrani Samaraweera; "Results of long storage of coupled loop molasses desugarization extract," *Journal of Sugar Beet Research*, vol. 42, 2005. p.72.

[2] Martinez, Alonso N; Prieto, Hernandez T; Melnikov B, "Determination of the Optimum Contact Time between Calcium Saccharate and Cane Juice in the Hot Alkalization Process," 1984, pp.66-69.

[3] Mcgillivray, Terry, David Groom, Jim Heggeness, Joe Wallevand, "A Review of Pilot Plant Boiling of Extract From Coupled Loop and Simulated Moving Bed Molasses Desugarization Plants," January- July 2005, p.73.

[4] Mc Ginnis; "Beet Sugar Technology," 3d Edition, published by *Beet sugar development foundation*, 1983, pp.105-117.

[5] Mosen A., Molasses Desugaring Process, Beet Sugar Handbook, 2005, pp.517-546.

[6] North, Coobes S; Taylor K; Koster KC, "The Practical Development and Application of Saccharate Liming at the Pongola Sugar Mill,"1981, proceedings, *South African Sugar Technologists Association*, pp. 55, 71 – 74.

[7] Rouanne F, "Method for Determination of Monocalcium Saccharate in Sugar Juices," 1991. French – patent – Application.