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# Laboratory testing of, three samples of major sugar beet sources of Iran for manufacturing sugar

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**ABSTRACT**

*Testing quality of sugar beets is an important stage of manufacturing sugar and needs physicochemical test in every phase of processing. In this article we examined the laboratory tests that performed in phase of sugar beet slice, raw juice, diluted juice, concentrated juice, and stage of first and second liming and carbonation with samples from three major source of culturing sugar beet in Iran: Mashhad, Qazvin and Buein Zahra. The test results showed that in some of laboratory tests Buein Zahra sample is out of acceptable limits set by Institute of Standards and Industrial Research of Iran (ISIRI) and this sample not suitable for sugar processing unlike Mashhad and Qazvin Samples.*

**Key words**: Sugar beet, sugar, physicochemical test.

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## INTRODUCTION

Sugar beet cultivated from Beta vulgaris, is a plant which contains a high concentration of sucrose. It is grown commercially for sugar production [1]. Sugar beet consists of the root and a rosette of leaves. Sugar is formed through a photosynthesis process in the plant leaves, and then stored in the root. Sugar can represent between 15 and 20 percent of root's total; however, the sugar content in sugar beets can vary from 12 percent to above 20 percent [2]. Nearly 75 percent of sugar beet is water and 25 percent of it is dry matter included 20 percent of total dry matter contains sucrose and soluble solids in water and the remaining 5 percent contains insoluble solids [2]. Sugar beet has three parts: The thick upper part of sugar beet is crown and it is the origin of leaves, a short and plain area below the crow that is called the neck, and the fleshy parts of sugar beet, called roots and also sugar store is in it [3]. Among all countries that are producers of sugar beets France, United States of America and Germany were top first three countries in producer of sugar beet in the year 2009, France with production 2.35, the United States with 27 and Germany with 9.25 million tons production per year [4]. According to Statistics Achieved by Iran's Syndicate sugar, amount of productions sugar beets between years of 2008 to 2011 was 4282000, 2015000, 3866000 and 4702000 million tons in 2008, 2009, 2010 and 2011 respectively, this statistic shows growth of sugar beet production in Iran [5]. Beginning extracting stage of sugar beets is before arrival to factory, and in this stage leaves and top of sugar beet a little under leaves, will cut off. This part of the sugar beet has less sugar and if this part would not cut off, a lot of secondary matters will enter to the juice and it will cause, difficult sugar extraction and decrease quality of extracted sugar [6]. The first stage in sugar factory after storage of sugar beet is measuring percentage of sugar in it. In production line after cleaning beets, sugar beets will cut in to the small slices and then sugar will extract by diffusion from beets. Product of this process is pulp and juice called raw juice because besides sugar, the juice

contains water, pectin, proteins, and pigments and other component. This raw juice sugar can't be used, because after extracting, the juice will needs purifying. It wouldn't reaches to 100 percent purity, but the juice will have a high percent purity. After that the juice should be transferred to other stage for more purification includes first and second liming and carbonation. The main stage of sugar production is refining of raw juice, and juice purity is directly related to removing non-sugar material. As a result, from this juice, high quality white sugar can be extracted. The color of juice that will leave diffusion is gray to black and melanoidin pigments cause it. Nowadays lime and carbon dioxide are used for the phase of purifying juice. Adding lime to raw juice takes place in two stages: first liming one and after that second liming, as a result colloidal material, proteins and insoluble salts will precipitate. Lime should not be added only in a single step, it cause sudden increase of pH that will be hydrolysis of sucrose. In carbonation stage, the main point is to precipitate the excess of lime added during liming, or during the gassing itself, in the form of calcium carbonate. In the first carbonation tank, the raw juice is mixed with milk of lime. Milk of lime [Ca (OH)2] is added to the mixture to adsorb the impurities in the mixture, then carbon dioxide (CO2) gas is bubbled through the mixture to precipitate the lime as insoluble calcium carbonate crystal and sucrose molecules will separated from the lime. In this phase, CO2 will reduce the juice pH to 11.2. The main goal of the second carbonation is the elimination by carbonic acid of all the lime which can be precipitated as calcium carbonate. In the second carbonation tank, the juice is again treated with CO2 to remove the remaining lime and impurities. The pH of the juice is lower during this second carbonation causing large, easily filterable, calcium carbonate crystals. After this stage, diluted juice moved to evaporator for concentration and after that concentrated juice moved to crystallization, to produced white sugar granules. If the action of refining was completed, sugar will take shape in the form of crystal [6]. Due to importance of these stages, monitoring of different properties is necessary, therefore the aim of this study was laboratory monitoring of three major sugar beet sources for manufacturing sugar in Iran.

## MATERIALS AND METHODS

Randomly three different factories (Mashhad, Qazvin, and Buein Zahra) for producing sugar beet slice and juices selected. The level of mark, pH, titratable acidity, alkalinity, and Swedish and Cillin number was measured according to the method of international standard number 6763 [7]. The pH values of samples were measured using pH meter. Brix and polarity was measured by refract meter and polarimeter respectively.

### Data Analysis

Data collected from the aforementioned study samples were analyzed based on 0.05% coefficient of error by a software program. The data analysis was performed using MINITAB statistical software, release 14.2 (MINITAB Inc., state college, PA and USA). At first such software program proved samples normal conditions and then the significant difference among data was precisely studied via Anova-one-way test.

## RESULTS AND DISCUSSION

### Sugar beet slice

Table 1 has shown physicochemical properties of difference sugar beet slice. The pH value of sugar beet slice show its quality and refer to sugar hydrolysis, and higher level of pH, shows higher quality of sugar beet slice, it means higher percent of sugar in sugar beet and therefore higher content of sucrose extraction. Table 1 has shown that pH of sample from Qazvin (6.00) and Mashhad (6.09) had a significant difference with Buein Zahra sample (5.24). Number of Cilin is length of 100 gram of sugar beet slice and shows quality of sugar beet slice. In this test according to the ISIRI acceptable limit for Cilin number should be in the range of 10 to 15 meters, statistical analysis shows significant difference ($p \leq 0.05$) between the three Cilin number of samples. According to the results the Cilin number of samples from Mashhad (13.15) was higher than Qazvin (10.76) and the Cilin number of Buein Zahra sample (8.37) was smaller than the other two and it's lower than standard acceptable limit. Therefore Mashhad and Qazvin samples are more suitable for manufacturing sugar. Mark content is the percent of insoluble material in sugar beet slice. According to Table 1, Mark content of all three samples has significant difference between each other; Buein Zahra samples (5.11%) were higher than the other samples ($p \leq 0.05$). The Mark content of Mashhad sample (4.74%) also is higher than Qazvin Sample (4.50). According to ISIRI acceptable limit for mark percent should be in the range of 4 to 5 percent.

The most important factor of sugar beet is sugar percent in purchased sugar beet. The sugar content can be determined by a machine called polarimeter that works based on polarized light and the polarized light is deflected

to the right or left by sugar that this deflection is caused by asymmetric carbon. According to angle of light, the sugar content can be determined. Polarimeter result according to Table 1, shows significant difference between the sugar content of Mashhad Sample (16.67) and Qazvin Sample (14.95) but Buein Zahra sample (15.90) is in range of both samples and it hasn't notable significant difference with them ($p \leq 0.05$).

Swedish number define as a total weight of slices those are bigger than five centimeters divided by total weight of slices those are smaller than one centimeter which is expressed as a percentage. In this test according to ISIRI [7] Swedish number should be higher than 10 gram, so all three samples are shown Swedish number above standard limit with Mashhad (22.90), Qazvin (19.50) and Buein Zahra (21.46).

The higher rates of weight, shows higher quality of sugar beet slice. The moos number defines as the total weight of slices those are smaller than one centimeter divided by 100 gram which is expressed as a percentage. Higher rates of moos number, shows lower quality of sugar beet slice. According to ISIRI [7] acceptable limit for moos is lower than 5 percent so all samples were in acceptable limit and had no significant difference ($p \leq 0.05$). Moos content of Mashhad, Qazvin and Buein Zahra sample were 0.04%, 0.04% and 0.03% respectively.

**Laboratory tests on Sugar beet Raw Juice**

Sugar beet is sliced and mixed with hot water in the juice-making machine or diffusion at about 70 °C, then sugar from beet tissue enters the water and raw juice is manufactured. According to ISIRI [7], raw juice pH value of normal sugar beet must be 5.8 to 6.2 and it's one of important factors to show that sugar beet is or isn't suitable for manufacturing sugar. According to Table 2 ,pH of Qazvin (6.00) and Mashhad sample (5.90) were in the same range and both have significant difference ($p \leq 0.05$) with the pH value of Buein Zahra sample with (5.50), therefore the pH value of Buein Zahra sample was out of ISIRI limit.

Brix define as percent of soluble solids that may or may not contain sugar but Pol, is percentage of sugar. Quation (Q) is defined as Pol divided by Brix (BX) which is expressed as a percentage. If Pol is equal to Brix, Q value is equal to 100%, but usually the Q value is less than 100%, because Pol is lower than Brix. The results of percentage of Pol according to Table 2 has shown that all samples were in the same ranges and don't have significant difference ($p \leq 0.05$) but Buein Zahra sample was more proper because it has higher percentage of Pol ( 13.70%) .

Table 2 has shown the Brix of experimented samples. There was no significant difference between the brix of Buein Zahra sample (15.85) with the other two samples but the brix of Mashhad (15.50) and Qazvin sample (16.20) are shown significant difference ($p \leq 0.05$) with each other. Also Qazvin sample has higher percent of soluble solids compared with the other two samples. According ISIRI the Quation value (Q) in Sugar beet raw juice should be in the range of 85 to 87, as the results of Table 2 showed that all three samples there weren't significant differences and Buein Zahra samples has higher Q value (86.43) compared with Mashhad (85.80) and Qazvin sample (81.21).

**Refining raw juice**

Chemical properties of sugar beet in first and second deification and saturation have shown in Table 3. According to ISIRI, pH of first liming should be 10.8 to 11.2, and result test has shown that samples pH were in acceptable range and pH of Qazvin sample (11.915) was higher than Mashhad (11.18) and Buein Zahra (11.25) samples. The results of Table 2 has shown that alkalinity of samples was in standard acceptable range that is 0.2 to 0.3, there is no significant difference between alkalinity of samples ($p \leq 0.05$) also, alkalinity of Buein Zahra sample (0.30) was in higher level in comparing with Mashhad and Qazvin (0.29). In second liming, the juice pH will be reach to about 12.6, in this stage the melanoidin pigments are also disintegrate. Second liming pH value should be in the range of 11 to 12, the results of experimented samples has shown that there were no significant difference between samples, and its mean value was 12.30. According to international standard the second liming alkalinity must be in the range of 1.1 to 2, so alkalinity of samples were acceptable and there were no significant difference ($p \leq 0.05$), however alkalinity of Qazvin sample (2.10) was higher than Mashhad (1.85) and Buein Zahra (1.95) samples.

According to ISIRI, pH value in first carbonation should be in the range of 10.8 to 11.2 so pH of Mashhad sample (10.90) was acceptable but Qazvin (10.20) and Buein Zahra (10.44) samples were lower than standard value.

The results of alkalinity are shown that alkalinity of Qazvin sample (0.07) was higher than Mashhad (0.05) and Buein Zahra (0.06) sample. However, all of samples were lower than ISIRI standard range.

The pH of second carbonation is shown in Table 3. The pH of Mashhad sample was higher than Buein Zahra (8.55) and Qazvin (8.40), but statistically there weren't significant differences between pH values of experimented samples.

**Diluted juice**

The no-sugar materials are separated from the sugar juice in the presence of lime and carbon dioxide, which are non-toxic natural materials and impurities will precipitate. The resulting product of this reaction is diluted juice with about 16% sugar. Statistically there was not any significant difference between the pH values of diluted juice samples. The pH of Qazvin (8.86) was higher than Mashhad (8.80) and Buein Zahra Sample (8.76).

The results of the percentage of sugar in diluted juice showed that there wasn't notable difference ($p \leq 0.05$) between Mashhad (14.25%), Buein Zahra (14.21%) and Qazvin sample (14.12%) and the results also showed that Mashhad sample had higher percentage of sugar comparing with the other two samples but all three samples are suitable and acceptable for manufacturing sugar.

According to ISIRI, brix content of diluted juice must be between 12 to 16%, Table 2 has shown that all three samples were acceptable but the Brix of Mashhad (15.60%) and Qazvin (15.47%) had significant difference with each other, also Buein Zahra sample (15.55%) was in the range of both of them.

According to ISIRI, if Q value is in range of 90 to 93, Juice has high quality. According to the results of Table 2, all three samples were in the range of ISIRI, however, Mashhad sample (91.42) is in higher level of quality comparing with Qazvin (91.39) and Buein Zahra (91.41) samples.

**Concentrated juice**

According to ISIRI, pHs of all concentrated juice were in acceptable range of pH (8 to 9) and this value for Mashhad, Qazvin and Buein Zahra were 8.87, 8.90 and 8.88 respectively. Sugar content in concentrated juice samples were in the same range, and Mashhad sample (50.82%) had higher sugar percent comparing with Qazvin (50.73%) and Buein Zahra (50.80%) samples. According to ISIRI, Brix of concentrated juice must be in the range of 50 to 70%, Table 2 has shown that all three samples were in the same acceptable range and Brix of Mashhad (55.59%) was higher than Qazvin (55.50%) and Buein Zahra (55.55%).

**Table1: physicochemical properties of sugar beet slice**

| | Properties | Buein Zahra | Qazvin | Mashhad |
|---|---|---|---|---|
| Sugar Beet Slice Experiments | pH | $5.24 \pm 0.00^{b}$ | $6.00 \pm 0.14^{a}$ | $6.09 \pm 0.00^{a}$ |
| | Cilin No. | $8.37 \pm 0.04^{c}$ | $10.76 \pm 0.77^{b}$ | $13.15 \pm 0.12^{a}$ |
| | Mark (%) | $5.11 \pm 0.01^{a}$ | $4.50 \pm 0.00^{c}$ | $4.74 \pm 0.08^{b}$ |
| | Sugar (%) | $15.90 \pm 0.42^{ab}$ | $14.95 \pm 0.03^{b}$ | $16.67 \pm 0.03^{a}$ |
| | Swedish No. | $21.46 \pm 0.08^{a}$ | $19.50 \pm 2.12^{a}$ | $22.90 \pm 0.14^{a}$ |
| | moos number | $0.03 \pm 0.00^{a}$ | $0.04 \pm 0.01^{a}$ | $0.04 \pm 0.00^{a}$ |

**Table 2: Chemical properties of Raw, Dilution and Concentration of sugar beet Juice**

| | Properties | Buein Zahra | Qazvin | Mashhad |
|---|---|---|---|---|
| Raw Juice | pH | $5.50 \pm 0.00^{b}$ | $6.00 \pm 0.42^{a}$ | $5.90 \pm 0.00^{a}$ |
| | Pol | $13.70 \pm 0.14^{a}$ | $13.15 \pm 1.48^{a}$ | $13.30 \pm 0.02^{a}$ |
| | Brix | $15.85 \pm 0.07^{ab}$ | $16.20 \pm 0.14^{a}$ | $15.50 \pm 0.01^{b}$ |
| | Q | $86.43 \pm 0.50^{a}$ | $81.21 \pm 9.87^{a}$ | $85.80 \pm 0.02^{a}$ |
| Diluted Juice | pH | $8.76 \pm 0.03^{a}$ | $8.86 \pm 0.02^{a}$ | $8.80 \pm 0.02^{a}$ |
| | Pol | $14.21 \pm 0.49^{a}$ | $14.12 \pm 0.02^{a}$ | $14.25 \pm 0.35^{a}$ |
| | Brix | $15.55 \pm 0.03^{ab}$ | $15.47 \pm 0.01^{b}$ | $15.60 \pm 0.02^{a}$ |
| | Q | $91.41 \pm 0.01^{a}$ | $91.39 \pm 0.01^{a}$ | $91.42 \pm 0.02^{a}$ |
| Concentrated Juice | pH | $8.88 \pm 0.01^{a}$ | $8.90 \pm 0.00^{a}$ | $8.87 \pm 0.21^{a}$ |
| | Pol | $50.80 \pm 0.63^{a}$ | $50.73 \pm 0.42^{a}$ | $50.82 \pm 0.35^{a}$ |
| | Brix | $55.55 \pm 0.03^{a}$ | $55.50 \pm 0.02^{a}$ | $55.59 \pm 0.01^{a}$ |
| | Q | $91.47 \pm 0.01^{a}$ | $91.41 \pm 0.02^{a}$ | $91.45 \pm 0.01^{a}$ |

Quation value in concentrated juice shouldn't have notable difference with diluted juice Quation value, because in this stage only water of juice separated by concentration. Test result of Quation value has shown that although all three samples were in suitable rang but Buein Zahra sample (91.47) was a little more proper for manufacturing sugar

because its Quation percent. The percent of Quation in Buein Zahra was higher than Qazvin (91.41%) and Mashhad (91.45%) samples.

**Table 3: Chemical properties of Sugar Beet in deification 1 and 2, Saturation 1 and 2**

| Experiment | Sample | pH | Alkalinity |
|---|---|---|---|
| First Liming | Buein Zahra | 11.25 ± 0.07[a] | 0.30 ± 0.01[a] |
| | Qazvin | 11.91 ± 0.59[a] | 0.29 ± 0.02[a] |
| | Mashhad | 11.18 ± 0.02[a] | 0.29 ± 0.63[a] |
| Second Liming | Buein Zahra | 12.33 ± 0.01[a] | 1.95 ± 0.07[a] |
| | Qazvin | 12.21 ± 0.28[a] | 2.10 ± 0.28[a] |
| | Mashhad | 12.37 ± 0.00[a] | 1.85 ± 0.21[a] |
| First Carbonation | Buein Zahra | 10.44 ± 0.05[b] | 0.06 ± 0.01[a] |
| | Qazvin | 10.20 ± 0.14[b] | 0.07 ± 0.01[a] |
| | Mashhad | 10.90 ± 0.02[a] | 0.05 ± 0.01[a] |
| Second Carbonation | Buein Zahra | 8.55 ± 0.07[a] | - |
| | Qazvin | 8.40 ± 0.28[a] | - |
| | Mashhad | 8.70 ± 0.28[a] | - |

## CONCLUSION

All of this tests and steps mentioned in this article help us to reach our main goal which that improving quality of sugar. First, we examine physicochemical properties of sugar beet slices such as measuring length of slices, moos percent, swedish no, mark content and etc, to check that it is appropriate or not for manufacturing sugar, after that beet slices enter to production line, and main operations start for manufacturing sugar such as refining raw juice, first and second liming and carbonation however after all this steps all sugar in sugar beets can't be extracted which call sugar waste. But sugar percent in final product must be 100 percent.

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