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Construction and Usage of Control Charts for Some Properties of Sugar Crystals A Case Study: Al Gunid Sugar Factory, Gezira state, Sudan

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ABSTRACT

Statistical process control benefits organization by providing a systemic method for monitoring and evaluation of process variation. In this research application of statistical process control using variables control charts on the data from Al Gunaid Sugar Factory season (2015 – 2016) to test quality for three properties of sugar crystal namely purity%, colour(IU) and moisture%. The samples were selected at systemic randomness to cover all the season days. The periodic interval of sample was about 2 hours, the sample size is equal 10 and the subgroups are equal 15. Two variables control charts were constructed ($\bar{x}$- charts and R$^-$- charts) for the purity%, colour (IU) and moisture % of sugar crystals. Six random samples were taken and measured for the purity%, colour and moisture and plotted on the constructed charts. The . The $\bar{x}$ charts for purity of sugar crystal showed that, Three %average of purity% was 98.03 points were located below lower action limit and one point was located above upper action limits other points were located within the stable limits. This means that process was out of control The average of colour was 342.24 (IU). The $\bar{x}$ -chart for colour of sugar showed that three points were located above upper action limit and three points were located above upper warning limits. This means that the process was out of control and therefore the cause for that should be searched for. The average of moisture was 0.0572 %. $\bar{x}$ – chart for moisture showed that one point was located above upper warning limit, other points were located between the upper and lower warning limits this indicated the process was under control. The study recommended to construct control charts for other properties of sugar crystal such as Ash% , and Brix% .

Key words: Control Charts, Quality, Crystalization.

1.0 Introduction

Sugar are substances commonly used to give a sweet taste, they are short-chain, soluble carbohydrates, many of which are used in food. They are composed of carbon, hydrogen, and oxygen. There are various types of sugars derived from different sources. Simple sugars are called monosaccharides and include glucose , fructose, and galactose. The granulated sugar most customarily used as food is sucrose .

Sucrose is a disaccharide sugar obtained from sugar cane and beet . (sucrose hydrolyses into fructose and glucose.) Other disaccharides include maltose and lactose. Longer chains of sugars are called oligosaccharides like dextran. Chemically-different substances may also have a sweet taste, but are not classified as sugars some are used as lower-calorie food substitutes for sugar described as artificial sweeteners (Baikow,1982).

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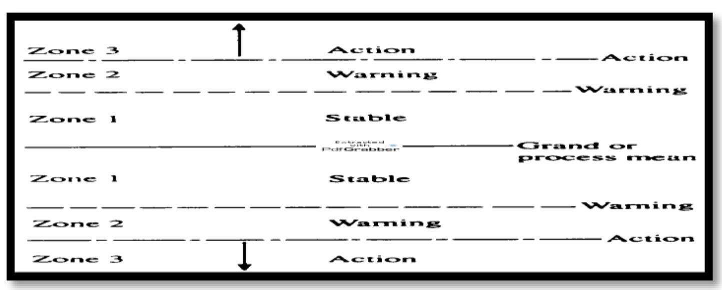
Control Charts (Shewhart Charts): 1.1

The control chart was invented by Walter A.Shewhart while working for bell labs in the 1920s.A control chart is a graphic representation of the variation in the computed statistics being produced by the process. It showed how the variation of particular set of data, representing process Control charts contains a centreline for average, upper and lower characteristic, was produced. control limits. Upper warning limit (UWL) and lower warning Limit (LWL) may also be added Generally .Action is required if a result is beyond either of the control limits. The UWL and LWL are set at a level so that most of the results will fall between the lines when a system is running in control (Shewhart, 1920).

The frequency plot of observing shows the overall amount and form of variation during the period of time sampled, but it fails to indicate how or when that variation was produced, (Oakland,2003). Also the purpose of a control chart is to detect change in the performance of process. If a control chart is compared with histogram, a control chart illustrates the dynamic performance of the process, where as a histogram gives a static picture of variations around a mean or average. Ideally these should be used together to detect changes in absolute level centering or accuracy and changes in variability spread or precision, (Wadsworth, 2004).

The control chart has three zones and the action required depends on the zone in which the results fall. As shown in Fig.(1.1)

- Zone1: the process is under control, if its results fall in this zone.
- Zone2: it warning zone, and the process may be showing special causes of variation when the results fall in this zone. More information is needed.
- Zone3: when the results fall in this zone, the process is unstable. Action must be taken , where appropriate, the process is adjusted, here special causes of variation present.



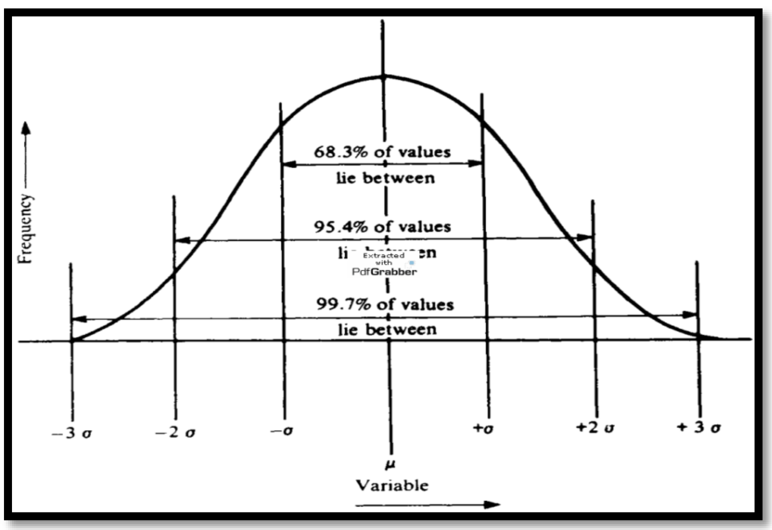
Fig(1.1):The three zones on the Mean Chart
Source :(Oakland,2001)

1.2 The Normal Distribution:

The meaning of the standard deviation is perhaps most easily explained in terms of the normal distribution. If a continuous variable is monitored, such as the lengths of rod from the cutting process, the volume of painting tins from a filling process, the weights of tablets from a pelletizing process, or the monthly sales of a product, that variable will usually be distributed normally about a mean μ. The spread of values may be measured in terms of the population standard deviation, (σ) which defines the width of the bell-shaped curve. Fig. (1.2) shows the proportion of the output expected to be found between the values of $\mu \pm \sigma$, $\mu \pm 2\sigma$ and $\mu \pm 3\sigma$

1.3 Uses of Control Charts:

Control charts are useful for analysing and controlling repetitive processes because they help to determine when corrective actions are needed, because they display running records of performance, control charts provide numerous types of information to management.(Montgomery, 2009).Control chart is a useful tool for studying variation. The limits quality gives the control chart analytical power to enable its user to determine whether a process can be considered stable and thus, predictable, or unstable, unpredictable.



Fig(1.2):Normal Distribution
Source :(Oakland,2003)

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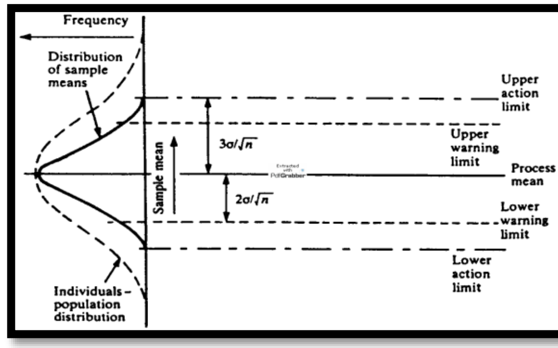

Fig (1.3):Principle of Mean Control Charts
Source :(Oakland,2003

1.4 Equations Used for Construction of the Charts:

1.4.1 Construction of Average Charts or $\overline{X}$ Charts:

$\bar{x}$ = Total of Means ($\bar{x}$)/Number of samples‹process Mean

$\bar{R}$ =Total of Ranges($\bar{R}$) /Number of samples‹Mean Range

σ =standard deviation ‹σ= $\bar{R}$ /d_n

$d_n$is a factor depends only on the sample size n as shown on table (1)

For sample size 10 d_n=3.078

The formulae for setting the action and warning lines on mean charts are:

Upper action line at $\bar{x}+3\sigma/\sqrt{n}$
Upper warning line $\bar{x}+2\sigma/\sqrt{n}$
Process or grand mean at $\bar{x}$
Lower warning line at $\bar{x}-2\sigma/\sqrt{n}$
Lower action line at $\bar{x}-3\sigma/\sqrt{n}$

$\bar{x}$ = process or grand mean of xi items ,σ = standard deviation of sample
n=number of items

1.4.2 Range Chart:

An $\bar{R}$-chart or (Range chart) :is specifically designed for detecting changes in variability.
Because an $\bar{x}$-chart is not sufficient on its own, it needs to be supplemented with an $\bar{R}$-chart.
Constants $D_{.001}$,$D_{.025}$,$D_{.975}$and $D_{.999}$ used to calculate the control limits for a Range chart.

Upper control limits $\bar{R}*.D_{0.999}$
Lower control limits $\bar{R}*.D_{0.001}$
Upper warning limits $\bar{R}*.D_{0.975}$
Lower warning limits $\bar{R}*.D_{0.025}$

The multiplier D is obtained from samples table (1). There are tables of pairs of values $D_{0.999}, D_{0.001}, D_{0.975}, D_{0.025}$

Table (1.1) Relationship between Standard Deviation and Range and Control Chart Limits for Sample Range
Source: (Oakland, 2003)

Sample size	**For lower limits**	**For upper limits**	

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	$D_{0.001}$	$D_{0.025}$	$D_{0.975}$	$D_{0.999}$	Sample sizeN	Factor d_n
2	0.00	0.04	2.81	4.12	2	1.13
3	0.04	0.18	2.17	2.98	3	1.69
4	0.10	0.29	1.93	2.57	4	2.06
5	0.16	0.37	1.81	2.36	5	2.33
6	0.21	0.42	1.72	2.21	6	2.53
7	0.26	0.46	1.66	2.11	7	2.70
8	0.29	0.50	1.62	2.04	8	2.85
9	0.32	0.52	1.58	1.99	9	2.97
10	0.35	0.54	1.56	1.94	10	3.08

(1.2) : 6 Samples for the Three Properties of Sugar Crystal from Algnaid Sugar Factory. Table

Number of sample	Purity %	Colour(IU)	Moisture%
1	97.5	365	0.056
2	97.8	360	0.059
3	97.5	355	0.061
4	98.0	353	0.062

5	97.40	351	0.059
6	98.6	359	0.055

2.0 Materials:

The materials used in this study are:

- Sugar crystals
- Distilled water
- Lead acetate
- Filtration papers
- Soduim hydroxide NaOH
- Hydrochloric acid HCL

2.1 Apparatus :

The apparatus used in this study are:

- Polarimeter
- Moisture meter
- pH-meter
- Sucroscan device
- Refractometer device

2.2 Methods:

Construction of control charts for variables data collected from Algnaid Sugar Factory(GSF) were used to construct control charts for X^- charts and R^- charts .

Furture samples were taken to check if the running process was under or out of control for the three properties namely purity% ,colour(IU) and moisture %**.**

The methods include tests of properties which are chosen for the study. and the experimental work was carried out in central laboratory in Algnaid sugar factory. The International Commission for Uniform Methods of Sugar Analysis(ICUMSA) was used.

2.2.1 Colour Test :

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Control Limits of $\overline{R}$Chart				
	UAL	**LAL**	**UWL**	**LWL**
Purity%	**2.1**	**.38**	**1.70**	**.59**
Colour (IU)	**88.1**	**15.9**	**70.8**	**24.5**
Moisture%	**.031**	**.005**	**.025**	**.008**

Colour is the degree of sugar colour it ranges from (400-900)IU. 3grams of sugar was taken and put in a glass cup with a capacity of 75 ml and distilled water was added until 75 ml was completed. Then the solution was shaken well until dissolving all the granules of sugar and adjust pH at 7 using pH meter if it was higher than 7 by adding drops of HCL. If less than 7 drops of NaOH were added then degree of colour was measured in sucroscan device, at wave length 420 nanometers . Brix% was measured using a refractometer device and then the degree of colour was calculated.

2.2.2 Polarity Test :

Polarity is a ratio of pure sucrose in sugar. 26 grams of sugar was taken and put in a glass cup and distilled water was added until 100 ml was completed. Then 5grams lead acetate was added and solution was shaken well until melting all the granules of sugar and then solution was filtered using 45 microns filtration paper. Then the filtered solution was taken and measured in polarimeter device.

2.2.3 Moisture Test:

Moisture is a water content in sugar crystals. 10 grams of sugar was taken and put in a digital Moisture meter device for 5 minutes and then the moisture content was read.

3.0 Results and Discussions

Table (3.1) below show the control chart limits for $\overline{\boldsymbol{R}}$charts which were calculated from equations in section 1.4

Table (3.2) below shows the control limils for $\bar{x}$ – chart which were calculated from eyqations in section (1.4).

Table(3.1):Control Charts Limits for R⁻ Charts:

Table (3.2) control charts limits for $\bar{x}$ charts

From the data on tables (3,1) and (3,2), control charts for ranges ($\bar{R}$) and averages ($\bar{X}$) for each of the three properties purity%, colour and moisture % were drawn as shown in figures (3.1) and (3.2) for purity, figures (3.4) and (3.5) for colour and figures (3.7) and (3.8) for moisture %.

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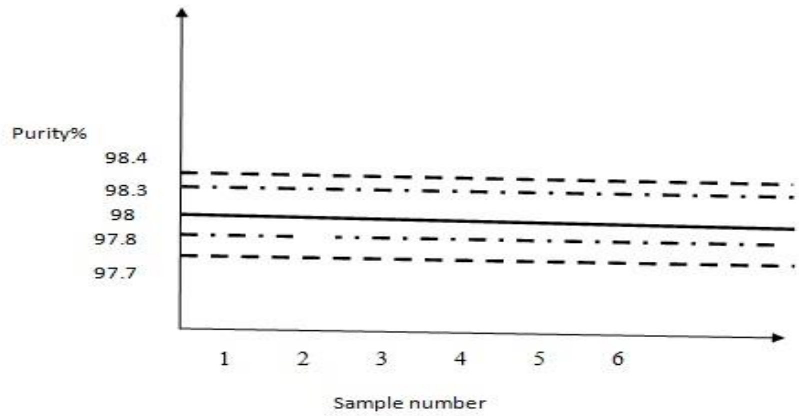

rom(GSF)Fig (3.1):$\bar{X}$ Chart for Purity%of Sugar Crystal
Source:

Control Limits of $\bar{X}$Chart

Own

	The Average (X)	The Range (R)	Standard Deviation (S)	UAL	LAL	UWL	LWL
Purity%	98.03	1.09	.354	98.37	97.69	98.30	97.80
Colour (IU)	342.3	45.4	14.75	356	328	351	332
Moisture %	.057	.016	.0052	.062	.052	.060	.053

calculations based on secondary sample

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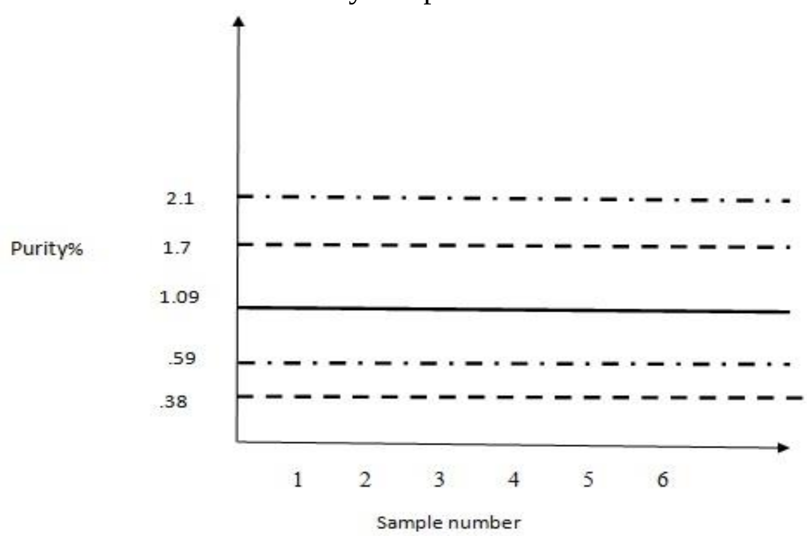

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Source: Owncalcalations based on secondary sample from(GSF)

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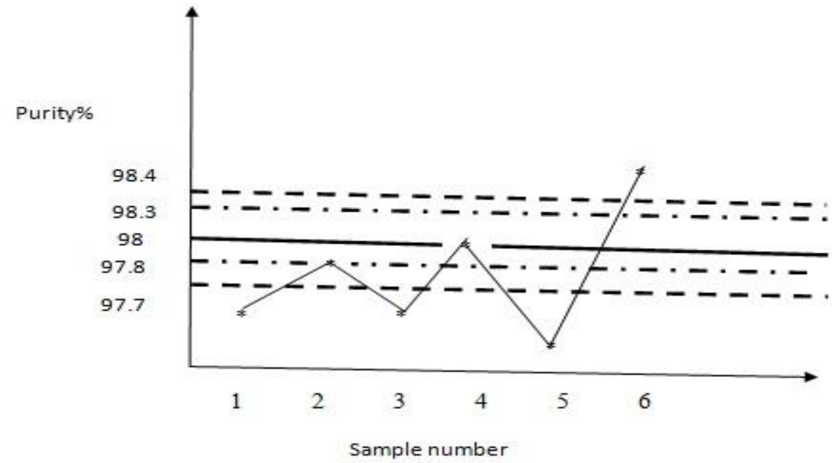

Fig (3.3): $\bar{X}$ Chart for Purity % of Sugar Crystal
Source: Own experimental work

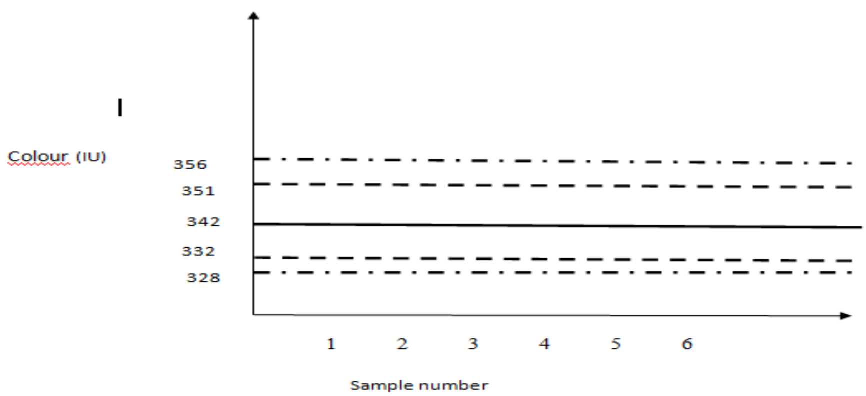

Fig (

Source: Own calculations based on secondary sample from(GSF)

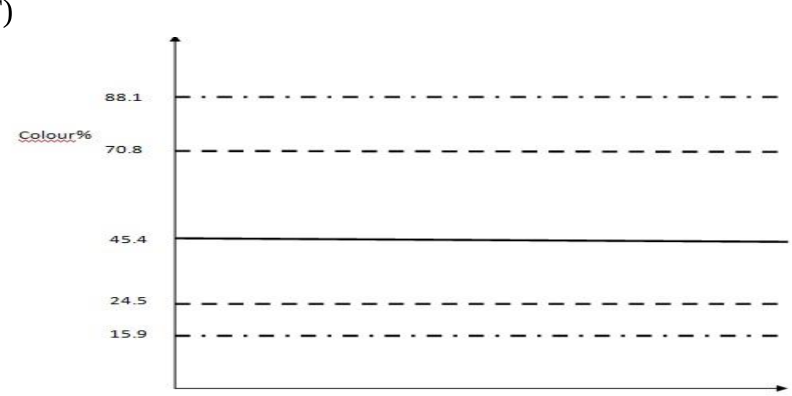

Fig (3.5):$\bar{R}$ Chart for Colour (IU) of Sugar Crystal.
Source: Own calculations based on secondary sample from(GSF)

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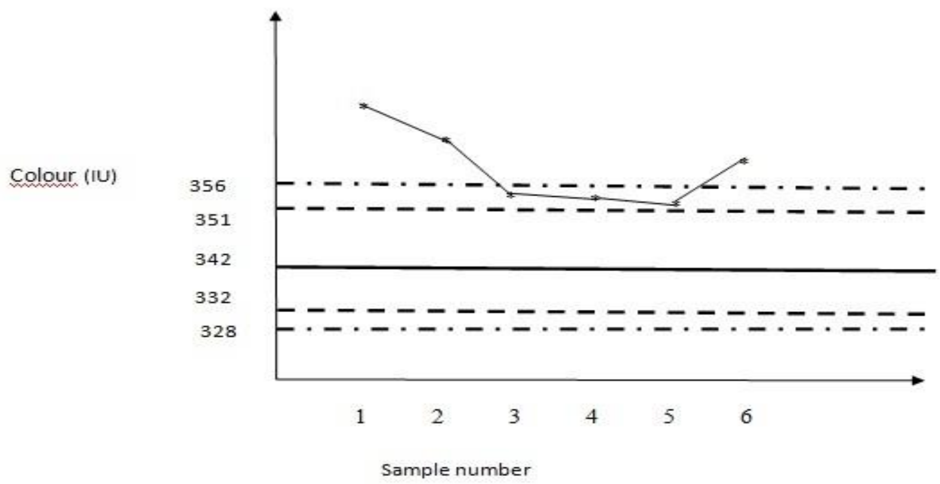

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Source: Own experimental work

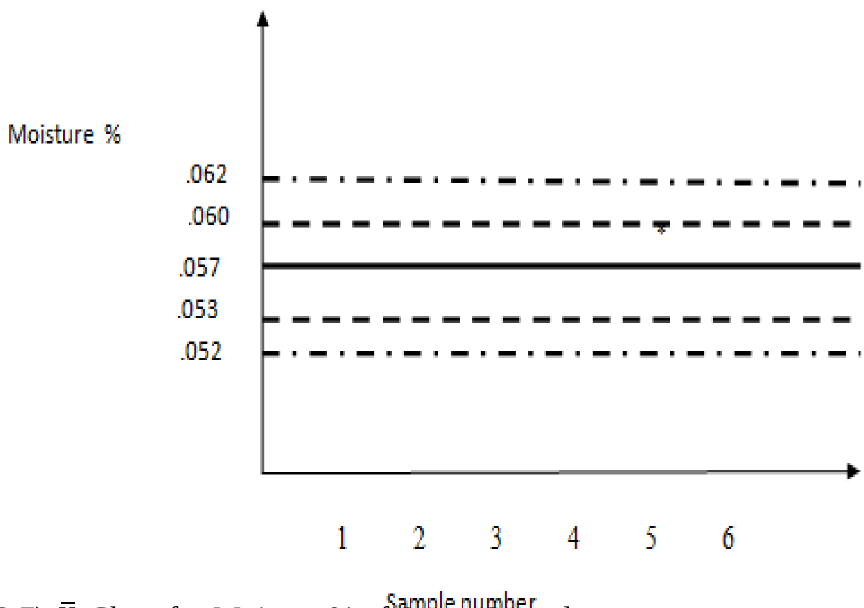

Fig (3.7):$\bar{X}$- Chart for Moisture% of Sugar Crystal

Source: Own calculations based on secondary sample from(GSF)

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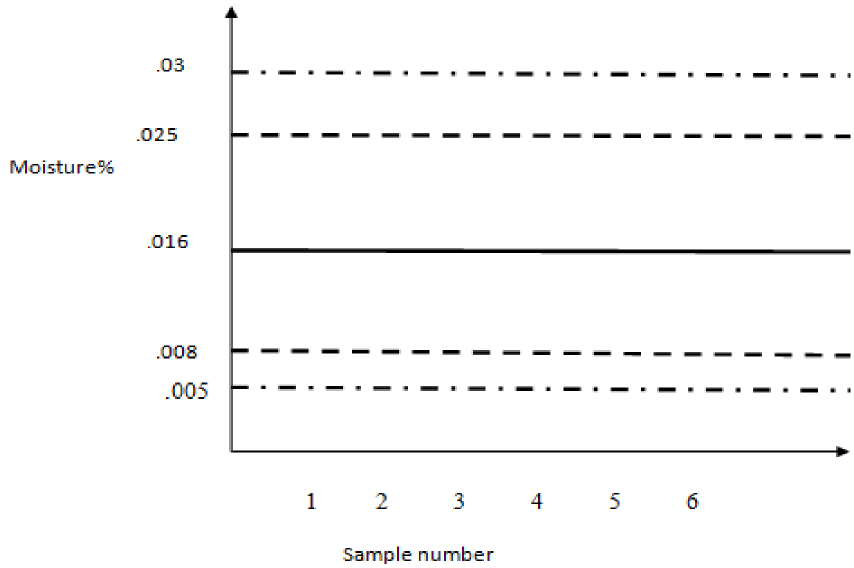

Fig (3.8):$\bar{R}$ Chart for Moisture % of Sugar Crystal

Source: Own calculations based on secondary sample from(GSF)

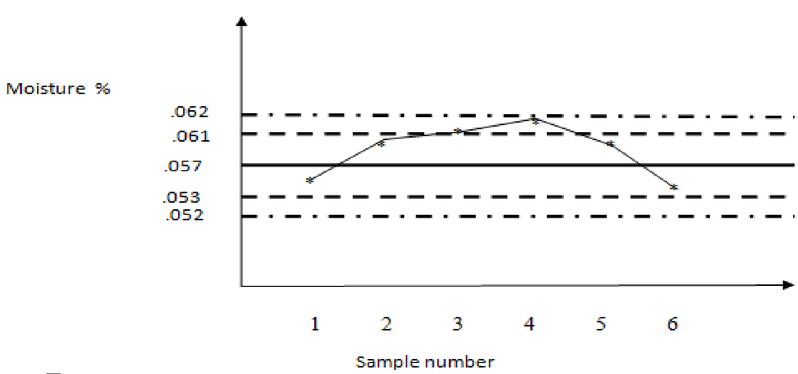

Fig (3.9):$\bar{X}$ Chart for Moisture % of Sugar Crystal

Source: Own experimental work

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The values obtained from tested samples as shown in table (1.2) were plotted on their respective charts as shown in figures (3.3), (3.6) and (3.9).

(I) Fig (3.3) shows that three points are located below lower action limit and one point is located above upper action limits other points are located within the stable limits .process is out of control.

(II) Fig (3.6) shows that point 3 points are located above upper action limit and three points are located above upper warning limits This means the cause for variations in points must be searched for then process line must be checked to find out the reason behind this deviation and must be removed the process is out of control. the process is out of control.

(III) Fig (3.9) shows that one point located above upper warning limits other points are located between upper and lower warning limit the process is under control

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إنشاء مخططات التحكم لبعض خواص بلورات السكر
دراسة حالة :مصنع سكر الجنيد،ولاية الجزيرة، السودان

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الملخص

الرقابة الإحصائية على العمليات تصلح للمنظومات لأنها توفر طريقة منهجية لمراقبة وتقييم التباين في العمليات. في هذا البحث تم تطبيق الرقابة الإحصائية على العمليات بإستخدام مخططات التحكم للمتغيرات على بيانات مأخوذة من مصنع سكر الجنيد للموسم(2015-2016) لاختبار جودة ثلاثة خواص من خصائص بلورات السكر وهي النقاوة%، اللون(IU) والرطوبة%. تم أخذ عينة عشوائية منتظمة غطت جميع أيام الموسم ،طول فترة المعاينة حوالي 2 ساعة، وحجم العينة يساوي 10 وعدد المجموعات الجزئية يساوي 15 ، تم رسم مخططات التحكم لكل من بيانات النقاوة ،اللون والرطوبة .تم أخذ 6عينات عشوائية من السكر وتم قياس النقاوة ،اللون والرطوبة ثم رسمت العينات على مخططات الجودة. وكانت النتائج على النحو التالي,وجد أن متوسط عينات النقاوة هو 98.03. خريطة المتوسط (x¯-chart) لبيانات النقاوة أوضحت انه توجد ثلاثة نقاط تقع تحت حد التصحيح الأدنى ونقطة واحدة تقع فوق حد التصحيح الأعلى والنقاط الأخرى تقع ضمن الحدود المستقرة، وأن العملية قد خرجت من نطاق السيطرة. وجد أن متوسط عينات اللون هو 342.24 (IU) .خريطة المتوسط (x¯-chart) لبيانات لون السكر أوضحت انه توجد ثلاثة نقاط تقع فوق حد التصحيح الأعلى وثلاثة نقاط تقع فوق حد الإنذار الأعلى وهذا يقود للبحث عن سبب هذا الانحراف والتحقق منه وتصحيحه وأن العملية قد خرجت من نطاق السيطرة .وجد أن متوسط العينات للرطوبة هو .0.0572. خريطة المتوسط (x¯-chart) لبيانات الرطوبة أوضحت انه توجد نقطة واحدة تقع فوق حد الإنذار الأعلى والنقاط الأخرى تقع بين حدي الإنذار الأعلى والأدنى لذلك فإن العملية تعتبر مستقرة إحصائيا وتحت السيطرة .أوصت الدراسة بإنشاء مخططات التحكم للخواص الأخرى لبلورات السكر مثل نسبة الرماد (Ash)، والمواد الصلبة الذائبة(Brix%) .

كلمات مفتاحية: مخططات التحكم، الجودة، ، البلورة