LEAN Six Sigma Application in Sugar Industry

Babar Bilal

Bilal Consultancy Private Limited

Multan, Pakistan

babar@bilalconsultancy.com , bilalconsultancylimited@gmail.com

Abstract

Milling section is a heart of sugar industry. In one of the State of the Art sugar Industry of Pakistan, the moisture content in Last Mill Baggase poll (milling) rose higher up to 51.5%, resulting in troublesome situation. LSS in conjugation with DMAIC technique is executed to obtain optimal settings for major significant factors, contributing in the escalation of moisture. Keeping in view the massive sophisticated processes involved in sugar industry, response surface optimization technique was deployed following the regression analysis, resulted in the saving of overall 1 Million PKR per annum.

Keywords

LEAN, Six Sigma, Sugar Industry, Baggase Moisture, DMAIC, Minitab.

Introduction

LEAN SIX SIGMA

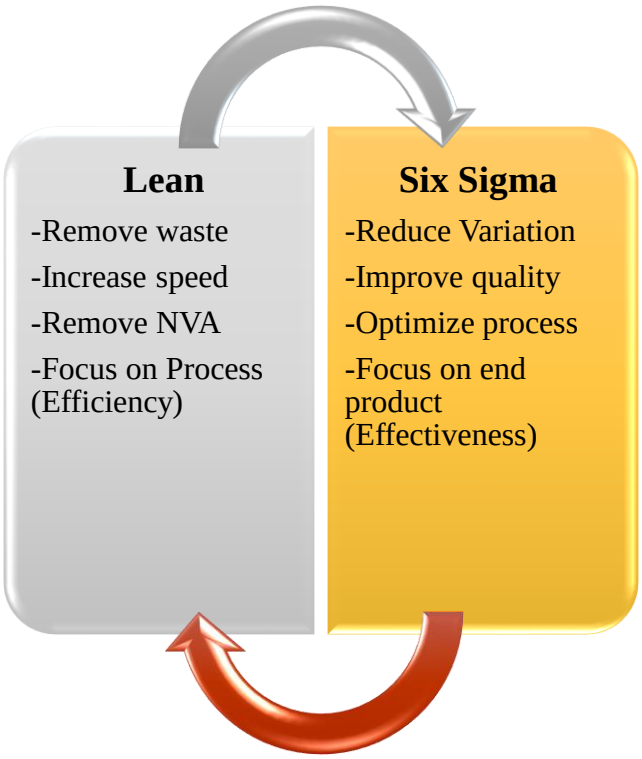
LEAN is a philosophy which focuses on the elimination of wastages from the processes ultimately enhancing the efficiency of system. While Six Sigma plays a role in the diminishing of variation from the processes, increasing the effectiveness of intended output through rigorous statistical analysis.

LEAN is a well-structured, data-driven methodology aiming towards the elimination of wastes, imparted due to product, processes or systems in all kinds of manufacturing, service delivery, management, and other business activities. LEAN methodology is based on the combination of well-established philosophy, set of tools, methodologies & metrics, enabling the organization to see the hidden defects factory.

Six sigma, as a philosophy, is a true measure or control of equation Y=f(x). It generally depicts that by controlling x inputs which are transformed into Y output through function f, we can achieve excellence. Also, it is equipped with the high standards statistical control tools which are very helpful in the data analysis to see the cumbersome event in a crystal clear view. As far as methodologies are concerned, it deals with DMAIC & DMADV techniques, each with its own perks. Lastly, it is a measure of metrics which are set for any process or system. Six sigma is perceived a myth by many traditional or conventional practitioners of quality system due to its 3.4 defects per million methodology. Though, it only makes the processes play in a safe premises where defect & variation would be minimum

Due to its highly efficient impact these methods have recently become very popular in USA, Germany etc. Even in 2007, General Electric published the report listing the savings of almost 1.6 billion due to six sigma

Figure 1LEAN Vs Six Sigma



Sugar Milling Process

Sugar Industry holds a significant importance, when it comes to the overall global consumption of top products. Milling section in this industry is vital to al, the successor ones. Moisture in Last Mill Baggase Poll must be as less as possible to enhance the sucrose content and clarity in the final product. The paper deals specifically with the moisture content minimization in bagasse poll.

Efforts of continuous improvement have been made at different levels.

- As, chromatographic separating of sugar is improved as a big part of delivering a quality output. (Z. Bubnik *, 2003).
- Being milling a nucleus of sugar industry, membrane filtration also needs to be improved to increase the sucrose content of sugar. (A. HINKOVÁ**, 2000)
- Sugar industrial hypothetical technical evaluation has also helped Indian associations to formulate a future strategy. (Sunil KUMAR, 2012)
- Quality & technological evaluation surrey also resulted n a dire need of optimization methods in Pakistan's KPK industry. (Babar Bilal, 2015)
- Similarly, in an overall survey of sugar industry effectiveness, efforts to uplift the improvement culture is highlighted. (ABDUL RAHEMAN)
- PH & Moisture impact, during storage also tend to affect the sugar quality. (Kochergin)

DMAIC

A complete project is carried out in the light of tools & techniques carved out by Lean Six Sigma aspect.

The whole project is carried by following the essence of DMAIC approach,

- Define (What is the project?)
- Measure (Obtain relevant data regarding objective statement)
- Analyze (Statistical Analysis of obtained data)
- Improve (Problem rectification approaches)
- Control (Sustain the amendments proposed)

Define Phase

The purpose of this step is to clearly articulate the business problem, goal, potential resources, project scope and high-level project timeline. The key tools involved in this phase are,

- Project Selection
- Project Charter
- SIPOC Diagram

Project Selection

It is evident from the figure below to get start with the Moisture content Project, keeping in view the company's CTQ drill down, which goes as,

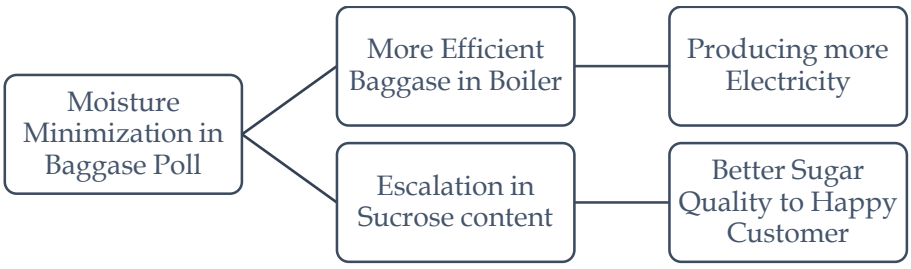


Figure 2 CTQ DrillDown

After an in-depth session with Sugar Industry's top management, QFD tools is used to map out the possible projects & select the one with highest priority.

Sugar Industry Projects

Sugar Industry Projects

Prioritization Factors	Importance	Baggase Moisture Minimization	Pan Cake Optimal Setings	OEE at Sugar Packing Section		Total
Cost required for project completion	3	H	H	L		57
Anticipate failure, if Project not done	1	M	L	L		5
Time required to complete it	2	M	L	L		10
Results						
Cost required for project completion	3	27	27	3		57
Anticipate failure, if Project not done	1	3	1	1		5
Time required to complete it	2	6	2	2		10
Total		36	30	6		

QFD Controls

☑ View Total ☑ View Results

☐ View Zero Importance Items

Sort QFD | Partition QFD

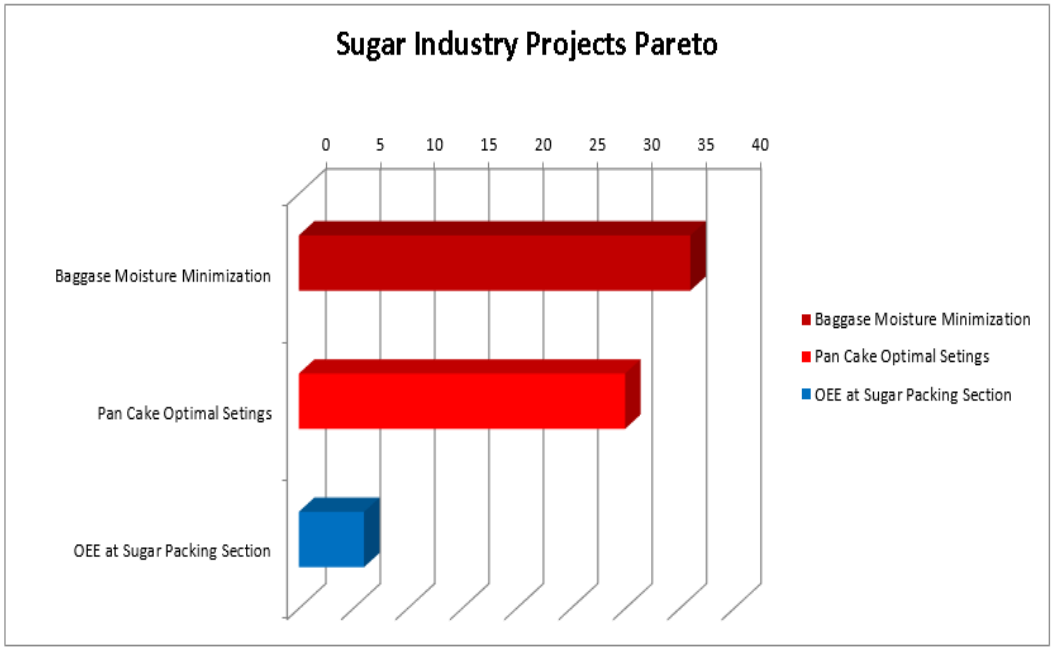


Figure 3 QFD for Project Selection

Project Charter

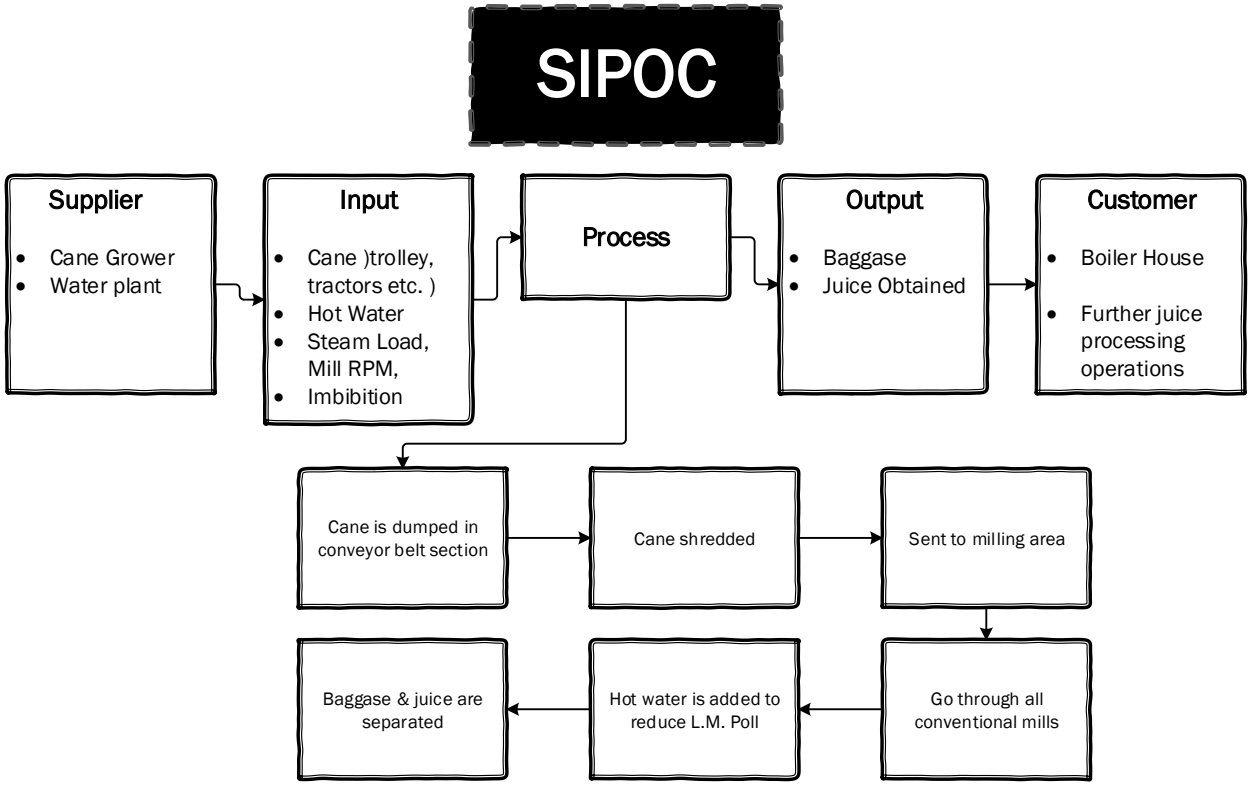
Elements	Description
Background Statement	• Milling, being a nucleus of sugar industry holds significant position in overall processes. If moisture is decreased from last mill of milling section, than better utilization of process can be achieved.
Problem Statement	• To lessen the moisture content in Baggase Poll from 51% to 50.0%, resulting in a saving of around 1 Million PKR per annum.
Scope	• Six sigma project entails the milling section encompassing the input & output outlets.
Deliverables	• To find out the cause triggering high-level moisture • To map out the factors impacting the bottom-line. • Systematic SOP's designing. • Control Charts must be made to avoid the occurrence in future too.

Table 1 Project Charter

SIPOC Diagram

The next step is SIPOC analysis which consists of identifying supplier, inputs, process, outputs, and customer of the whole process. The SIPOC analysis describes the whole process at macro-level. It tells how the process serves its customers; where the process originates; who are the suppliers; who are the customers; how the inputs are processed and transformed into final output; and what the intermediate steps are. The SIPOC analyses, thus, helps to better understand the whole process and makes improvement possible.

Figure 4 SIPOC Diagram



Measure Phase

It involves establishing a baseline for data collection & total numbers of factors responsible for an effect occurrence.

Tools deployed in Measure Phase are,

- Sample Size Calculation
- Process Mapping
- Cause & Effect Diagram

Sample Size Calculation

Total season days included 110 days. Thus, our sample data size is obtained with the help of calculator.

Estimated Population Size	110

Continuous Data	Inputs	Answer
Standard Deviation	3.0	
Confidence Level (e.g. 95%)	95.0%	
Precision (e.g., ± 2 units)	1.2	
Sample Size (per lowest level)		24
Adjusted Minimum Sample Size		20

Table 2 Sample Size Calculation

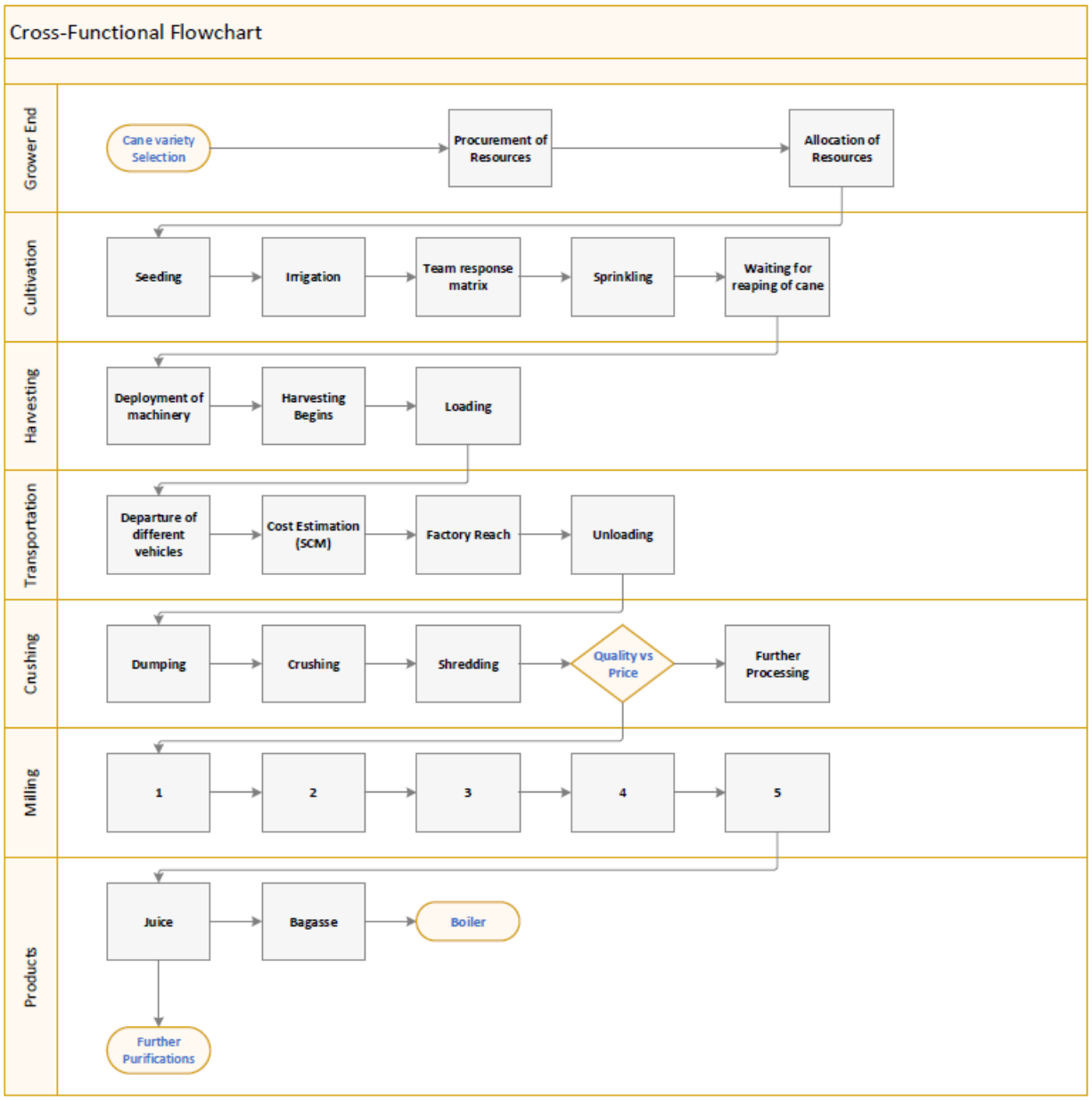
- Assuming S.D.D of 3 along the precision around 2 in the presence of CI at 95% give us 24 number of sample size. (8 days selected from beginning, 8 middle & 8 at the end of a season

Process Mapping

Process map shows how process are aligned with respect to each other. It clarifies the macroscopic over-view which helps in the final war against defects.

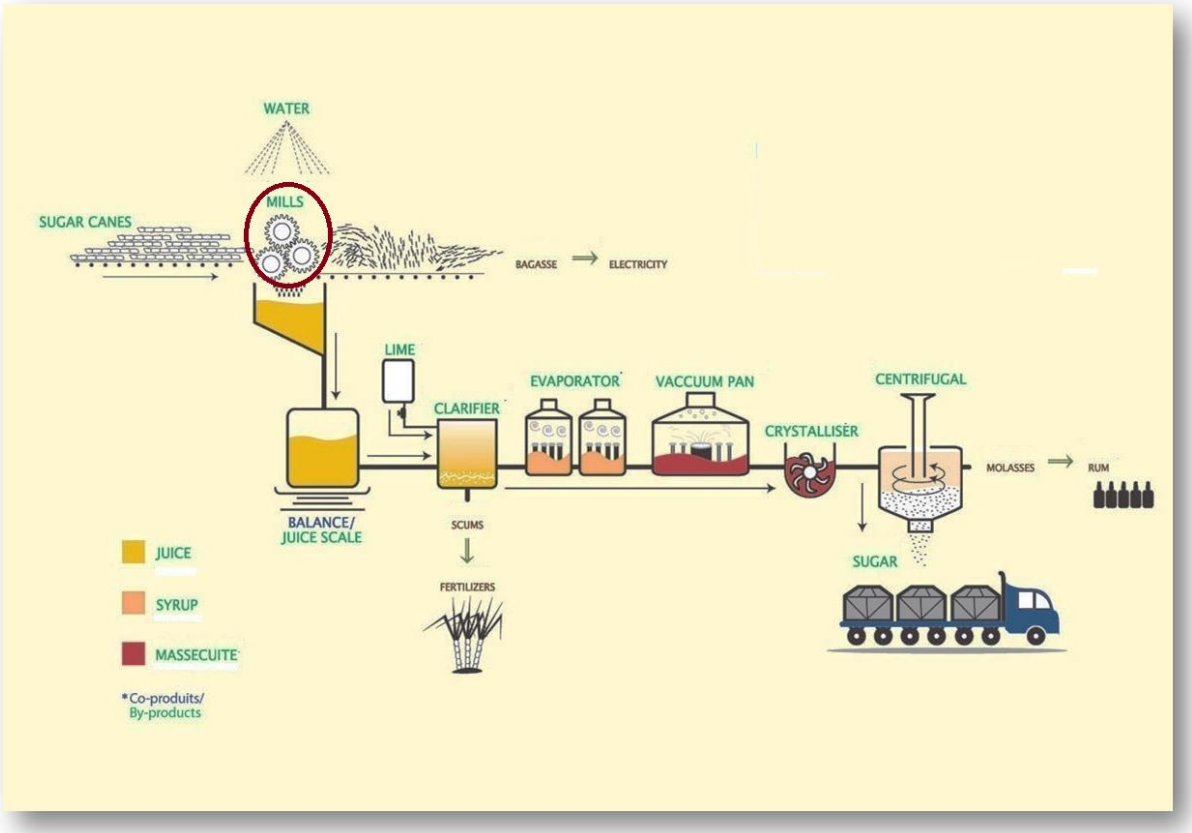
As per the below cross functional chart from seeding to the milling section, it is evident that many stakeholders play a role till sugarcane processing. Thus, proper cultivation method & pesticide attached check also holds an importance in lessening the moisture content.

Figure 5 Process Mapping



To give a better overall process overview, here is a pictorial representation of process (circled).

Figure 6 Sugar Pictorial process



Cause & Effect Diagram

Through Brainstorming, following causes were mapped out along an impacted effect. Below is given a generic description of factors

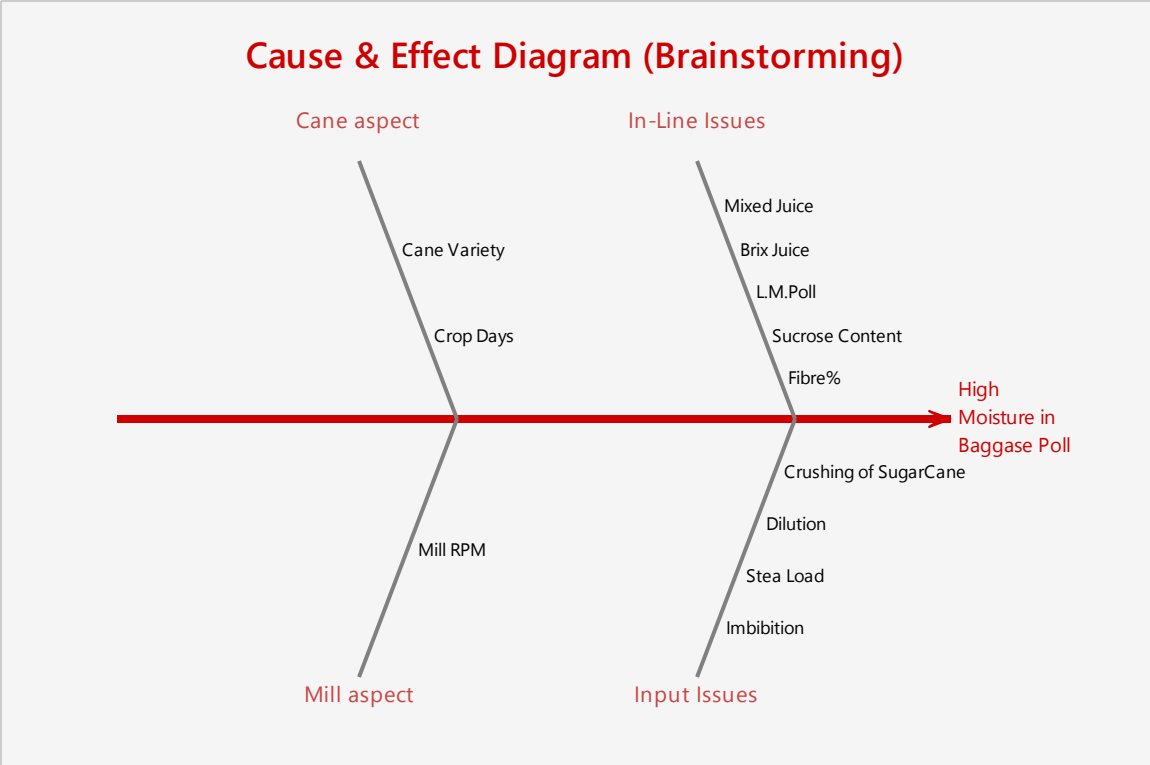


Figure 7C&E

Here is a snapshot of data generated,

Classification	Crop days	Date	Mixed Juice M.T /D	Brix M Juice%	Steam Loadkill /Day	Imbibition /hr M.T	Moisture	Fibre % content %	Fibre % cane	Cane variety %	Crushing M.T	Dilution	L.M.Ipol %
A	1	[illegible]	2929	[illegible]	497.00	31.106	70.55	9.9481	13.13	99.55	3174.407	24.85	3.40
A	2	[illegible]	4700	[illegible]	653.00	24.704	70.93	9.8274	14.25	99.33	4975.930	28.08	2.76
A	3	[illegible]	5901	[illegible]	790.00	25.047	70.71	9.9487	13.87	100.00	6148.827	30.08	2.77
A	4	[illegible]	5720	[illegible]	773.00	22.911	70.70	10.0151	13.72	100.00	6077.670	28.22	2.73
A	5	[illegible]	6200	[illegible]	830.00	24.190	70.44	10.2138	13.49	99.17	6479.317	25.84	3.11
A	6	[illegible]	4790	[illegible]	704.00	22.667	70.20	10.1932	13.84	99.18	5104.230	25.25	3.13
A	7	[illegible]	5543	[illegible]	695.00	26.073	70.38	10.2567	14.27	100.00	5752.681	27.90	2.81
B	25	[illegible]	7521	[illegible]	740.00	27.486	70.23	11.6669	13.13	99.70	7496.633	24.14	2.76
B	26	[illegible]	7487	[illegible]	736.00	27.478	70.30	11.6547	13.18	99.64	7442.256	24.10	2.70
B	27	[illegible]	7525	[illegible]	739.00	27.323	70.27	11.6174	13.87	99.70	7539.450	23.96	2.77
B	28	[illegible]	7397	[illegible]	732.00	27.648	70.36	11.6235	13.71	100.00	7414.567	24.02	2.88
B	29	[illegible]	7490	[illegible]	752.00	28.667	70.16	11.7253	14.05	100.00	7708.273	23.85	2.77
B	40	[illegible]	7620	[illegible]	743.00	29.005	70.20	11.9227	14.08	99.45	7619.346	23.92	2.76
B	41	[illegible]	7142	[illegible]	695.00	28.942	70.42	11.4894	14.03	100.00	7142.250	23.97	2.74
B	42	[illegible]	7448	[illegible]	734.00	29.740	70.37	11.4946	14.04	99.70	7397.720	24.31	2.62
C	89	[illegible]	5735	[illegible]	638.00	30.323	70.23	12.4807	14.11	100.00	5645.705	25.82	2.83
C	90	[illegible]	5462	[illegible]	603.00	28.884	69.93	12.5146	14.24	100.00	5473.516	25.75	2.82
C	91	[illegible]	4040	[illegible]	472.00	28.220	70.03	12.4048	14.19	100.00	4077.081	25.69	2.82
C	92	[illegible]	3100	[illegible]	346.00	28.840	70.07	12.4140	14.37	100.00	3120.943	25.25	2.76
C	93	[illegible]	No data	[illegible]	NO	NO	NO	NO	NO	NO	No data	NO	NO
C	94	[illegible]	2780	[illegible]	317.00	28.841	71.07	12.2077	13.62	100.00	2778.028	23.82	3.07
C	95	[illegible]	3652	[illegible]	409.00	28.789	70.97	12.1789	14.73	100.00	3647.227	24.55	2.87
C	96	[illegible]	2410	[illegible]	276.00	30.982	70.15	12.1707	14.22	99.57	2395.500	25.45	2.87
C	97	[illegible]	2768	[illegible]	292.00	29.948	70.12	11.8718	14.84	100.00	2918.940	26.18	2.88

Table 3 Data Generated

Analyze Phase

The complete analysis in this phase is subjected to narrow down the number of factors to few numbers, so that optimal settings for milling configuration can be obtained.

Following tools will play a role in this aspect,

- Graphical Summary
- Process Capability Analysis
- Hypothesis Testing
- Response Surface Optimization

Graphical Summary

In the light of subjected analysis, following interpretations can be made,

- Data is non-normal (As p <0.05)
- Skewness is in a right direction and most of the data is skewed towards left side.
- Kurtoses value is also positive, depicting less variation in our sample data.
- Box Plot states the median value (a central tendency value for non-normal distribution)

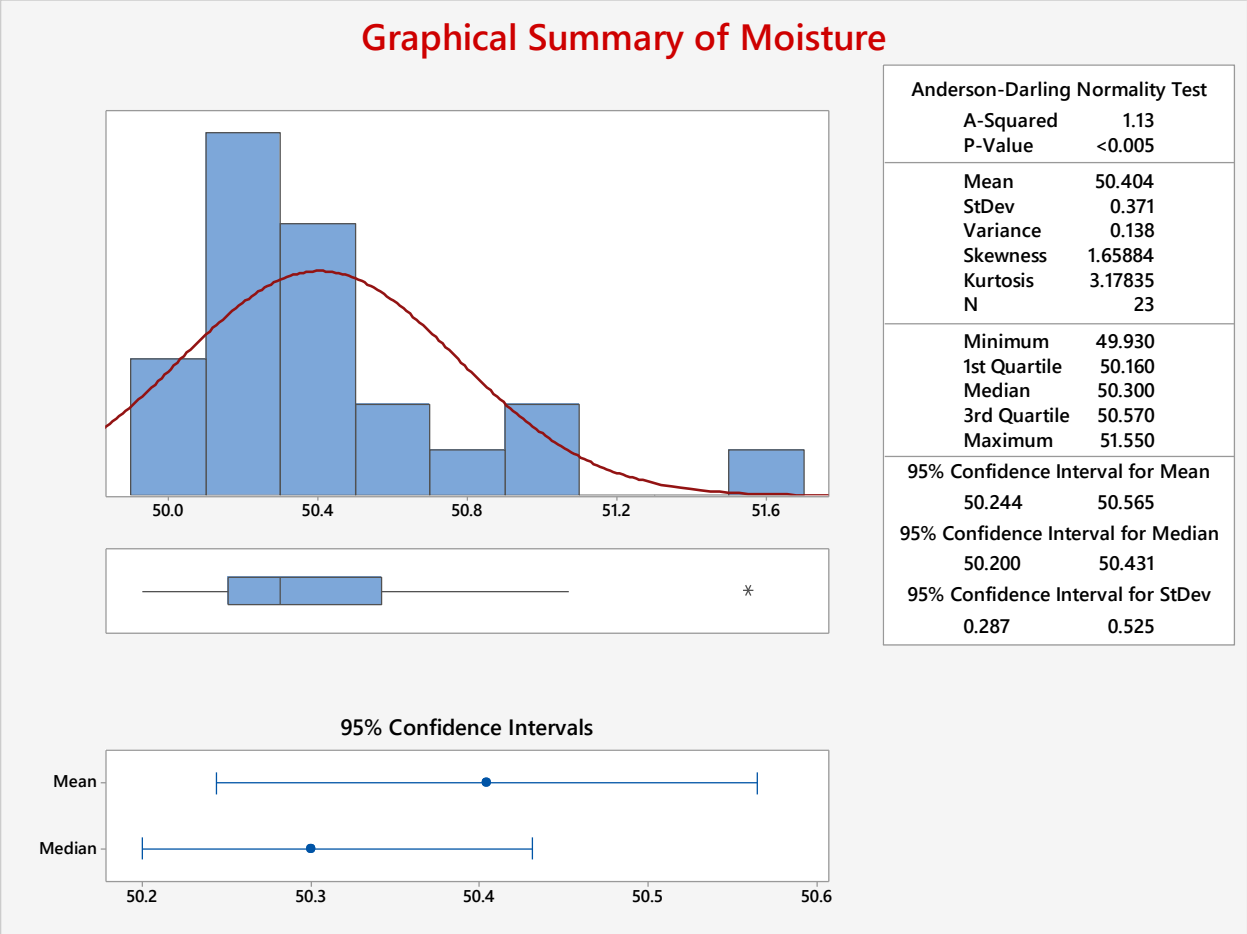


Figure 8 Graphical Summary

Process Capability Analysis

Customer demands moisture to be at 4. While the control limits for the process are 48.5 & 50.5 respectively.

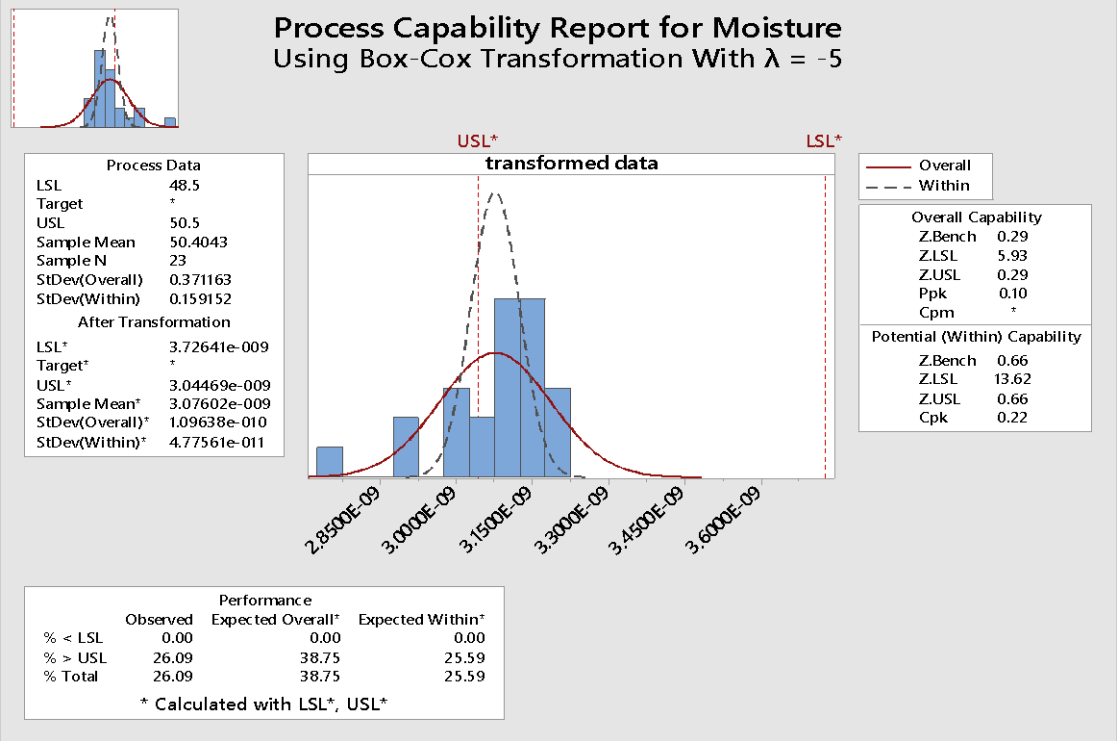


Figure 9 Process Capability

Here,

- Z-score is around 0.66 and if even a 1.5 sigma shift is added than it would round up to 2.1 (less than 3 sigma).
- Special cause variations are present in the process.
- Box-Cox transformation is used to convert non-normal data to normal one before capability computation.
- Cpk (process [performance) is also too low, requiring revision of milling settings

The 6-Pack capability analysis is also shown below,

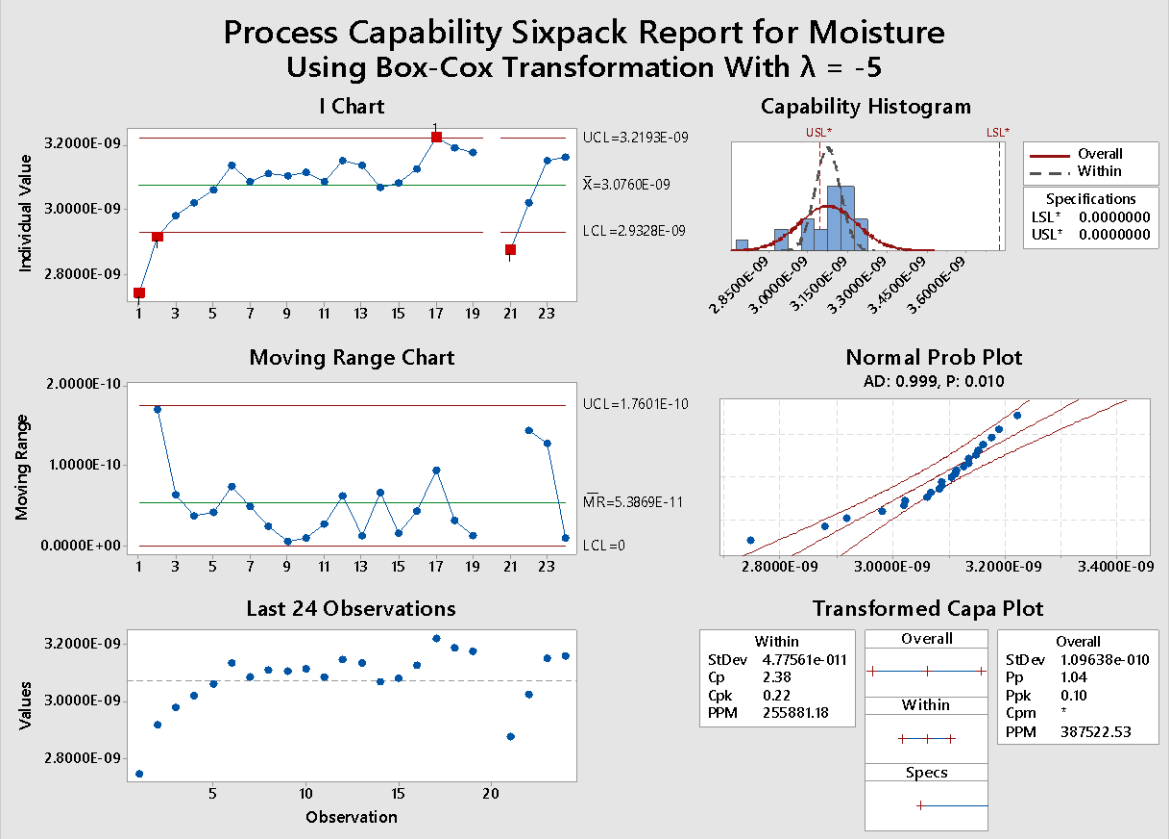


Figure 10 6 Pack

Thus, 26% defects are being produced out of DPMO.

Hypothesis Testing

Now, we will be brining big guns like Pearson correlation & regression to narrow down the number of factors. (As our both variables are continuous)

Pearson Correlation

Let us have a look at the P-value & Correlation strength among different factors. (With respect to Moisture only)

	Moisture
Mixed Juice M.T	-0.264
	0.223
Brix M.juice%	-0.505
	0.014
Steam LoadMill /	-0.043
	0.846
Imbibtion /hr M.	-0.571
	0.004
Sucrose content	-0.541
	0.008
Fiber % cane	-0.361
	0.091
Cane variety %	-0.168
	0.443
Crushing M.T	-0.235
	0.280
Diluction	0.137
	0.535
L.M.Jpol%	0.534
	0.009
Mill RPM	-0.230
	0.292

Figure 11 Correlation Coefficient

- Thus, on the basis of correlation coefficient & pvalue, following factors are narrowed down for analysis.(Brix Juice/ Imbibition/ Sucrose Content/ L.M.Jpol)
- One more factor (on the basis of Affinity diagram session, Mill RPM is also introduced).

Regression Analysis

Following the correlation, let us have a look how much variation is imparted by mapped out factors.

NOTE

In order to interpret the below figures, general norms of regression will be highlighted. Firstly, look at the %age of variation explained by the model (R-square adjusted) & the relationship factor between X & Y. If Rsquare adjusted value is high, than it means high variation is explained by a factor X and it is significantly impacting factor Y.

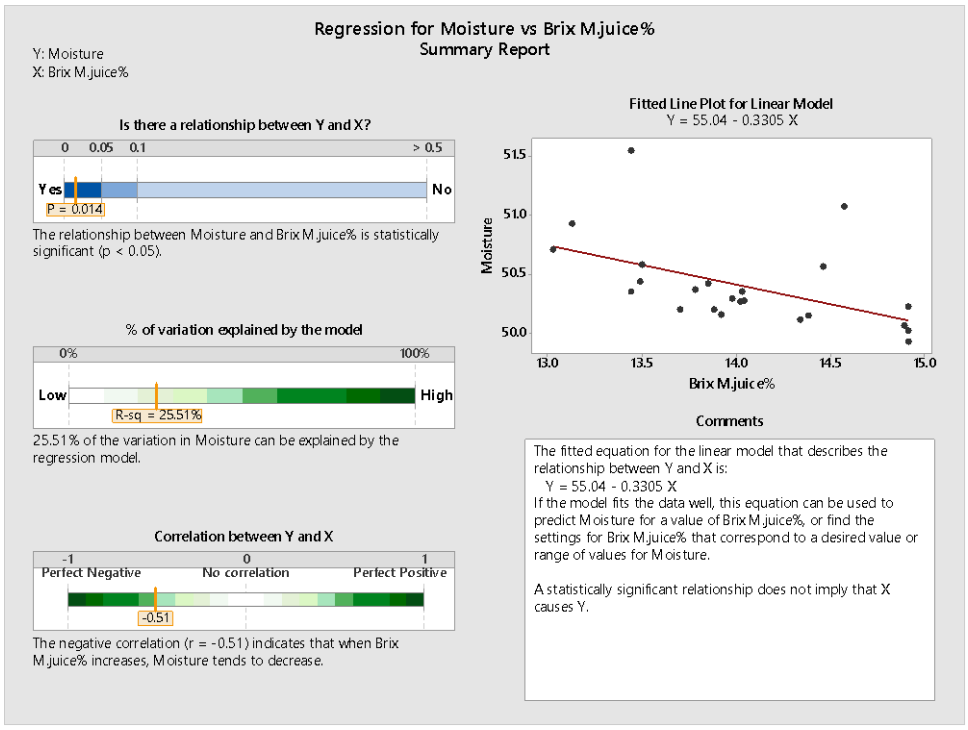


Figure 12 Brix Regression

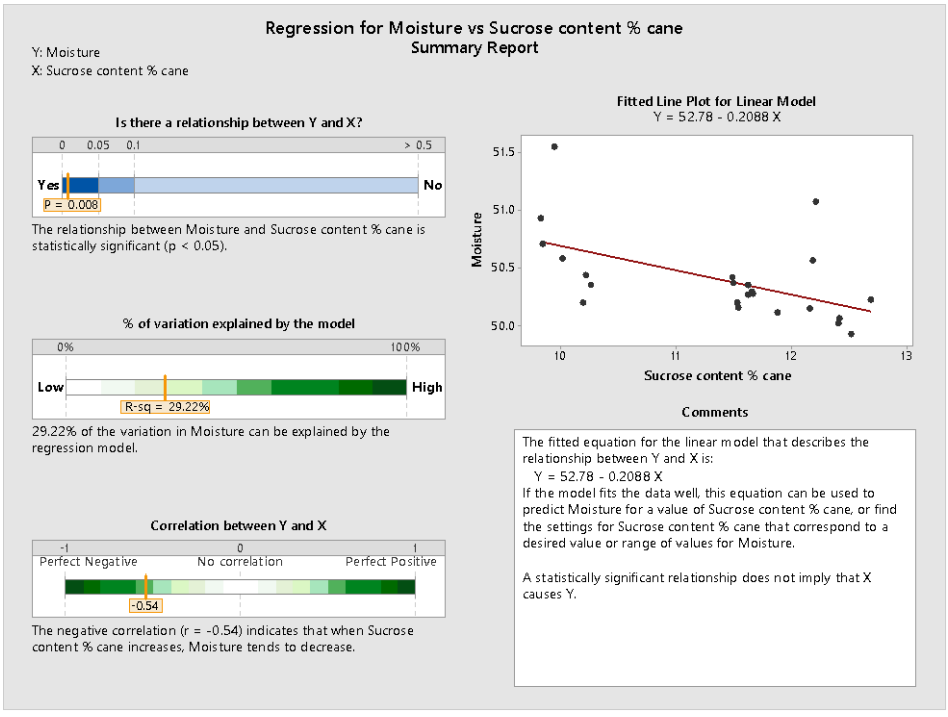


Figure 13 Sucrose Content Regression

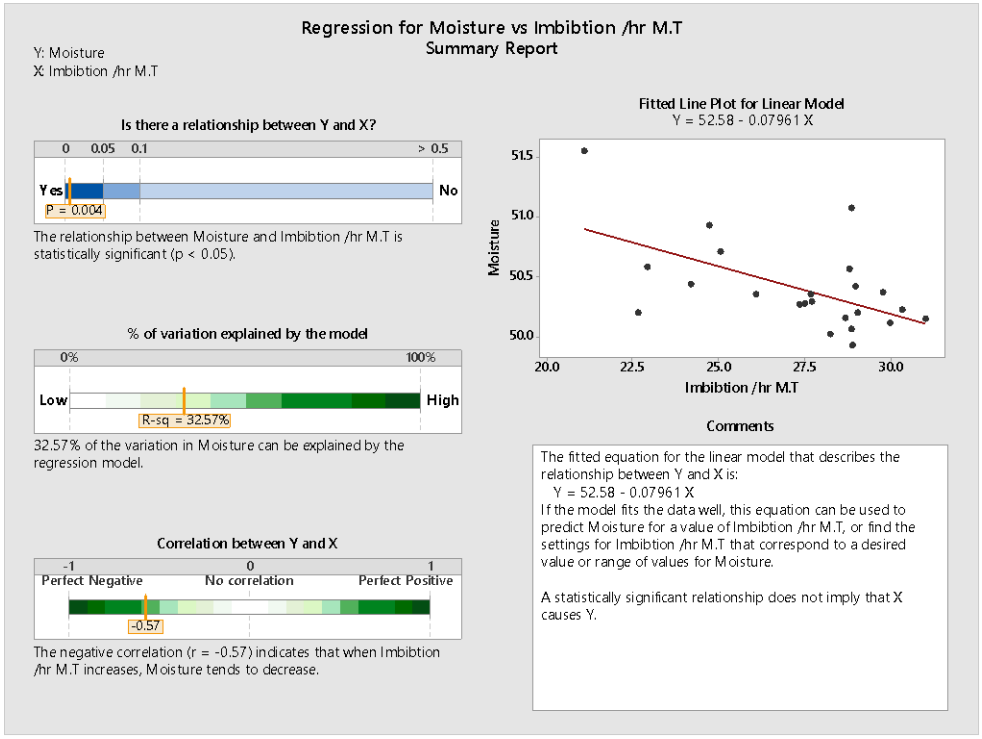


Figure 14 Imbibition Regression

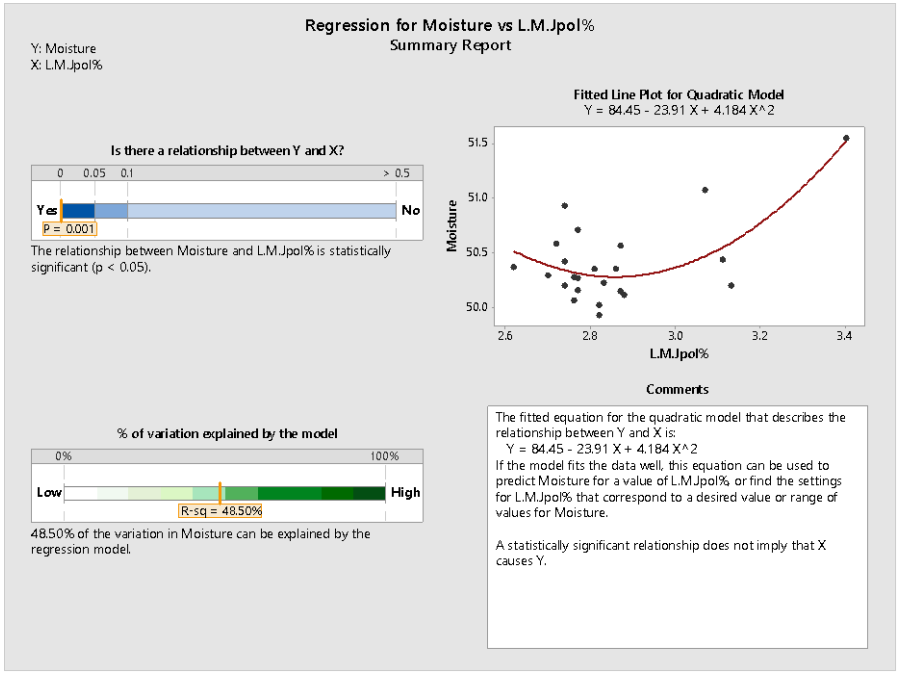


Figure 15 LM Poll Regression

An overall aggregated regression impact is,

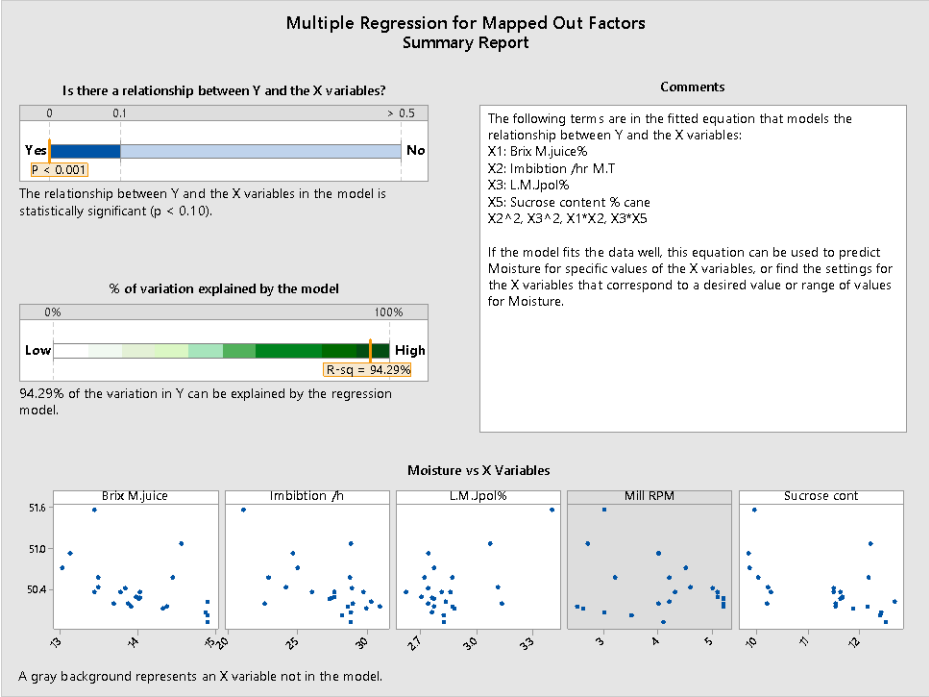


Figure 16 Overall Regression

Thus, as per R-sq. adjusted value, almost 95% variation is contributed by our mentioned factors. It means out of many brainstormed factors in previous ishikawa diagram, only these scrutinized factors are contributing to high level of moisture variation in the system. By improving or obtaining an optimal settings of these factors, variation level can be reduced to a higher context.

Improve Phase

AS per the convenience and easy to use methodology, RSO along contour plotting is used instead of DOE in improve phase.

The main objective is to **find an optimal settings for our factors.**

Response Surface Optimization

After confirming the factors impact, let us now look for an optimal setting of these factors by using RSO.

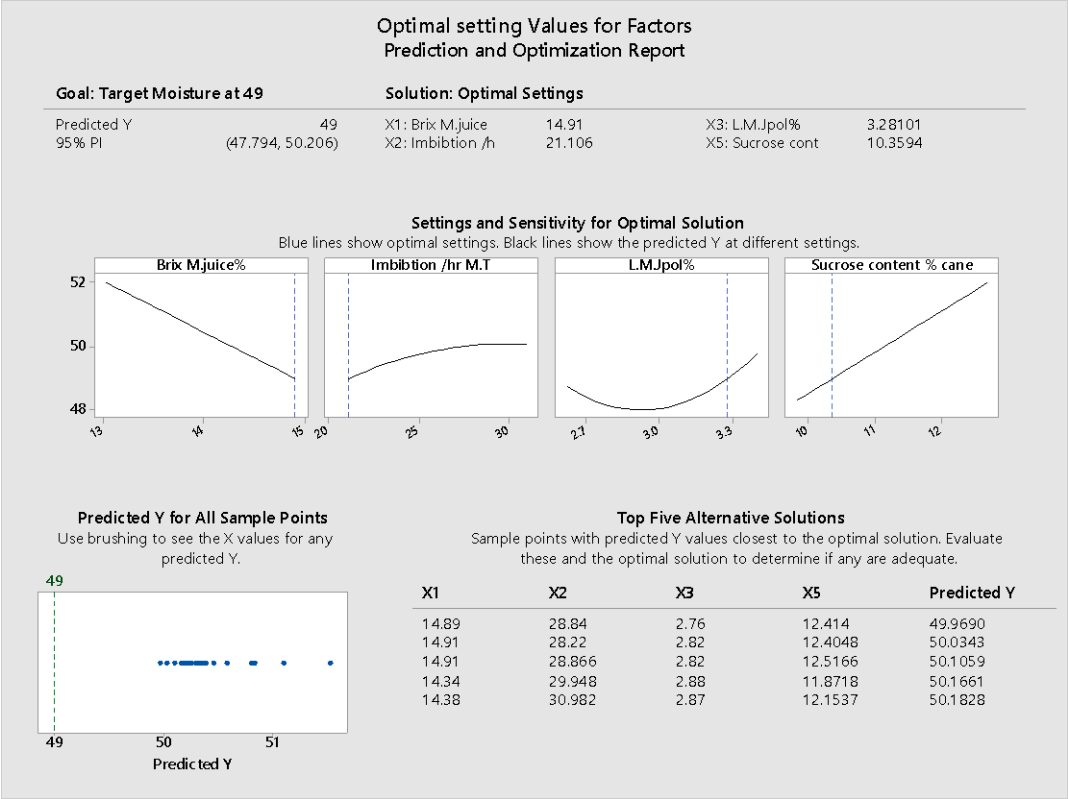


Figure 17 Optimal Settings

In the figure above, optimal settings have been generated which will surely result in the generation of minimum moisture. Let us have look at the contour plotting too (explaining, how factors behave at different values with each other)

Contour Plotting

The interpretation of these graphs is very general. Let us have a look at the figure below (and rest of the figures can be explained simultaneously)

It is clear from the figure below, that when brix level is around 14.8 and imbibition is around 22 than the moisture is minimum (Blue area). Similarly, when brix is around 13.2 & imbibition is around 23 or more than the moisture is increased (Green color)

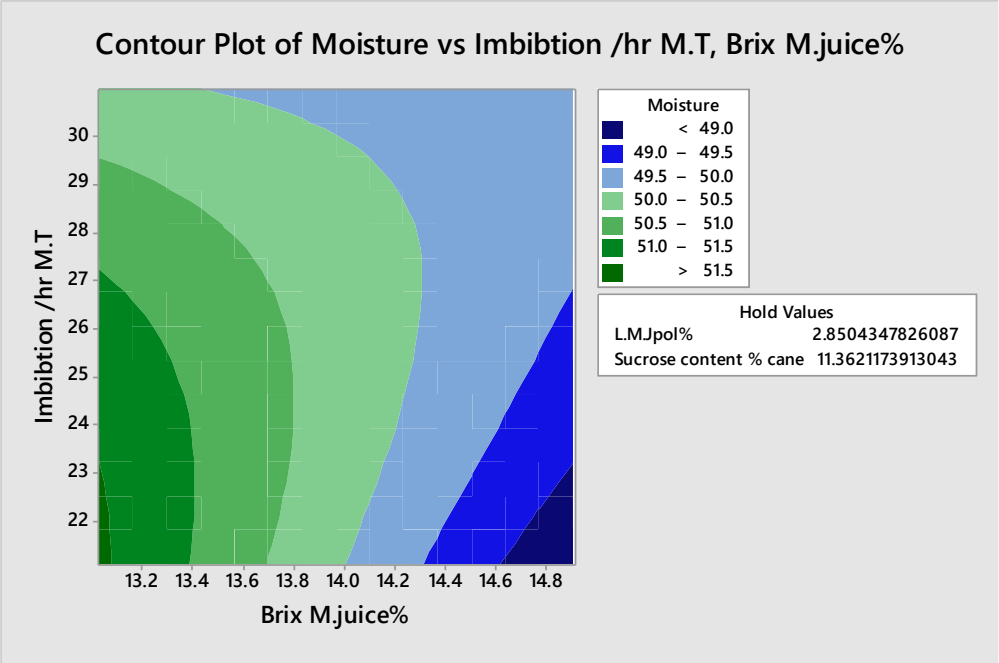


Figure 18 Contour 1

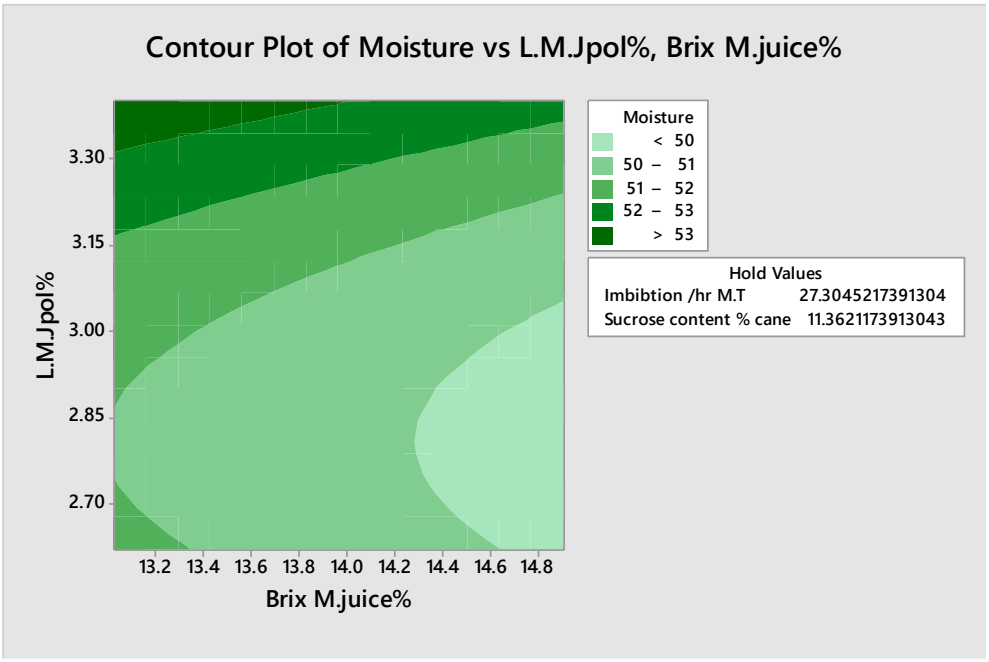


Figure 19 Contour 2

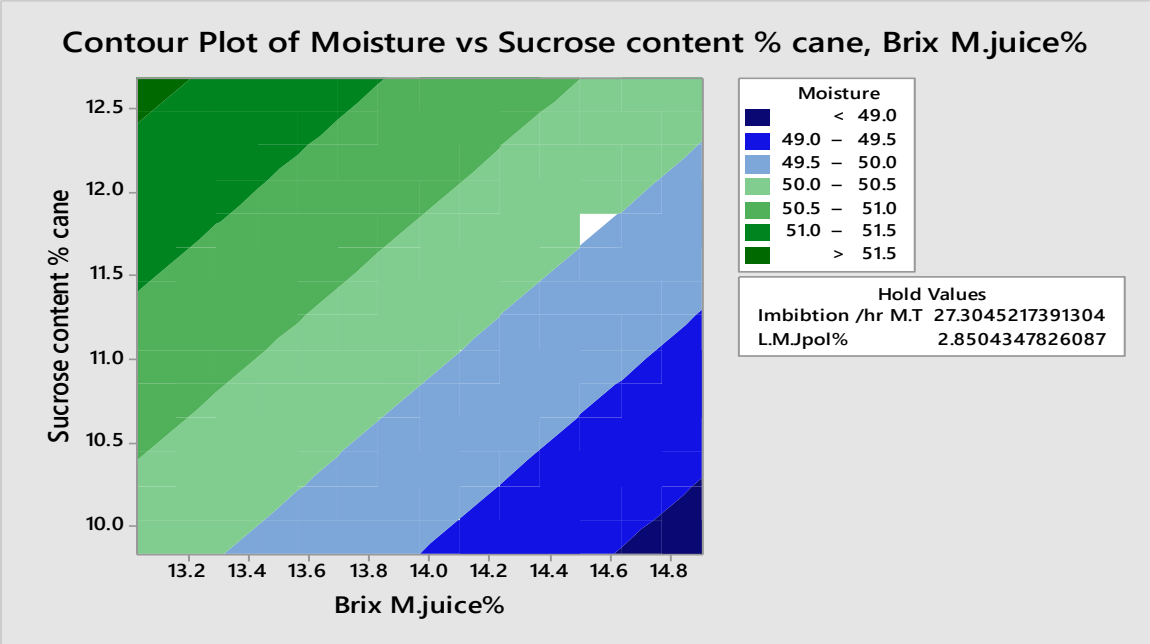


Figure 20 Contour 3

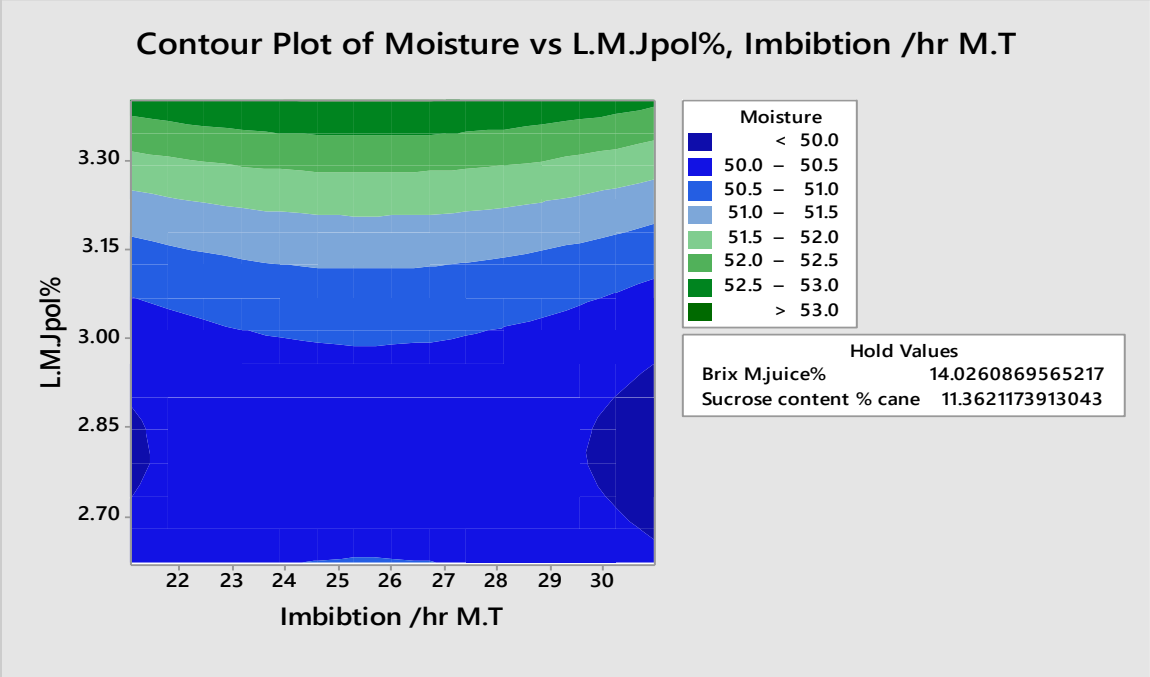


Figure 21 Contour 4

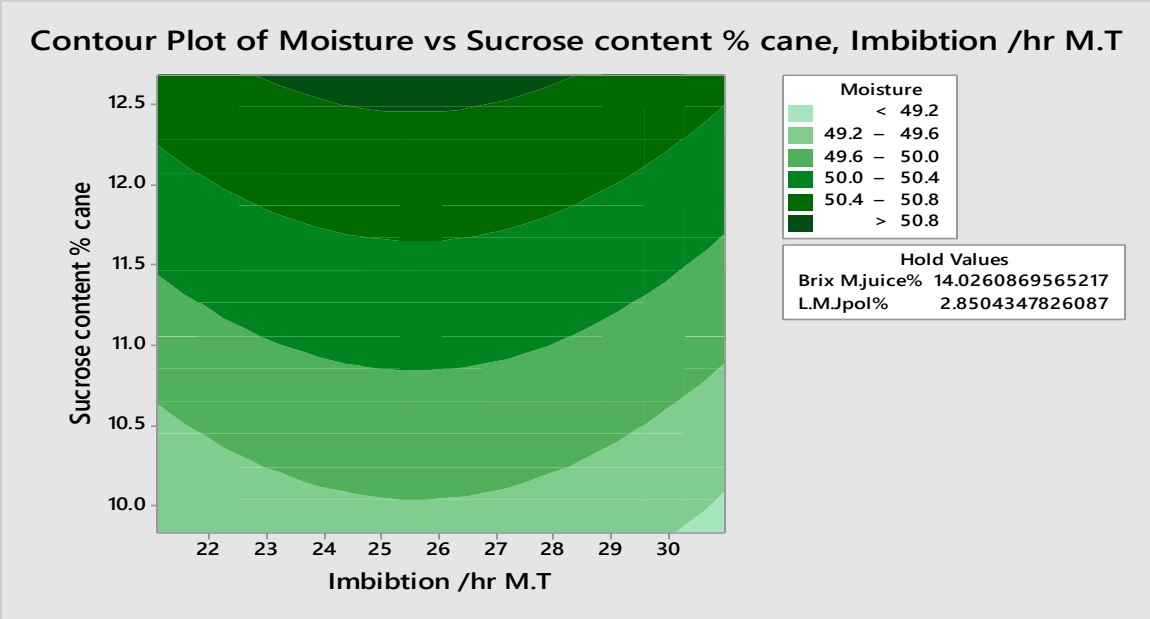


Figure 22Contour 5

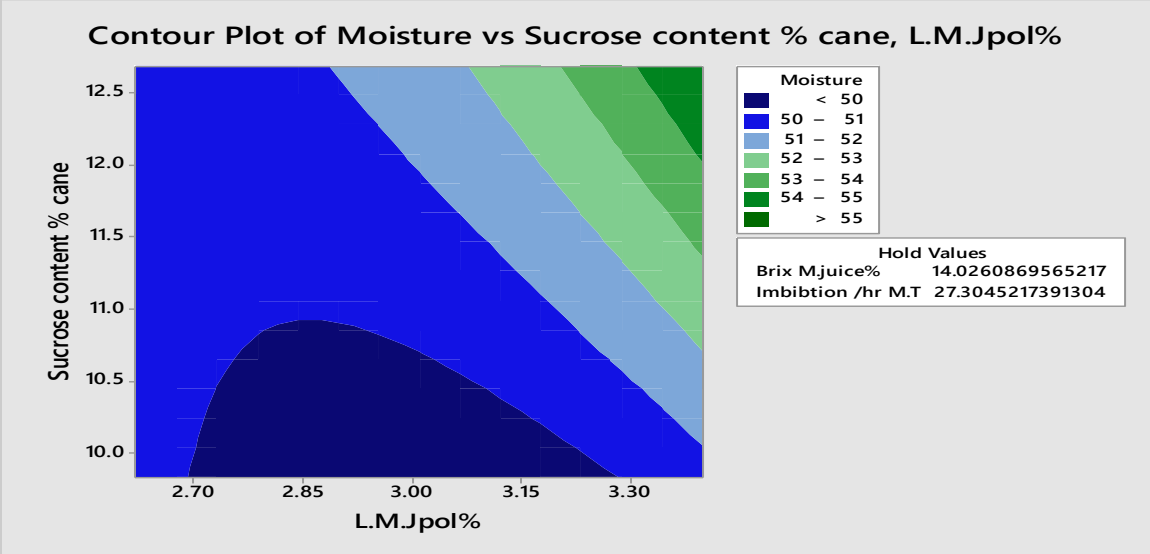


Figure 23Contour 6

Surface Plotting

Clear values can be seen (in relation) where moisture is low. (It is just an extension of contour plotting) and the main purpose is to see how other values behave when a subjected value is compared in values against them. Same pattern is being observed in pictures below as obtained n contour plotting.

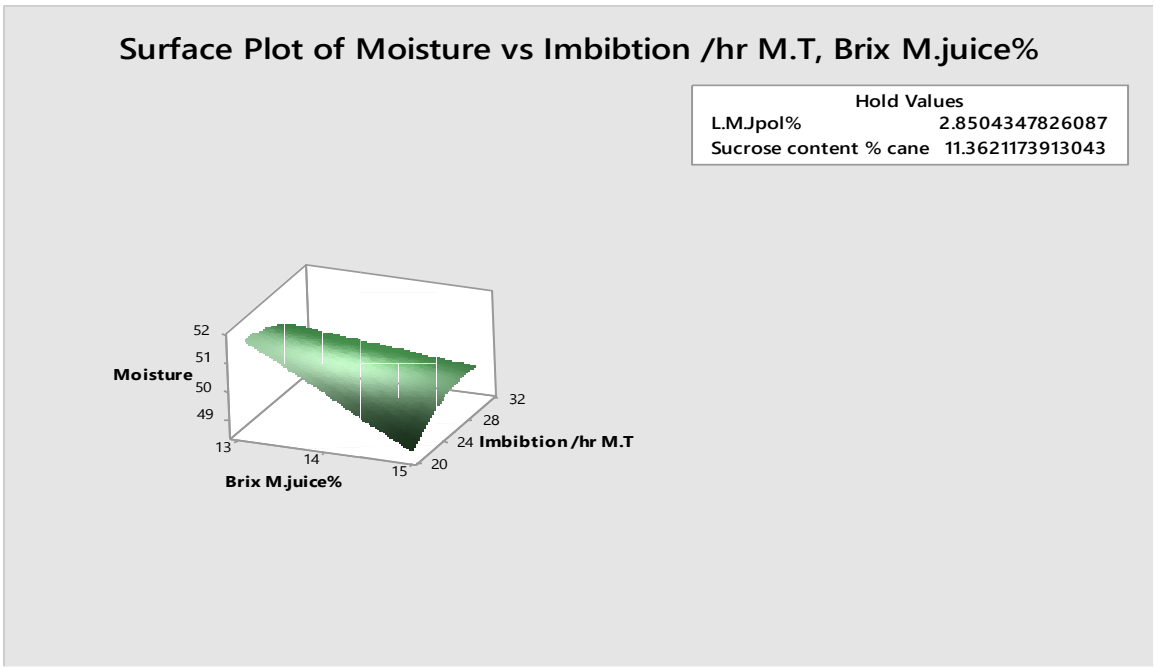


Figure 24 Plot 1

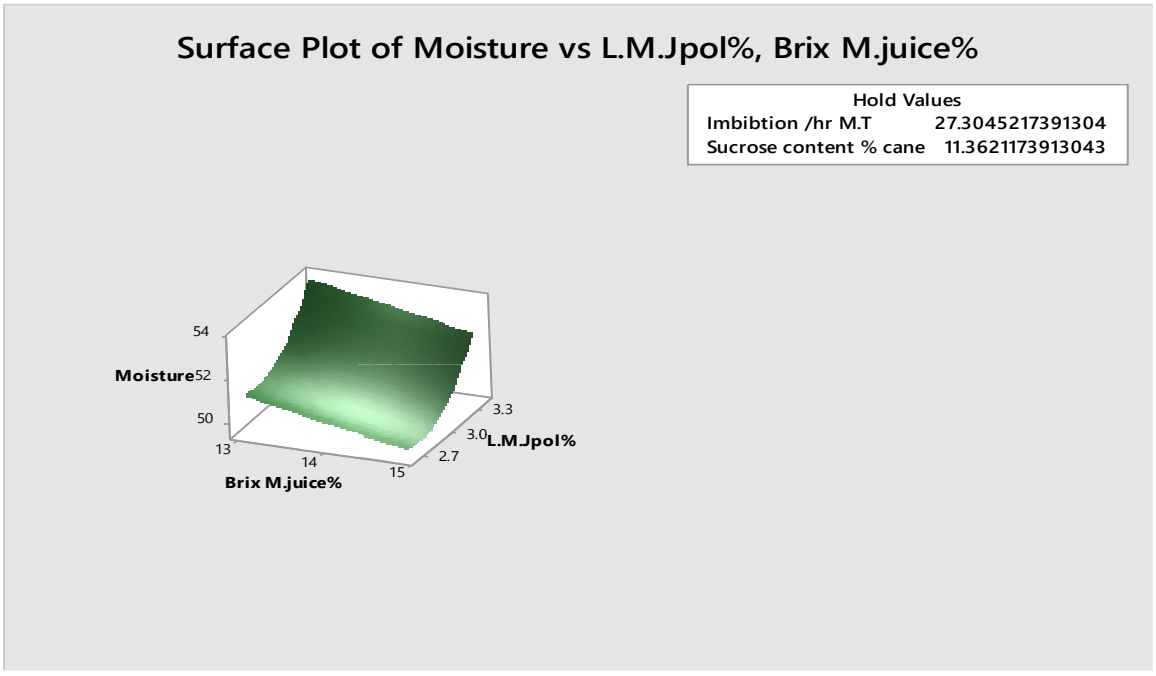


Figure 25 Plot 2

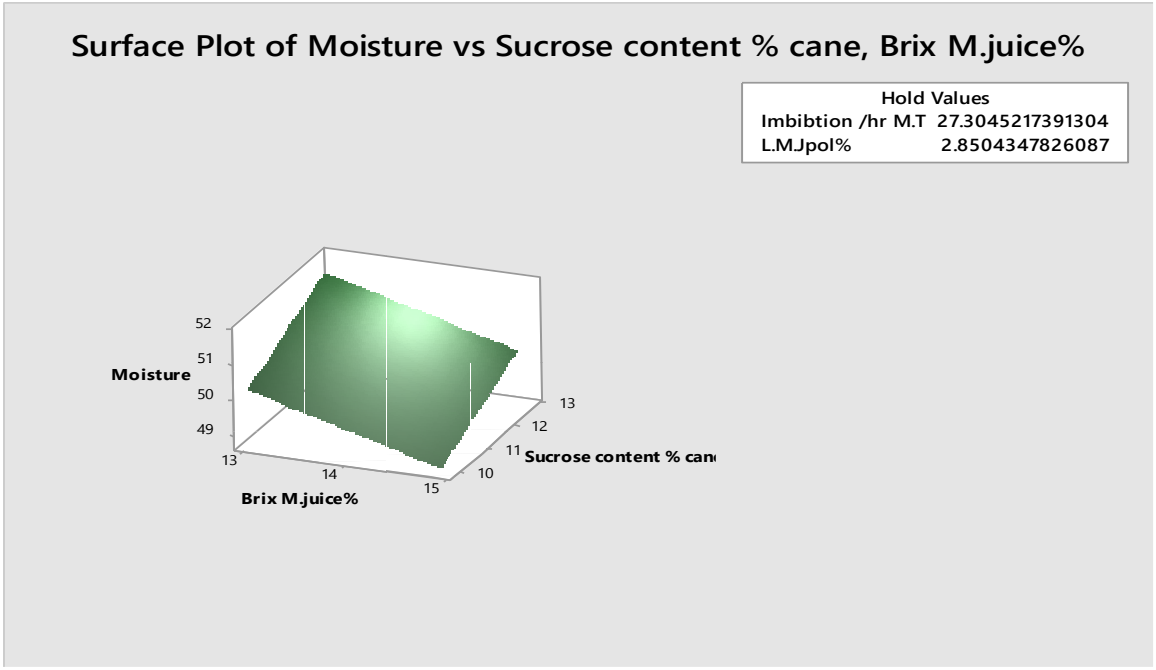


Figure 26 Plot 3

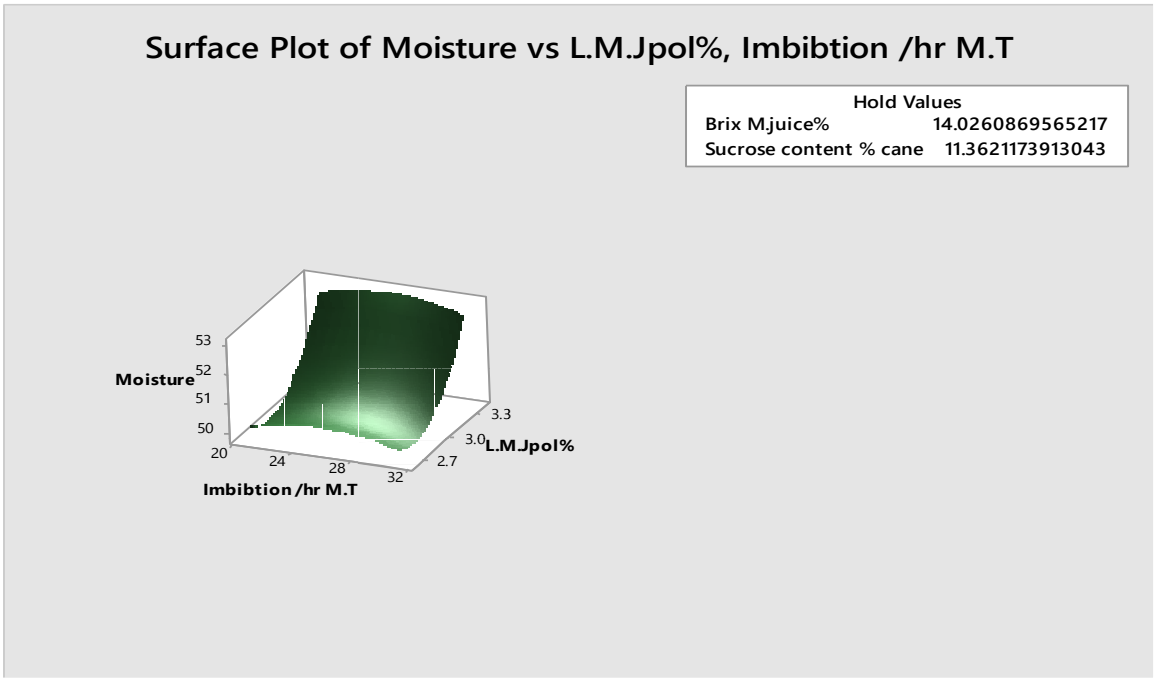


Figure 27 Plot 4

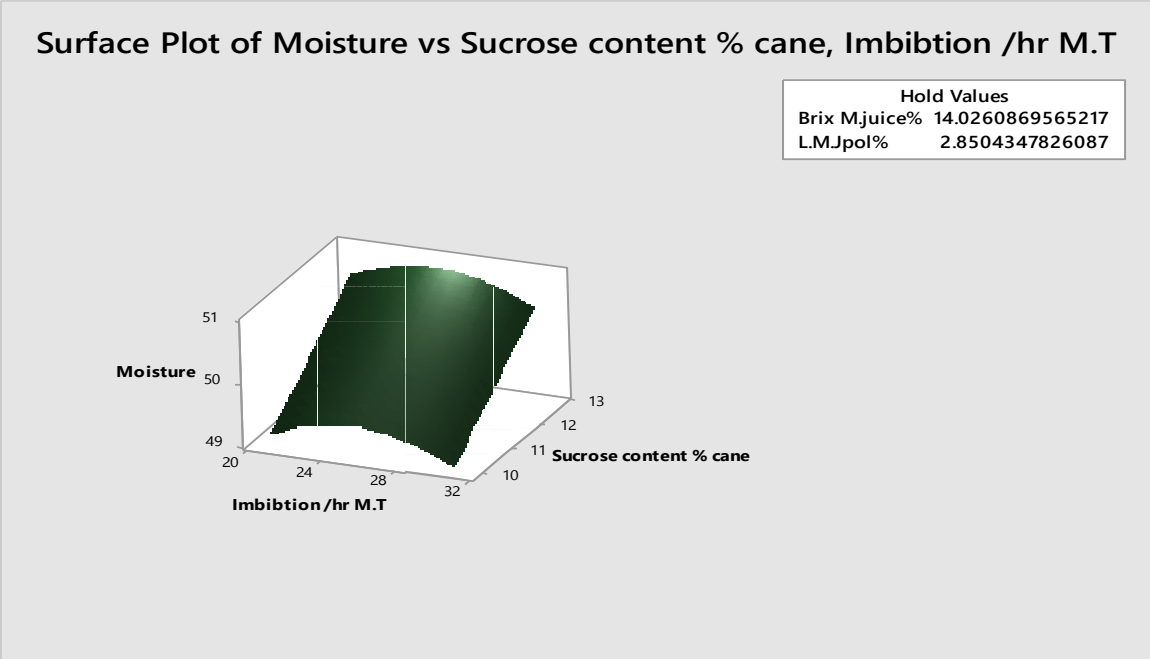


Figure 28 Plot 5

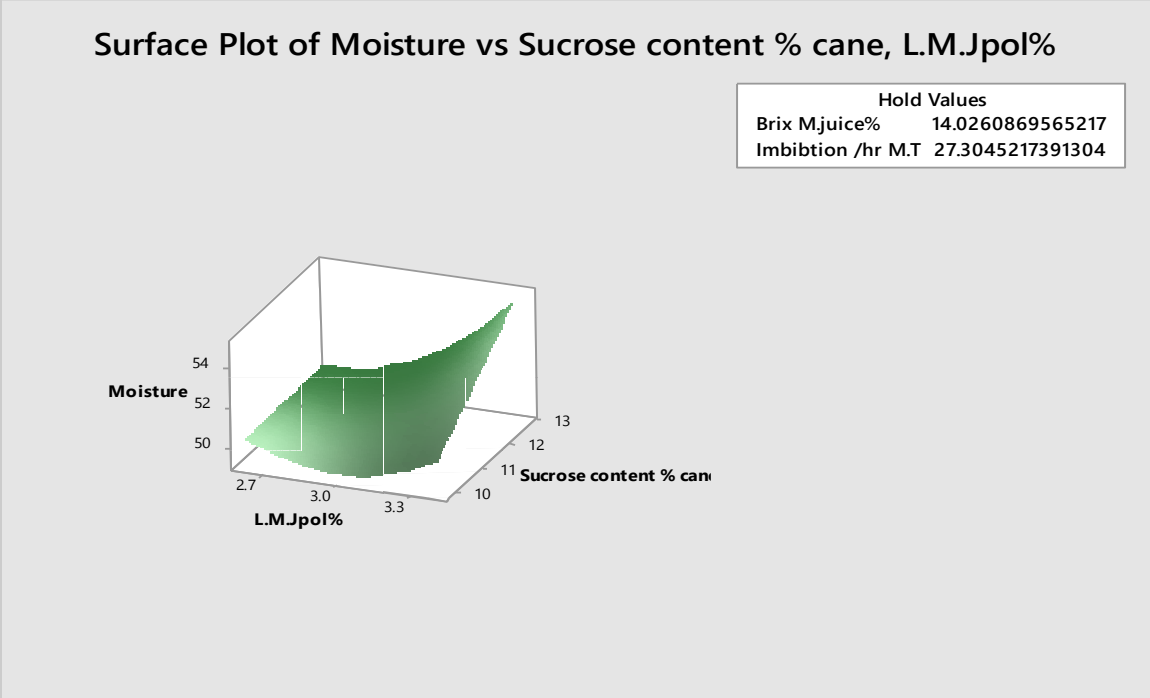
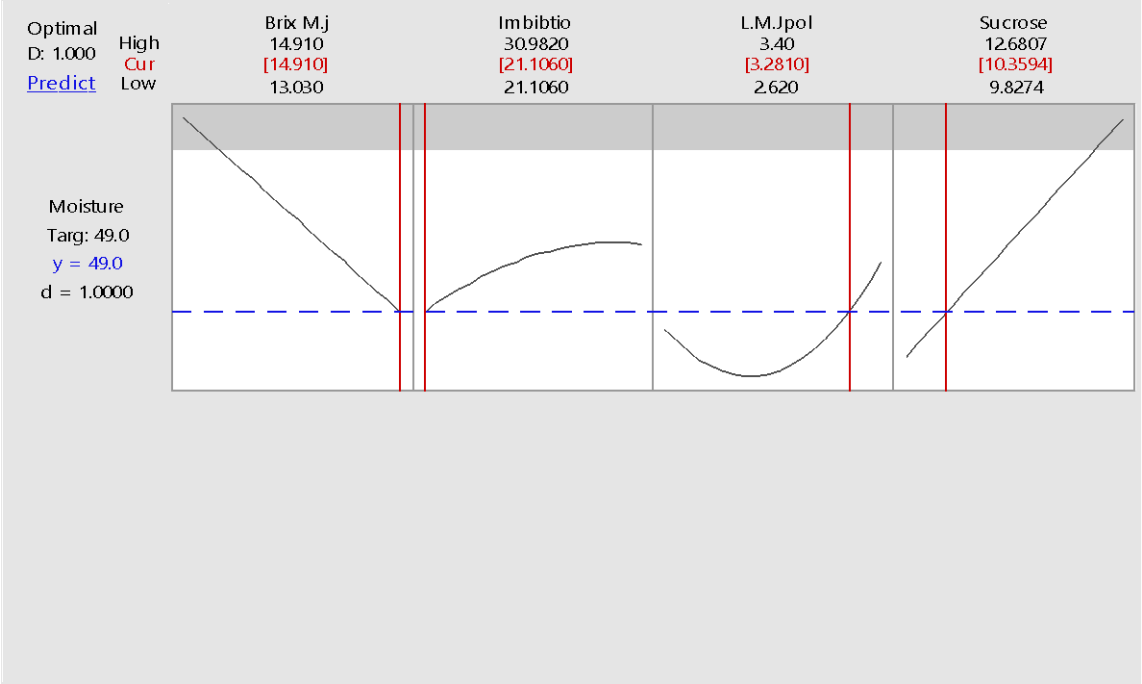


Figure 29 Plot 6

Thus optimal values obtained in (Response Surface Optimization) must be followed in order to get desired moisture level.

Figure 30 Resposne Surfcae Optimization



Response surface optimization is a bug gun, which is specially used to generate ethic X values against an Y target output (49). It is an advanced statistical tool of DOE in which direct values can be generated with an optimal settings of X factors.

Control Phase

In last phase, to sustain the improvement,

- **I-MR Chart** is introduced here with a subgroup size (1) i.e.: No rational subgrouping exists.
- Also, **dashboard** metrics comprising of **KPI'S** is established keeping the company's strategical objective in line
- **SOP revision** is done from the main hub of farmers (To grow better yield sugarcane increasing sucrose content) to a milling area floor (Optimal settings Compliance check)

Standard Operating procedure (General)

Table 4 SOP

	Department #	**SOP #**	
		Revision #	

BILAL CONSULTANCY INDUSTRIAL SOLUTIONS UNDER ONE ROOF		**Execution date**	
Page #		**Reviewed (LAST)**	
SOP		**Signed By**	

Purpose

- Describe the process along relevant background information.

Scope

- Identify the intended audience and /or activities where the SOP may be relevant, by mapping out the flowchart.

Prerequisites

- Outline information required before proceeding with the listed procedure; for example, worksheets.

Responsibilities

- Identify the personnel & their typical responsibilities by charting out the RACI matrix.

Procedure

- Provide the 5W's required to perform this procedure (who, what, when, where, why, how).

References

- List resources that may be useful when executing the generic task/

Definitions

- Identify and define frequently used terms in terms of dictionary context.

Conclusion

The project is carried to reinforce the importance of advanced techniques applications in continuous production process. As the sugar industry is comprise of may sophisticated processes & machinery, so blend of good technical knowledge along LSS expertise befalls a good fortune over a company. In this project Baggase poll moisture is targeted and all the subsequent acuities are than performed with the help of tools like Process Mapping, SIPOOC, Hypothesis testing, Regression analysis etc., which resulted in a net saving & enhanced the profit bottom line of sugar stature. Still there is a long way to go in terms of Continuous improvement as per futuristic disruptions. (Rizvi)

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Biography

Mr. Babar is an Industrial Engineer by profession and Lean Six Black Belt certified from **USA**. He is also a **certified** Business Consultant and has been involved in numerous training and optimization projects all over the Pakistan. He has **published** Research papers at many different prestigious forums. Despite being a young professional, he is making continuous strides in the business by being a practitioner of Blue Ocean Strategical mark. Mr. Babar Bilal has been associated with big names in an industry. His clients fall in Sugar, Textile, Hosiery, Education Institutes, Automotive, Oil & Gas domain. He is **currently** a member of American Society of Quality & **running** an operation management company aiming to enhance the productivity of organizations in a proficient manner by dealing in Business Process Excellence (Consultancy/Training), Engineering & infrastructure and IT technological domain. Also, he is a **co-founder** of Titans Institute (E-learning startup). His core **expertise/interests** includes Process excellence in industrial & **healthcare** sector, Six Sigma, LEAN, Blue Ocean Strategy, Business Benchmarking, Manufacturing, Simulation and Supply Chain Management.