

Reduce the Moisture of conditioned wheat

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ROADMAP



Overview



Define



Measure



Analyse



Improve



Control

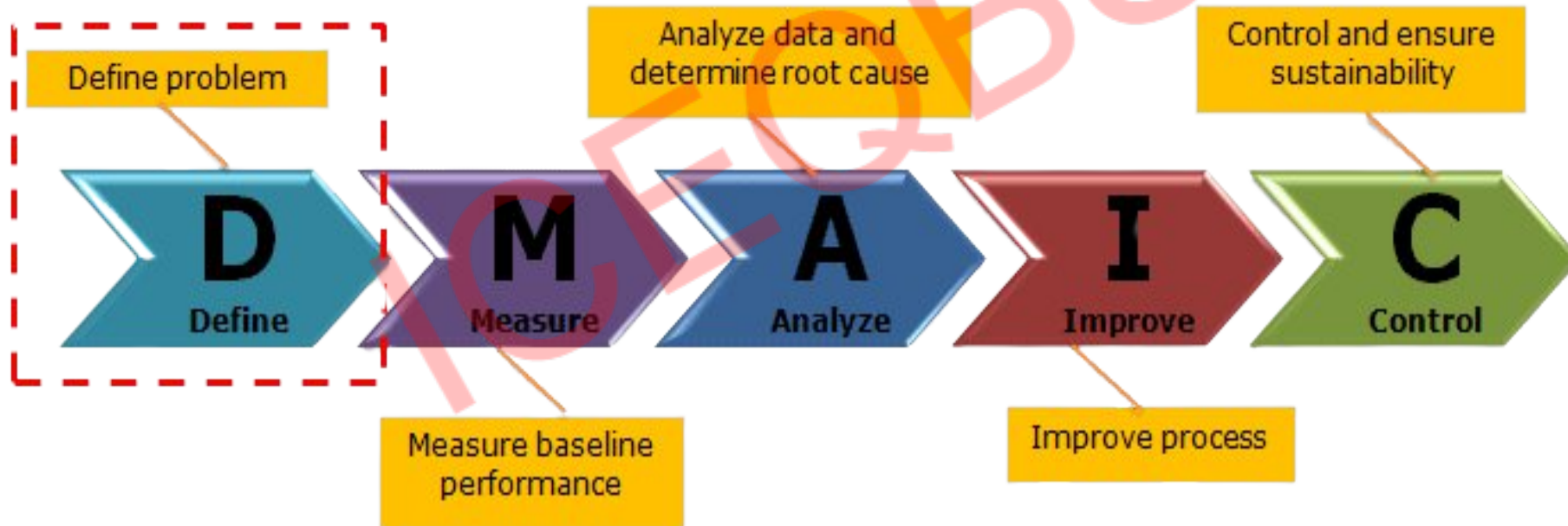
OVERVIEW



Background

The wheat conditioning (tempering) process currently exhibits high variability in moisture content, with an average Moisture Standard Deviation of about 14%, significantly above the target of $\leq 3.5\%$. This inconsistency leads to fluctuations in flour quality, reduced milling efficiency, and increased operational costs due to rework, wastage, and lower extraction rates. Stabilizing the tempering process is essential to ensure consistent moisture absorption, improve product quality, and enhance the reliability of downstream milling operations. By addressing this variation, the organization aims to strengthen customer confidence, reduce operational losses, and support its broader objective of improving production efficiency and cost competitiveness.

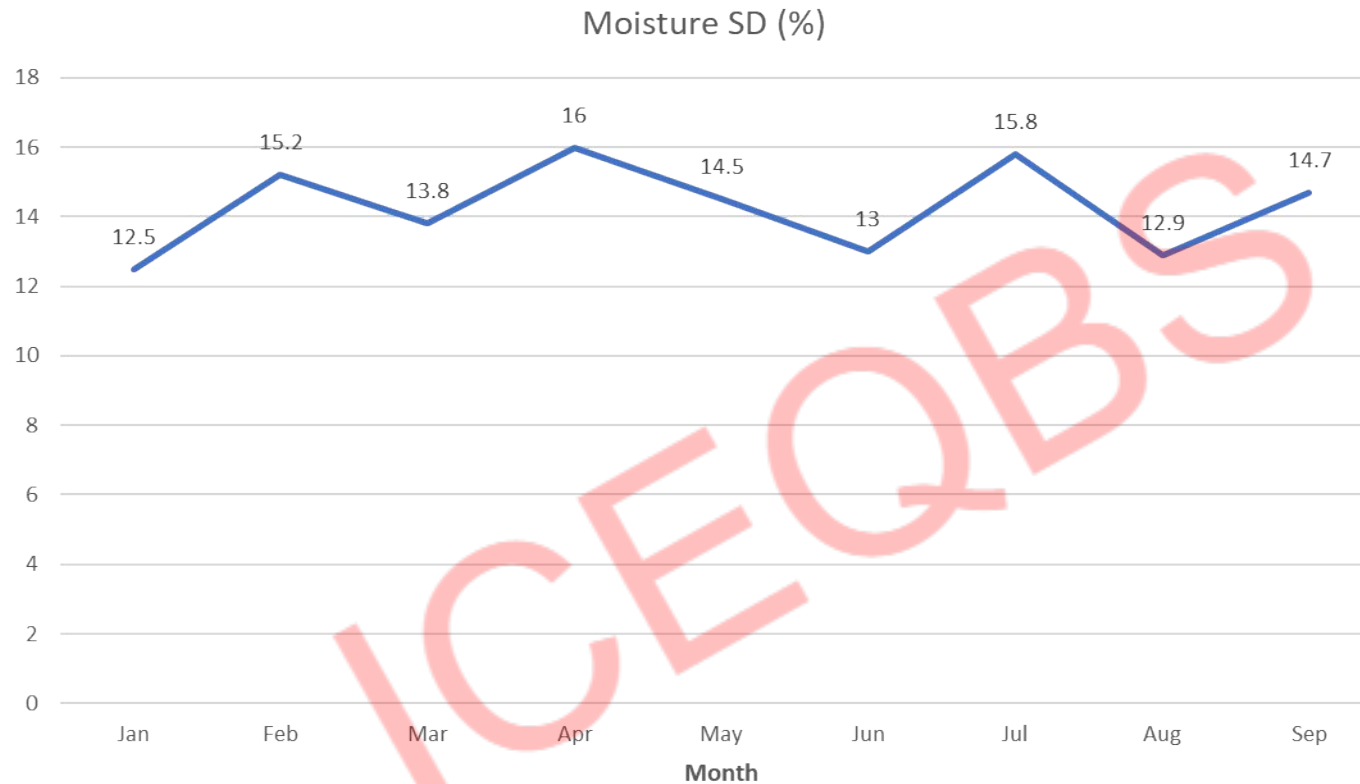
DEFINE PHASE



CTQ Tree :

Voice of customer	Critical to X	Primary Metric for improvement
<i>“Ensure consistent wheat moisture after tempering for stable flour quality</i>	CTC – Cost	Primary Metric - Y = Moisture Standard Deviation (%) Secondary Metric - Average Moisture Content (%)

Baseline Performance of Primary Metric (9 months data as Line chart)



Inference :

- Last 9 months data shows a significant variation and hence ideal problem to be taken up as a Six Sigma Project.

SIPOC

Suppliers (S)	Inputs (I)	Process (P)	Outputs (O)	Customers (C)
Wheat farmers / suppliers	Wheat	1. Receive wheat	Conditioned wheat with target moisture	Milling section
Water supplier	Water	2. Measure incoming wheat moisture	Moisture consistency report	Quality Control department
Maintenance team	Equipment (tempering tanks, mixers)	3. Add water according to process	Reduced moisture SD (%)	Downstream production lines
Production planners	SOPs, guidelines	4. Temper wheat (controlled time & mixing)	Uniformly tempered wheat	End customers (flour buyers)
QC / Lab	Temperature & humidity data	5. Monitor and record moisture	Process improvement data	Internal management team
Operators	Energy / power	6. Adjust process based on feedback	Standard operating procedure for consistent tempering	Plant operations team

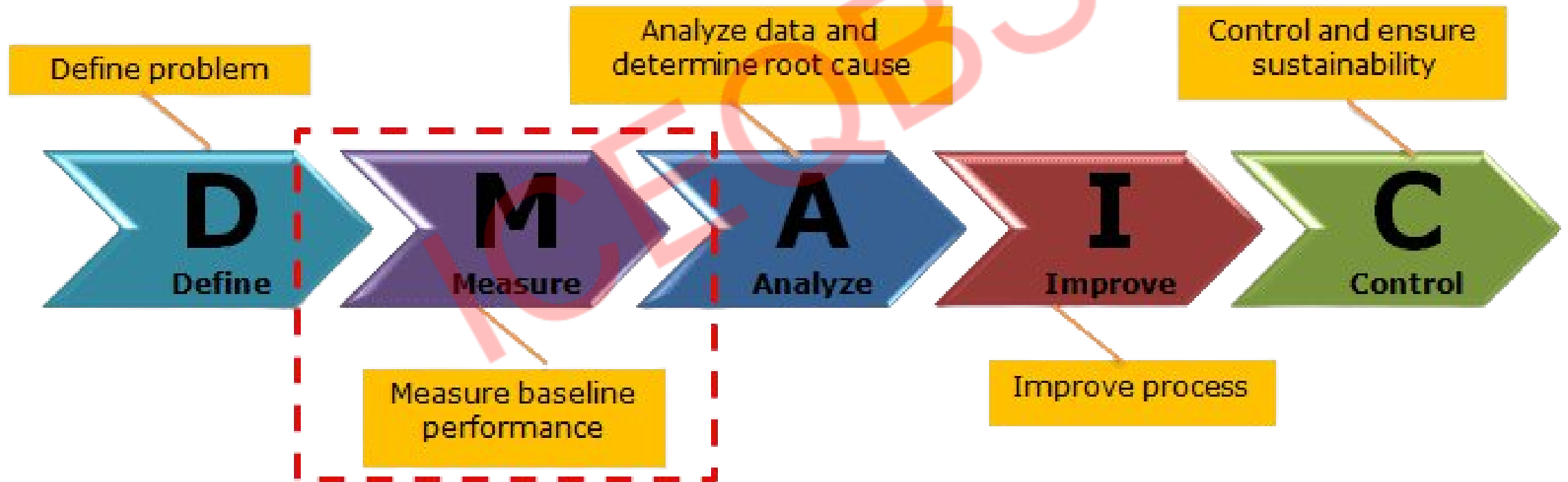
Project Charter

Project Title:		Reduce the Moisture of conditioned wheat		
Project Leader		Project Team Members:		
Manish Inamdar		Mark Patel Priya Kumar David Chen		
Champion/Sponsors:		Key Stake Holders		
John Smith		Milling Department Quality Control Lab Process Control Team End Consumers		
Problem Statement:		Goal Statement:		
The wheat conditioning (tempering) process exhibits high variability in moisture content, with an average Moisture Standard Deviation of 14%, far exceeding the target of $\leq 3.5\%$. This inconsistency leads to variable flour quality, reduced milling efficiency, and increased operational costs.		Reduce the Moisture Standard Deviation of conditioned wheat from an average of 14% to $\leq 3.5\%$ within 6 months, ensuring consistent product quality, improved milling efficiency, and reduced process variability		
Secondary Metric		Assumptions Made:		
Average Moisture Content (%)		Moisture measuring instruments are accurate. Wheat quality remains generally consistent. Required production/quality support is available.		

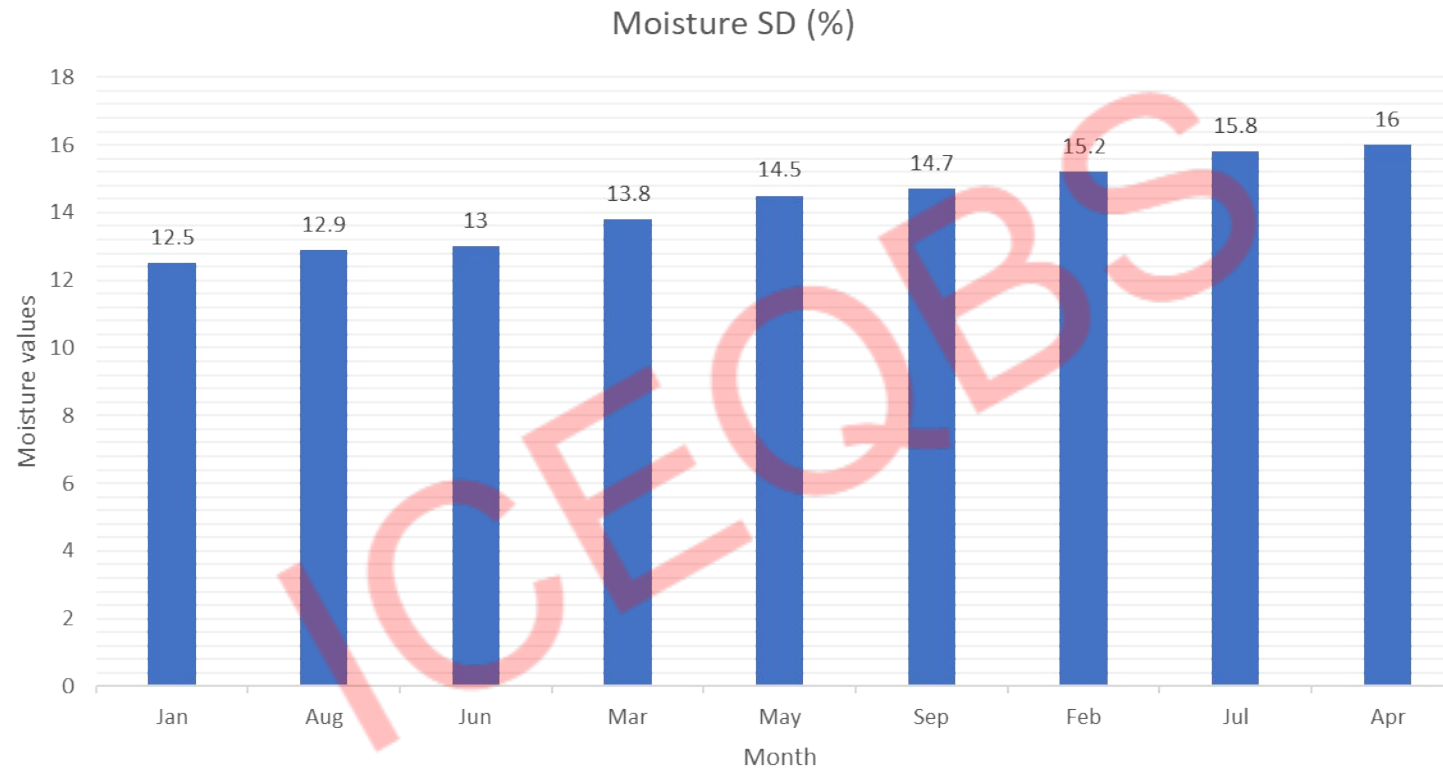
Project Charter

Tangible and Intangible Benefits:		Risk to Success:	
Lower rework/wastage, better extraction rates. Estimated savings: \$150,000/year . More consistent flour quality and customer trust. Improved process control and team collaboration		Raw wheat variability affecting moisture control. Operator non-compliance with revised SOPs. Equipment limitations or upgrade delays.	
In Scope:		Out of Scope:	
Wheat tempering process and moisture control. Parameter optimization and operator training.		Milling steps beyond tempering. Supplier or sourcing changes.	
Signatories:		Project Timeline:	
Project Sponsor : John Smith Maintenance –Head Finance Executive			

MEASURE PHASE



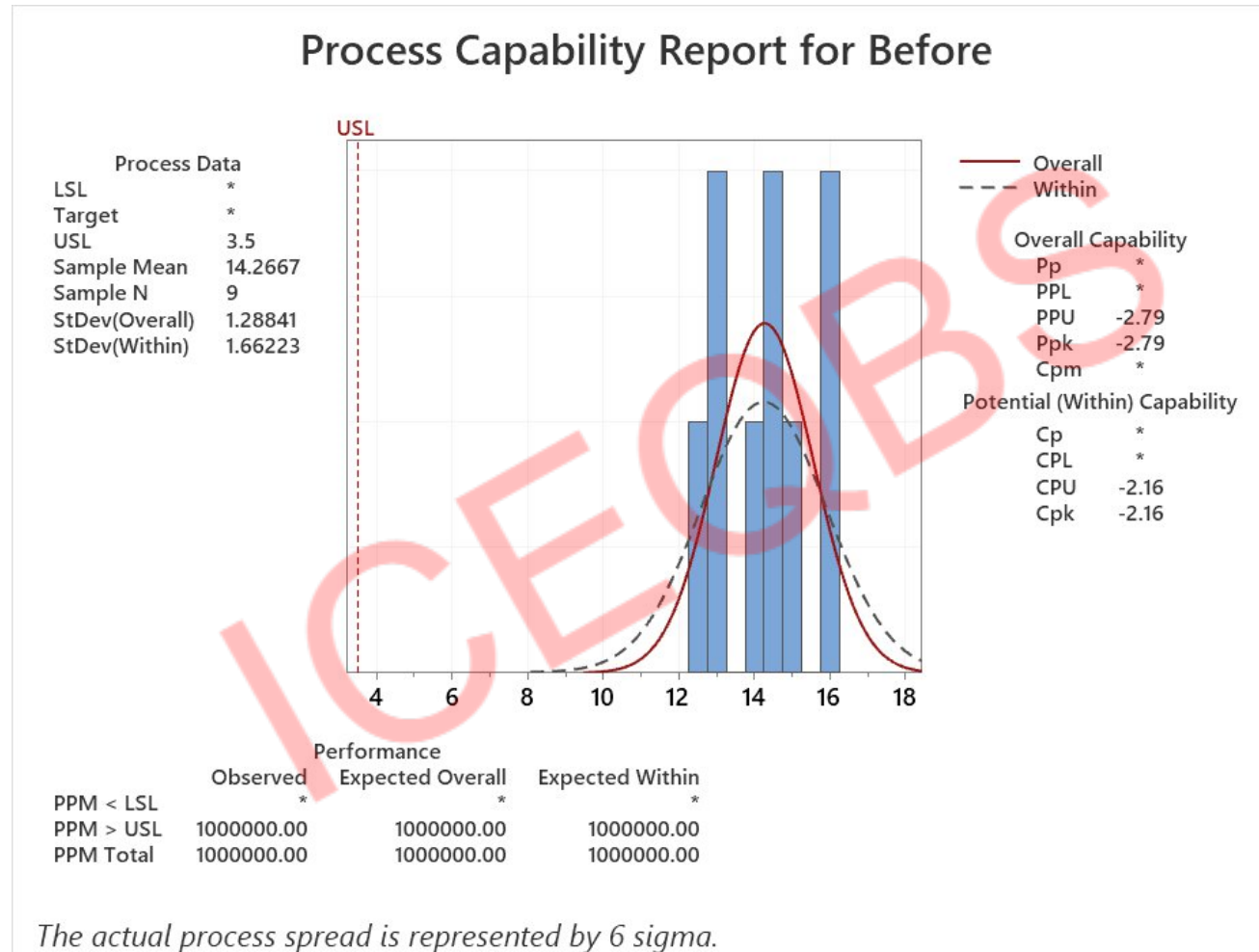
Data collection – Normality plot (Before improvement)



Inference :

- Moisture variation shows a consistent upward trend across months, indicating increasing instability in the process.

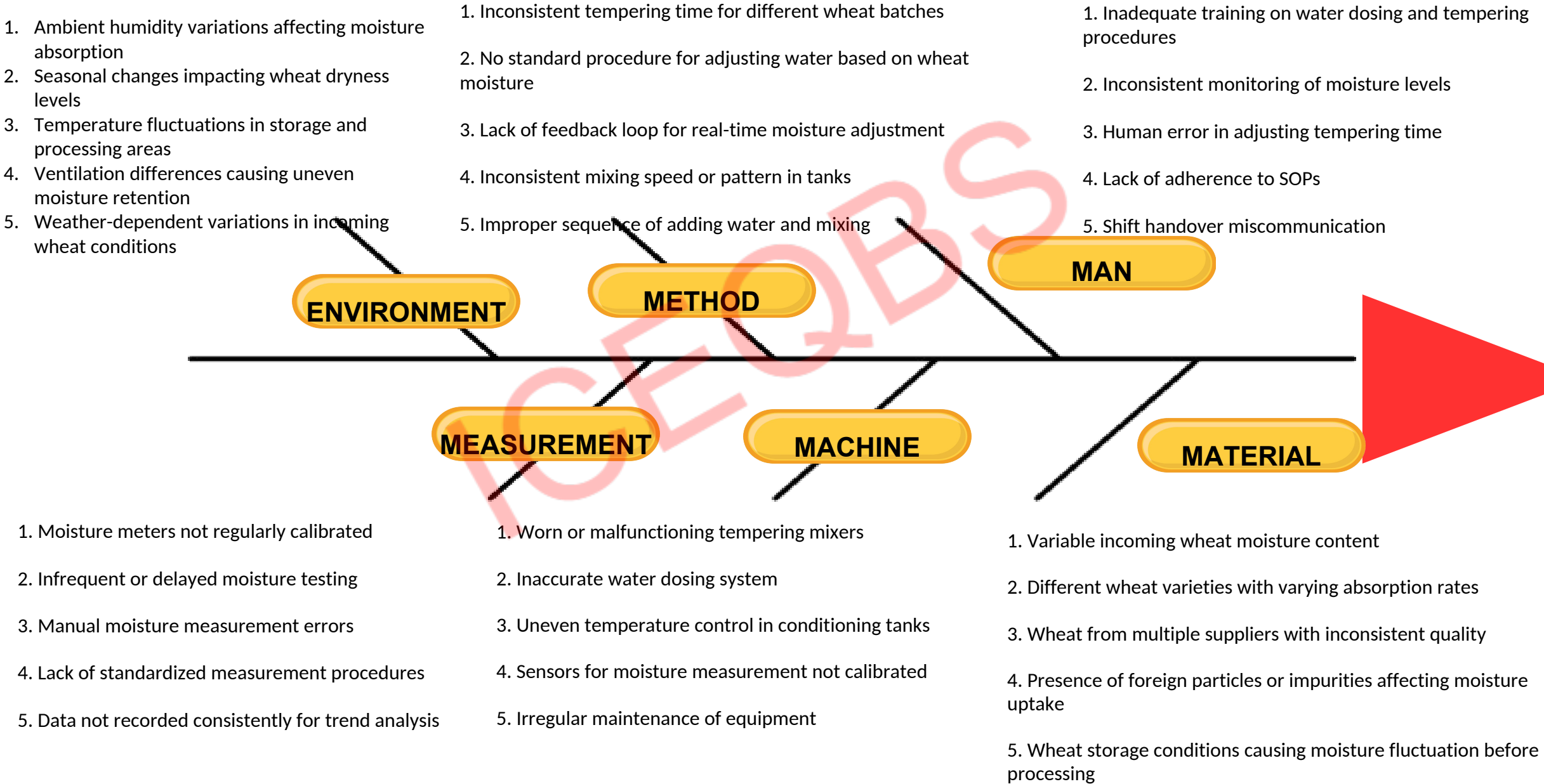
Data collection – Run Chart (Before improvement)



Inference :

The process is not capable, with all outputs beyond the USL and a negative Cpk.

Fish Bone Diagram



Common Causes & Special Causes

Common Causes

- Inconsistent tempering time for different wheat batches (Method)
- Variable incoming wheat moisture content (Material)
- Different wheat varieties with varying absorption rates (Material)
- Shift handover miscommunication (Man)
- Lack of standardized measurement procedures (Measurement)
- Infrequent or delayed moisture testing (Measurement)
- Lack of feedback loop for real-time moisture adjustment (Method)
- Improper sequence of adding water and mixing (Method)
- Operators' inconsistent monitoring of moisture levels (Man)

Special Causes

- Worn or malfunctioning tempering mixers (Machine)
- Inaccurate water dosing system (Machine)
- Sensors for moisture measurement not calibrated (Machine)
- Presence of foreign particles or impurities affecting moisture uptake (Material)
- Human error in adjusting tempering time (Man)
- Wheat storage conditions causing moisture fluctuation before processing (Material)
- Lack of adherence to SOPs (Man)
- Manual moisture measurement errors (Measurement)
- Irregular maintenance of equipment (Machine)

3M Analysis for Waste

MUDA

- Overuse of water beyond required moisture levels → increases drying time later
- Rework due to inconsistent moisture levels in wheat batches
- Excess energy consumption from running mixers or tempering tanks longer than necessary

Mura

- Fluctuating tempering time across different wheat lots
- Variable water addition due to inconsistent dosing by operators
- Inconsistent wheat moisture in incoming raw material batches

Muri

- Operators manually adjusting multiple tanks simultaneously, leading to fatigue
- Equipment operating beyond designed capacity to handle large batches
- Frequent corrective maintenance due to excessive wear on mixers and sensors

8 Wastes Analysis

Defects

- Batches rejected due to uneven moisture distribution
- Rework required to correct tempering inconsistencies

Overproduction

- Conditioning more wheat than required in a batch, creating excess
- Producing wheat with higher moisture than needed, requiring additional drying

Waiting

- Wheat waiting in tanks for long periods due to uneven processing schedules
- Delays caused by waiting for moisture measurement results before next batch

Non-Utilized Talent

- Operators not trained to use automated water dosing systems effectively
- Ignoring insights from QC analysts to optimize tempering process

Transportation

- Moving wheat multiple times between storage and tempering tanks unnecessarily
- Transporting water or chemicals long distances within the plant

Inventory

- Excess wheat stored in tanks leading to moisture variation
- Overstocking raw materials causing quality degradation

Motion

- Operators walking long distances to check multiple tempering tanks
- Reaching or bending repeatedly to manually adjust valves or water dosing

Overprocessing

- Excessive mixing beyond optimal tempering time
- Re-checking or re-adjusting moisture multiple times due to poor measurement

Action Plan for Low Hanging Fruits

Focus Area	Issue / Observation (from Gemba Walk)	Proposed Action	Lean Tool	Expected Benefit / Low-Hanging Fruit
Special Cause: Machine	Worn or malfunctioning mixers	Schedule preventive maintenance and check mixer blades	5S / TPM	Reduce variation, avoid breakdowns
Special Cause: Machine	Inaccurate water dosing system	Calibrate water dosing pumps	Kaizen / Standard Work	Improve moisture consistency
Special Cause: Measurement	Sensors not calibrated	Implement sensor calibration checklist	Standard Work / Poka-Yoke	Accurate real-time moisture measurement
3M – Man	Human errors in adjusting tempering time	Conduct short training on SOPs and monitoring	5S / Standard Work	Reduce errors, improve consistency
3M – Method	Inconsistent mixing and water addition sequence	Standardize process sequence in SOP	Standard Work / Visual Work Instructions	Reduce variability
3M – Material	Variable wheat moisture	Implement quick moisture check at intake	Poka-Yoke / Visual Controls	Reduce upstream variation impact

Action Plan for Low Hanging Fruits

Waste	Lean Tool	Action Plan	Benefit
Waste – Transportation	5S / Workplace Organization	Reorganize tank layout	Save operator time
Waste – Inventory	Just-In-Time	Reduce moisture variation & storage issues	Reduce moisture variation & storage issues
Waste – Motion	5S / Ergonomics	Save operator effort & time	Save operator effort & time
Waste – Waiting	Poka-Yoke / Visual Management	Faster decision-making	Faster decision-making
Waste – Overproduction	Kanban / Pull System	Reduce rework & energy	Reduce rework & energy
Waste – Overprocessing	Standard Work	Reduce operator effort	Reduce operator effort
Waste – Defects	Visual Management / Control Charts	Reduce rework	Reduce rework
Waste – Skills	Standard Work / 5S	Better utilization of talent	Better utilization of talent

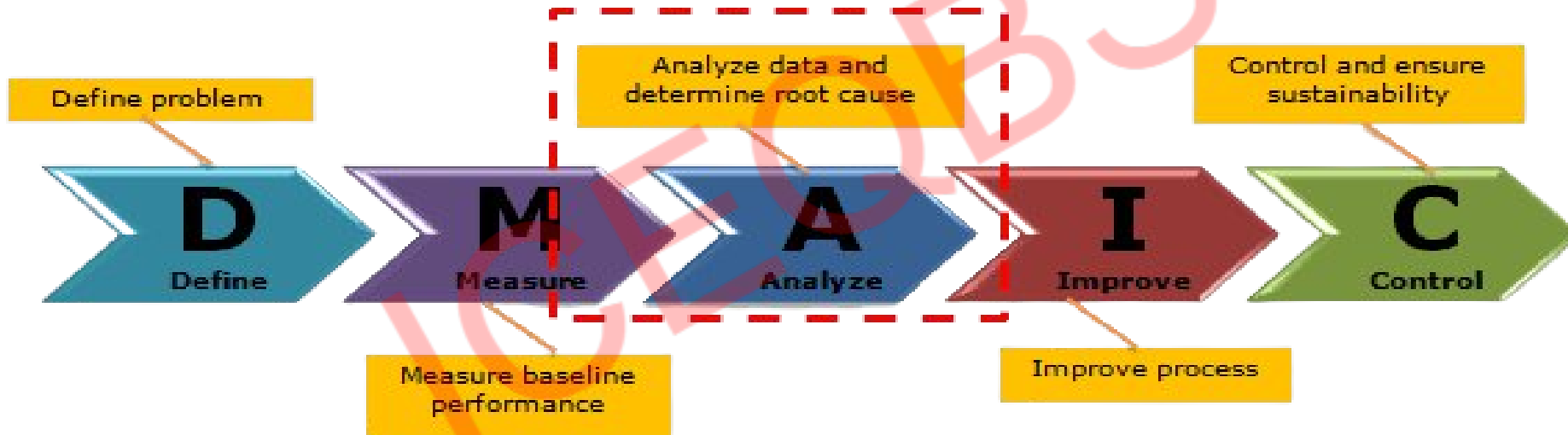
Top 12 Prioritized Root Causes (Based on Net Score)

Root Cause	Score
Tempering tank mixing efficiency	204
Water dosing calibration	183
Operator skill & training	158
SOP adherence	153
Measurement frequency	153
Moisture sensor calibration	141
Equipment wear & tear	138
Wheat lot variability	129
Water temperature control	108
Shift handover communication	93

Data Collection Plan

S. No.	Input / Root Cause	Data to be Collected	Measurement Method / Tool	Frequency / Sample Size	Data Source / Location
1	Tempering tank mixing efficiency	Mixing speed, batch mixing uniformity	Tachometer / Visual inspection / Timer	Every batch, 3 readings per batch	Tempering tanks
2	Water dosing calibration	Water flow rate, volume added per ton	Flow meter / Calibration checklist	Every batch / per shift	Water dosing system
3	Operator skill & training	Adherence to SOPs, correct sequence of steps	Observation checklist	Daily, per shift	Production floor
4	SOP adherence	Steps followed per SOP, deviations	SOP audit checklist	Weekly audit	Tempering area
5	Measurement frequency	Number of moisture checks per batch	Log sheets / Digital data capture	Every batch	Lab / QC
6	Moisture sensor calibration	Sensor readings vs. standard	Calibration gauge / Reference measurement	Monthly, plus after maintenance	Lab / Production floor
7	Equipment wear & tear	Motor vibration, blade condition, mixer performance	Visual inspection / Vibration meter	Weekly	Tempering tanks
8	Wheat lot variability	Incoming wheat moisture, batch source, variety	Moisture meter, intake records	Every lot	Receiving area
9	Water temperature control	Temperature of water added	Thermometer / Temperature sense	Every batch	Water supply line
10	Shift handover communication	Errors reported vs. completed actions	Handover checklist / Observation	Every shift	Production floor

ANALYSE PHASE



Analyse – Hypothesis testing

Factor	Type	Test	Null Hypothesis (H ₀)	Alternative (H ₁)
Supplier	Categorical	One-way ANOVA	$\mu_A = \mu_B = \mu_C$	At least one supplier mean differs
Ambient Humidity (%)	Continuous	Pearson Correlation	$\rho = 0$	$\rho \neq 0$
Milling Temp (°C)	Continuous	Pearson Correlation	$\rho = 0$	$\rho \neq 0$
Storage Days	Continuous	Pearson Correlation	$\rho = 0$	$\rho \neq 0$

Analyse – Hypothesis testing

Factor	Test	p-value	Significant?	Root Cause Validation
Supplier	ANOVA	0.018	✓ Yes	Supplier variation affects quality
Ambient Humidity	Correlation	0.004	✓ Yes	High humidity increases variability
Milling Temperature	Correlation	0.022	✓ Yes	High temp increases variability
Storage Days	Correlation	0.62	✗ No	No significant effect

Final Validated Critical Root Causes

Supplier variation — statistically significant ($p = 0.018$)

Ambient humidity fluctuations — strong correlation ($r = 0.81$)

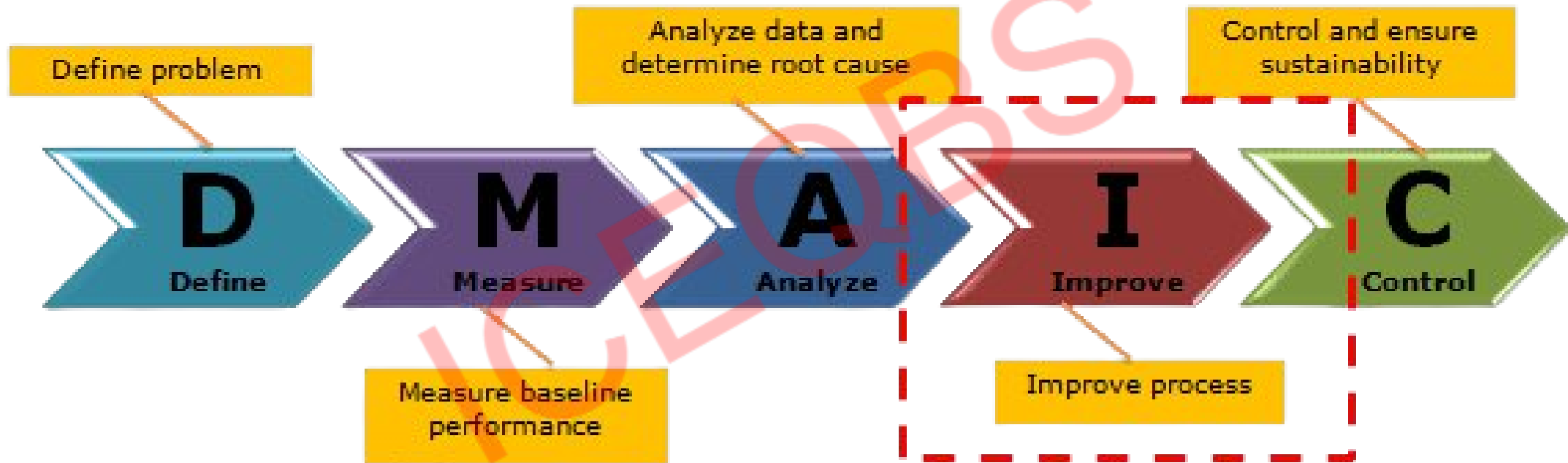
Milling temperature control — significant ($p = 0.022$)

These are the **validated root causes** for high moisture standard deviation

Summary of Statistically validated Root causes

- Supplier variation, Ambient humidity fluctuations and Milling temperature control are validated as critical root causes

IMPROVE PHASE



Improve

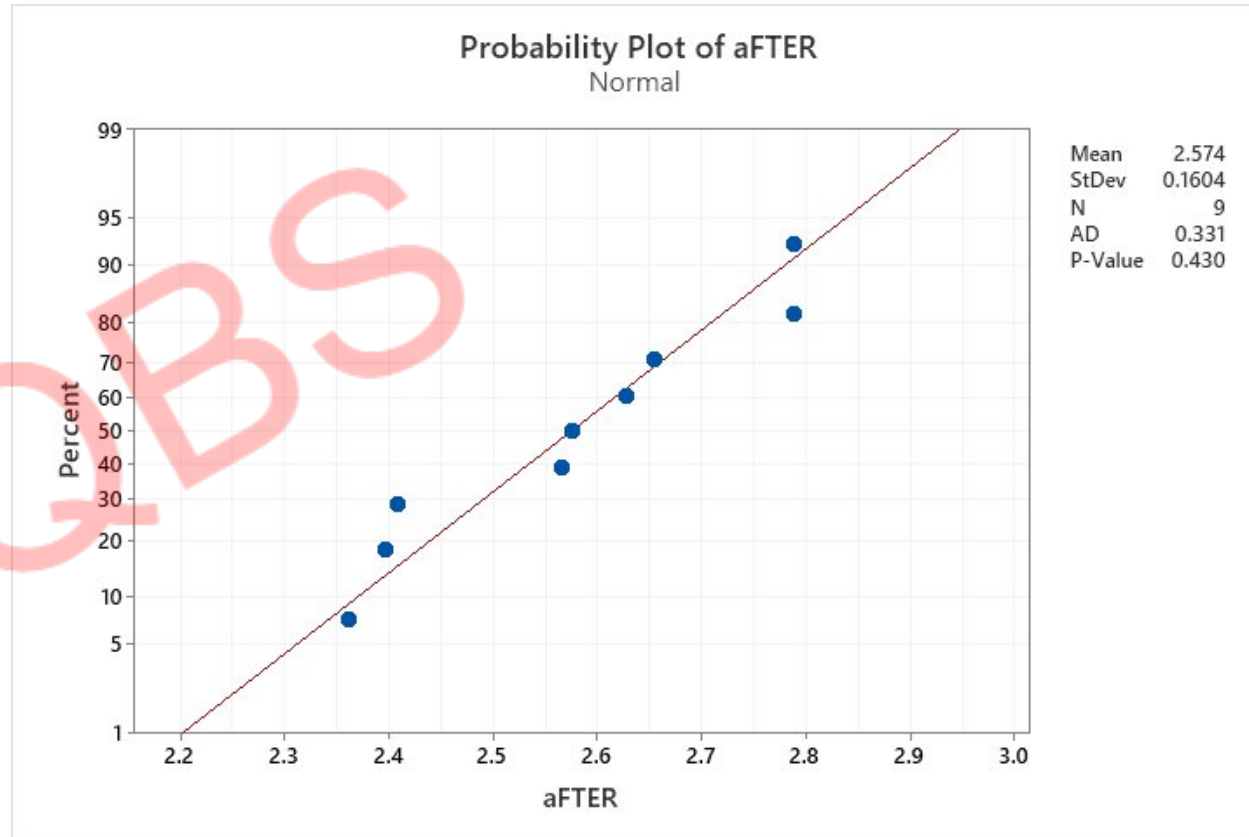
Root Cause	Evidence (Hypothesis Test)	Corrective Actions	Responsible	Timeline	Expected Outcome
1. Supplier Variation	ANOVA $p = 0.018 \rightarrow$ Significant difference between suppliers	- Establish supplier quality audit and qualification process. - Define and communicate consistent flour moisture and granulation specs. - Implement supplier scorecard tracking moisture consistency. - Conduct joint improvement workshops with Supplier B (high variability).	Procurement, Quality	1–2 months	Reduced between-supplier variation; more consistent raw material quality.
2. Ambient Humidity Fluctuations	Correlation $r = 0.81$, $p = 0.004 \rightarrow$ Strong positive relationship	- Install dehumidifiers in milling and packaging areas. - Implement humidity sensors with data logging and alarm triggers (e.g., $>65\%$). - Revise SOPs for humidity-controlled production scheduling. - Train operators on humidity management.	Production, Maintenance	2–3 months	Stable ambient humidity; minimized moisture absorption variance.
3. Milling Temperature Control	Correlation $r = 0.69$, $p = 0.022 \rightarrow$ Significant positive relationship	- Calibrate milling equipment temperature sensors monthly. - Set automatic control limits (e.g., $42\text{--}45^{\circ}\text{C}$) to maintain steady milling temperature. - Introduce preventive maintenance to reduce mechanical heat buildup. - Trend temperature vs. moisture SD daily in SPC chart.	Engineering, Production	1–2 months	Controlled milling temperature; reduced moisture variability.
4. Monitoring & Verification	Continuous Improvement	- Implement Statistical Process Control (SPC) chart for Moisture SD. - Monitor C_p and C_{pk} monthly to verify improvement. - Conduct MSA (Measurement System Analysis) for moisture analyser accuracy. - Document improvement in process capability reports.	Quality, Process Engineering	Ongoing	Sustained process control and predictable product quality.

Improve



Inference:

- Run chart – process is stable there is no special causes in the process (p value > 0.05)



Inference:

- Normality test – Data are normally distributed

Two-Sample T-Test and CI: Before, aFTER

μ_1 : population mean of Before

μ_2 : population mean of aFTER

Difference: $\mu_1 - \mu_2$

Equal variances are not assumed for this analysis.

Descriptive Statistics

Sample	N	Mean	StDev	SE Mean
Before	9	14.27	1.29	0.43
aFTER	9	2.574	0.160	0.053

Estimation for Difference

Difference	95% CI for Difference
11.693	(10.695, 12.691)

Estimation for Difference

Difference	95% CI for Difference
11.693	(10.695, 12.691)

Test

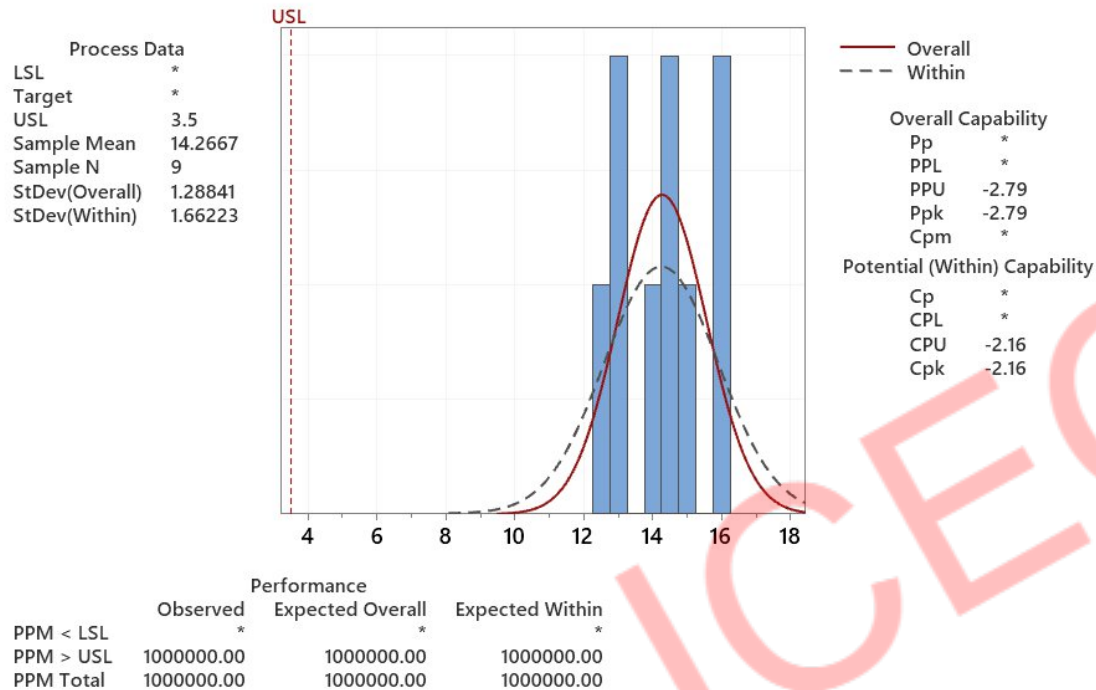
Null hypothesis	$H_0: \mu_1 - \mu_2 = 0$
Alternative hypothesis	$H_1: \mu_1 - \mu_2 \neq 0$

T-Value	DF	P-Value
27.02	8	0.000

There is **statistically significant difference** in mean moisture SD before and after the improvement (at the 5% level).

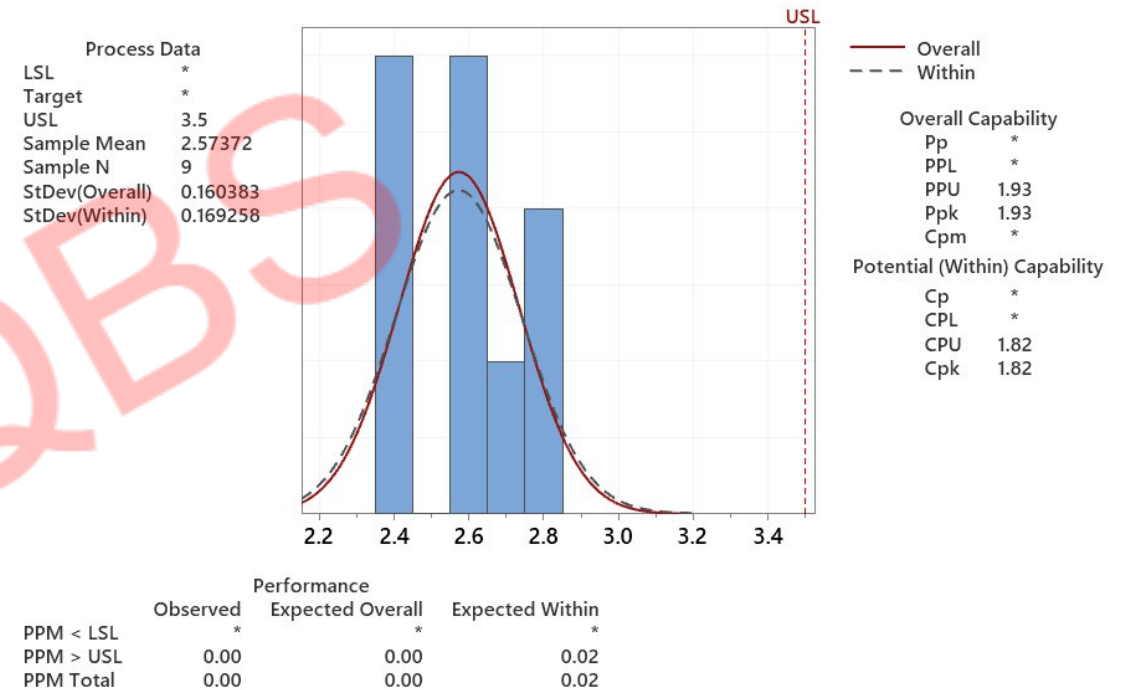
Improve – Process capability – Before & After Improvement

Process Capability Report for Before



The actual process spread is represented by 6 sigma.

Process Capability Report for aFTER

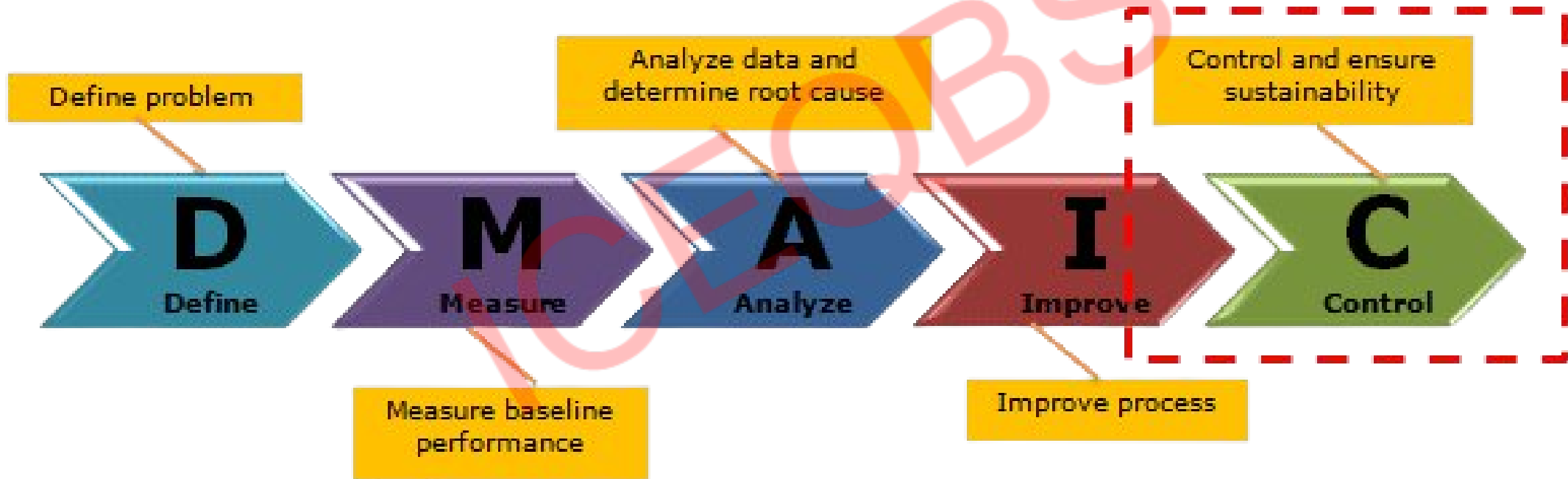


The actual process spread is represented by 6 sigma.

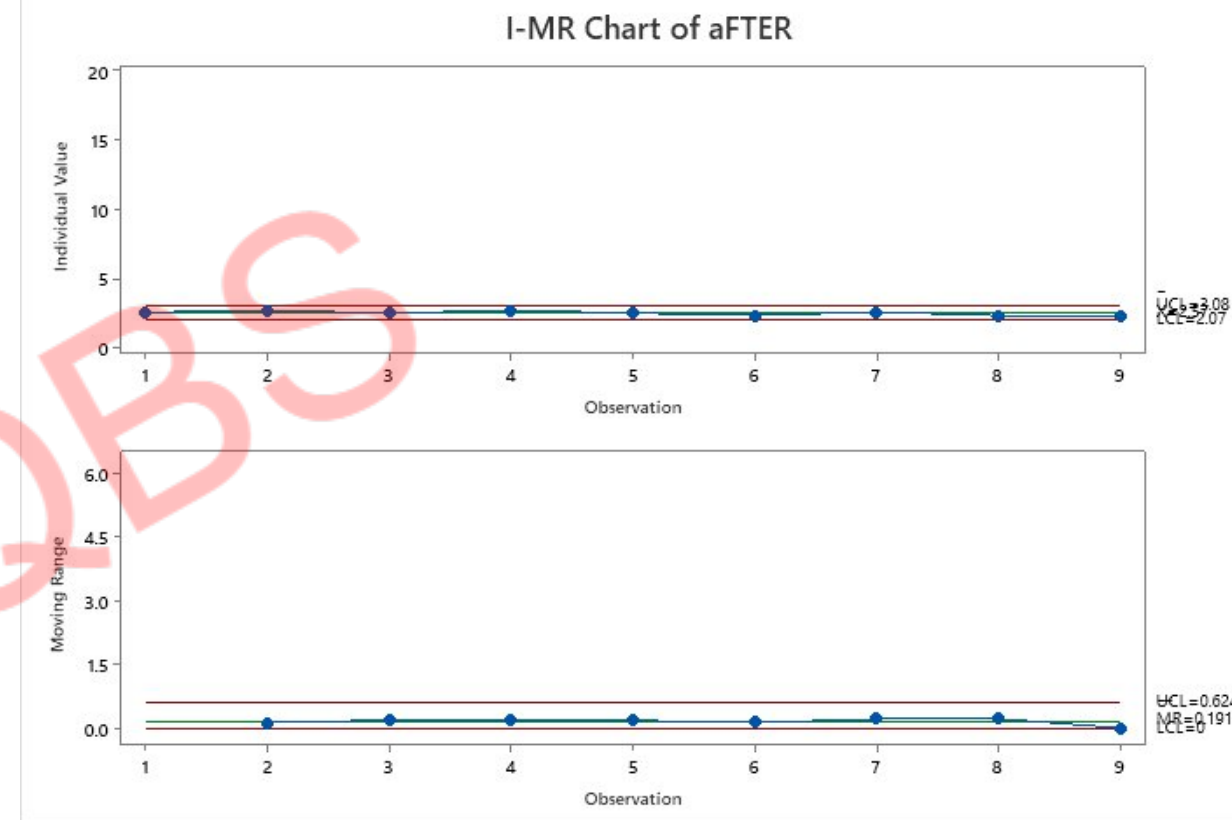
Inference :

- Before $C_{pk} <$ After C_{pk} , which shows process is much more capable after improvement
- There is less variability in system since stdev reduced after improvement
- After improvement the data are normally distributed near the target within specified limit

CONTROL PHASE



Improve (Statistical validation for Improvement – I-MR Chart)



Inference:

- As seen in control chart, before improvement mean was high and there was high variability in the **process** and after improvement, it has achieved the target

Control Plan

Process Step	Potential Failure Mode	Potential Effect(s) of Failure	Severity (S)	Potential Cause(s) of Failure	Occurrence (O)	Current Controls	Detection (D)	RPN (Risk Priority Number)	Recommended Actions
Moisture analyser calibration	Calibration skipped or inaccurate	Incorrect moisture readings, wrong decisions	9	Lack of training, lack of SOP compliance	4	Calibration schedule, logbook	3	108	Train operators, enforce calibration SOP; automate calibration reminders
Raw material inspection	Use of non-conforming flour batch	High moisture variability, product inconsistency	8	Poor batch traceability, manual error	5	Manual batch checking	4	160	Implement barcode scanning for batch verification; automated alerts for out-of-spec batches
Data recording and monitoring	Data entry errors	Incorrect trend analysis, delayed response	7	Manual data entry, lack of double-check	4	Paper log, manual review	5	140	Introduce automated data capture; use software with validation checks
Operator adherence to SOP	SOPs not followed	Process variability, loss of improvement	8	Inadequate training, lack of supervision	4	Training sessions, audits	4	128	Increase frequency of refresher training; use visual SOP reminders on floor
Cleaning and maintenance	Equipment not cleaned or maintained	Contamination affecting moisture readings	7	Time constraints, lack of accountability	3	Cleaning schedule, checklist	4	84	Assign clear responsibilities; use digital maintenance logs with alerts
Visual management tools	Control charts not updated or ignored	Inability to detect process drift	6	Lack of ownership, low awareness	3	Control charts posted, periodic reviews	5	90	Train staff on reading charts; make updates mandatory during shift changes
Poka-yoke mechanism malfunction	Alarm or sensor failure	Failures go undetected, defective products	9	Sensor faults, power failure	2	Periodic sensor checks	3	54	Implement redundancy; regular sensor testing and maintenance
5S Implementation	Poor compliance	Workplace disorder, increased errors	7	Low engagement, insufficient leadership support	4	5S audits, leader involvement	4	112	Incentivize 5S compliance; involve teams in 5S planning and audits

Control Plan Moisture SD Improvement							
Process Step	Critical Parameter	Specification / Target	Measurement Method	Frequency	Responsible Person	Control Method / Action	Reaction Plan / Corrective Action
Raw material receipt	Flour moisture	Target 14.2%, LSL 12.5%, USL 16%	Moisture analyser / lab test	Every batch	QC Operator	Barcode scanning & verification of batch; ensure moisture within spec	Reject batch if moisture out of range; notify supplier
Flour storage & handling	Moisture stability	±0.3% SD	Periodic moisture checks	Daily	Storekeeper / QC	FIFO, proper storage conditions, avoid humidity exposure	Adjust storage environment; segregate affected batches
Mixing & preparation	Process moisture control	±0.3% SD	Inline moisture sensor	Every batch / per shift	Production Operator	Check sensor readings before mixing; automatic alerts for deviations	Stop line; investigate deviation; recalibrate sensors
Baking process	Moisture retention	±0.3% SD	Temperature & humidity logs	Per batch	Production Supervisor	Use pre-set standard baking parameters; monitor oven conditions	Adjust baking parameters; document deviation
Moisture measurement	Moisture SD	Target 14.2%, SD <0.5%	Lab moisture analyser	Every batch / weekly audit	QC Analyst	Calibrated instruments; automatic logging to software	Re-calibrate analyser; repeat measurement
Data recording & trend review	Moisture SD trend	SD within control limits	Control chart / software	Daily / weekly review	QC Team / Production Lead	SPC charts posted; analyse trends; alerts for out-of-control signals	Investigate cause; implement corrective action
Poka-Yoke & SOP adherence	Compliance with standards	100% adherence	Visual check / checklist	Daily	Supervisors / Operators	Checklist verification; alarm for non-compliance	Re-train operator; stop line if critical step missed
5S & housekeeping	Workplace organization	Full compliance	5S audit checklist	Weekly / monthly	Team Leaders	5S standards enforced; visual management boards	Conduct training; re-audit and improve area
Continuous Improvement	Process capability (Cp, Cpk)	Cp ≥ 1.33, Cpk ≥ 1.0	SPC analysis, monthly reporting	Monthly	Process Engineer / QC	Evaluate process performance; identify improvement opportunities	Implement corrective/preventive actions; update SOP

Control Plan – 5S

5S for Sustaining Improvement

•Sort (Seiri)

- Remove outdated or unnecessary tools, equipment, and materials in the moisture measurement and baking areas.
- Keep only calibrated moisture analysers and approved flour batches to avoid mix-ups.

•Set in Order (Seiton)

- Organize instruments and raw material storage systematically with clear labels and designated places.
- Use visual cues (colour codes, floor markings) for material handling and measurement stations.

•Shine (Seiso)

- Schedule regular cleaning and maintenance for moisture analysers and baking equipment to ensure reliable measurements.
- Keep data logs and machines free of dust, spills, or contamination that might affect moisture readings.

•Standardize (Seiketsu)

- Develop standard operating procedures (SOPs) for moisture measurement and baking processes, including checklists.
- Use visual management tools like control charts posted near workstations to monitor moisture levels daily.

•Sustain (Shitsuke)

- Conduct regular 5S audits and team training to maintain discipline in processes.
- Encourage employee ownership through recognition programs for consistent adherence to standards.

Control Plan - Poka-Yoke Mechanisms for Moisture Consistency

•Measurement Device Lockout/Alerts

- Implement sensors that alert operators if moisture analysers are out of calibration or operating outside acceptable parameters.
- Use automatic data logging with alarms for moisture readings outside specification limits.

•Standardized Raw Material Batches

- Barcode scanning or RFID tags on flour bags to ensure only approved batches enter the production line.
- Prevent use of expired or wrong moisture-level flour batches.

•Process Parameter Interlocks

- Machine interlocks that prevent baking if moisture input readings are not within control limits.
- Automatic shutdown or stop signal if moisture readings deviate significantly during mixing or baking.

•Color-Coded Material Handling

- Use distinct color-coded containers or labels for different moisture ranges of flour to avoid mixing batches.
- Visual signals for operators when materials need rechecking or discarding.

•Checklist & Sign-off Systems

- Require operators to complete standardized checklists verifying moisture analyser calibration and readings before starting the batch.
- Electronic or paper trail to ensure accountability and traceability.



Results after improvement

- Project has achieved its intended results after improving thickness by identifying the variation cause and reducing the Moisture of conditioned wheat