MFI Plant Visit
Manufacturing Excellence

Visit Date: March 18th – 20th 2025

1 INTRODUCTION

This report provides an overview of the three-day visit on March 18-20th to the MFI manufacturing plant, located in West Jefferson, Ohio. The visit was conducted to troubleshoot and provide solutions to bottleneck processes, with a specific focus on batching. The team also provided an overview of methods to troubleshoot issues related to the standardization of total solids and pH, packaging material quality, plant KPIs and end-to-end waste analysis. The report highlights key observations, discussions and recommendations for potential solutions/improvements and agreed next steps.

2 CONFIDENTIALITY

All information shared and insights gained during this visit will be treated with strict confidentiality to protect the interests and intellectual property of both our partners and our organization. We will ensure that sensitive data remains secure and is used solely for the purpose of identifying and implementing mutually beneficial process improvements.

3 EXECUTIVE SUMMARY

PA and PNC extend our appreciation and thanks to the MFI team for hosting us on site for three days to assist with the optimization of production processes and collaborate on opportunities for improvement. The visit focused on batching and standardization bottlenecks, waste analysis, and a technical evaluation related to packaging materials. Key findings and achievements during the visit include:

- Batching process bottlenecks can be alleviated with improvements to process design, rate of ingredients addition, and elimination of standardization through variation reduction. The team has identified 10+ opportunities to reduce the batching time which requires an implementation strategy.
- Process variability during batching prevents the standardization process from being eliminated but there are opportunities to reduce variability through training, process standardization, and tighter equipment controls
- A model for calculating waste was created for the factory, but the calculated waste greatly differs from the shrinkage reports generated by MFI. It is necessary to review and reconcile these differences to ensure accurate waste reporting.
- Implementing best practices prior receiving packaging materials to the production floor will reduce downtime and packaging waste by catching supplier defects before entering equipment
- It is feasible to extract the data required for the KPI framework. Measuring this will allow for more targeted continuous improvement activities and benchmark performance to the co-man network

4 NEXT STEPS

Our team hopes to continue working with MFI on process optimization activities, and we believe our partnership will continue to create value and improve production efficiency. We see the following next steps as a logical continuation of our partnership:

- Joint effort between PNC, MFI, and PA to create roadmap for batching and standardization improvement initiatives and site visits
  - MFI to review this report and identify time to review topics outlined and establish dates for implementation
  - PNC to review and establish requirements for process changes
  - Measure baseline batching performance
  - Identify date for follow-up visit and implement planned process improvements
  - Measure future state performance
- MFI to share any agreed upon requested data during the site visit
- PA to share all documentation / source files for the information generated in this report including supplemental documentation discussed during the visit

5 VISIT DETAILS

Facility	**MFI, West Jefferson, OH**
Date(s)	March 18th - 20th
PNC Attendees	Lorita Whitehouse, Ron Renati
PA Attendees	Louise Oliver, John Reichert, Jim Phillips, Sara Do

6 AGENDA

The PA / PNC team visited MFI for a three-day visit to cover topics related to bottlenecks from the batching process, waste analysis, KPI data collection, and best practices packaging material handling. The agenda for the visit is listed below:

Day 1: Batching and Processing Waste Streams / Packaging Material Quality

Time (Duration)	Activity	Suggested Participants *
08:30 – 09:00 (.5 hr)	Introduction, Confirmation of Agenda and Overview of Objectives	• All
09:00 – 10:00 (1 hr)	Site Tour / Walk Through • Review of process / equipment improvements since last visit • Discuss current state challenges	• Dan • Max
10:00 – 11:00 (1 hr)	Review Plant Performance Metrics: • Current state reporting functionality • Review extraction methods with Tetra Pak • Review existing KPI reporting documents (operating manuals, training, etc.) • Initiate data collection process – including capture of process for pulling KPIs • Time study for batching	• Lauren • Massimo • Max
10:00 – 11:00 (1 hr)	Waste Streams – Discussion on Quantifying Losses • Ingredient addition -> raw batch tank • Raw batch tank -> filler	• Justin • Roman • Todd • Clay
11:00 – 12:30 (1.5 hr)	Data Collection for Waste Sources • Ingredient addition -> raw batch tank • Raw batch tank -> filler	• Justin (1st half) / Nick • Ramon • Todd • Clay
10:30 – 12:30 (2 hr)	Review Incoming Packaging Materials and Packaging Materials In-Process • Review quality of supplied packaging / document issues witnessed on-site • Challenges with packaging in production equipment • Review flavor clumping issues • Discuss challenges with real-time inventory tracking in SAP • Discuss palletizing robot performance challenges (not running today – 4pm start)	• Holly – SAP inventory • Justin (2nd half) • Nick • Lindsey • Massimo
12:30 – 13:30 (1 hr)	Lunch Break (*Aligned with Shift Schedule*)	• All

	Collection of Observations and Discussion on Operational Processes	
13:30 – 15:30 (2 hr)	Factory walkthrough to review packaging issues with operators on the line	
13:30 – 16:30	Cleaning equipment until 4pm /Top stops discussion	• Lauren • Massimo
13:30 – 16:30 (3 hr)	Data Collection for Waste Sources • Ingredient addition -> raw batch tank • Raw batch tank -> filler (specifically VTIS waste switchover to water when batching is constrained – consider SKU mix and PNCs contribution to waste)	• Max • Glenn
16:30 – 17:00 (0.5 hr)	Confirmation of Findings & Wrap Up Discussion	• All

Day 2: Filler to QA Hold Waste Stream Analysis

Time (Duration)	Activity	Suggested Participants *
08:30 (.5 hr)	Confirmation of Agenda and Investigations	• All
9:00 – 15:30	Validate KPI Data Collection • Collect data from Tetra Pak PLMS: OEE, downtime/stops, energy/water usage • Collect data from cross-functional teams: Quality, OTIF, Total Waste • Investigate recipe parsing, Tetra KPI definitions/calculations	• Massimo • Lauren
09:00 – 15:30 (1.5 hr)	In-Depth Discussion of Batching and Standardization Process • Review standardization data analysis • Discuss ingredient mixing challenges • Discuss batch kit number reporting issues • Discuss cocoa slurry batching process and challenges • Discuss water transfer between tanks • Discuss VTIS cleaning/maintenance challenges (Glenn, Christopher) • Create batching process map and identify opportunities for improvement	• Max • Todd / Dawn or Lindsey • Ramon • Clay • Joey • Dan Hansen
10:30 – 11:30 (1 hr)	Investigate downline stops – root cause Waste Streams – Discussion on Quantifying Losses • Filler -> QA hold • QA hold -> release	**(Filler / Packaging)** • Nick Fields • Shae – Trainer (Filler) • Massimo • Glenn **(QA)** Lindsey
11:30 – 12:30 (1 hr)	Data Collection for Waste Sources • Filler -> QA hold • QA hold -> release	• Production Manager • Quality Engineering Lead • Continuous Improvement Lead
12:30 – 13:30 (1 hr)	Lunch Break (*Aligned with Shift Schedule*) Collection of Observations and Discussion on Operational Processes	• All

13:30 – 16:30 (3 hr)	Data Collection for Waste Sources • Filler -> QA hold • QA hold -> release	• Process Engineering Lead • Quality Engineering Lead • Continuous Improvement Lead
15:30 – 16:00 (0.5 hr)	Confirmation of Findings & Wrap Up Discussion	• All

Day 3: Plant KPIs and Batching Future State Process

Time (Duration)	Activity	Suggested Participants *
08:30 – 09:00 (.5 hr)	Confirmation of Agenda and Investigations	• All
9:00 – 10:30 (1.5 hr)	Validate Plant Performance Metrics: • Review KPI data collected • Understand challenges with data collection • Validate data sources and reporting capabilities (Tetra filler, existing reports) • Compile a completed KPI scorecard	• Lauren • Massimo • Gary • Lindsey • [OTIF person]
9:00 – 15:00	Batching process future state development • Process map output • Review with operators	• Todd • Dawn or Lindsey • Ramon • Clay • Joey • Dan Hansen
12:00 – 13:00 (1 hr)	Lunch Break (*Aligned with Shift Schedule*) Collection of Observations and Discussion on Operational Processes	• All
13:00 – 15:00 (2 hr)	Reserve time for additional data collection from waste streams / KPI scorecard – This time slot to be established at the beginning of Day 2	• Process Engineering Lead • Quality Engineering Lead • Continuous Improvement Lead
15:00 – 15:30 (0.5 hr)	Confirmation of Findings & Wrap Up Discussion	• All

6.1 Batching and Standardization Process

6.1.1 Summary

The batching process can become a bottleneck process when fillers are operating at current OEE levels, and the team worked together to identify opportunities to ensure batching can keep pace with fillers. The current batch time is 241 minutes (end-to-end), and the team identified several solutions to reduce the time to 182 minutes, which would allow all fillers to operate at a higher OEE. These solutions are detailed below in the following sections.

6.1.2 Batching Process Overview

Recipes are stored into the Tetra Pak system controller which provides instructions which must be followed by operators. The batching process includes batch make-up, standardization, transfer to the surge tank for cold storage.

6.1.2.1 Batch Make-Up Process (see Figure 1)

- Two 600kg super sacks of MPC are pulled into the high shear mixer at a rate of approximately 28kg per vacuum cycle (approximately every 10 seconds). The super sack system is in the same room as the manual debagging station.
- 20kg sacks of MPC and calcium caseinate are manually debagged into a hopper which has a vacuum feed to the high shear mixer. The operators empty a bag as fast as the vacuum system is programmed to pull in material.
- Minors are added into a separate vacuum infeed to the high shear mixer.
- Ingredients are recirculated between the high shear mixer and the 4,000-gallon batching tanks. Note: the high shear mixer can provide slurry to both batching tanks.
- For cocoa based flavors: enough cocoa slurry is created for two 4,000-gallon batches. The cocoa batches follow a 45-minute hydration and kill step.

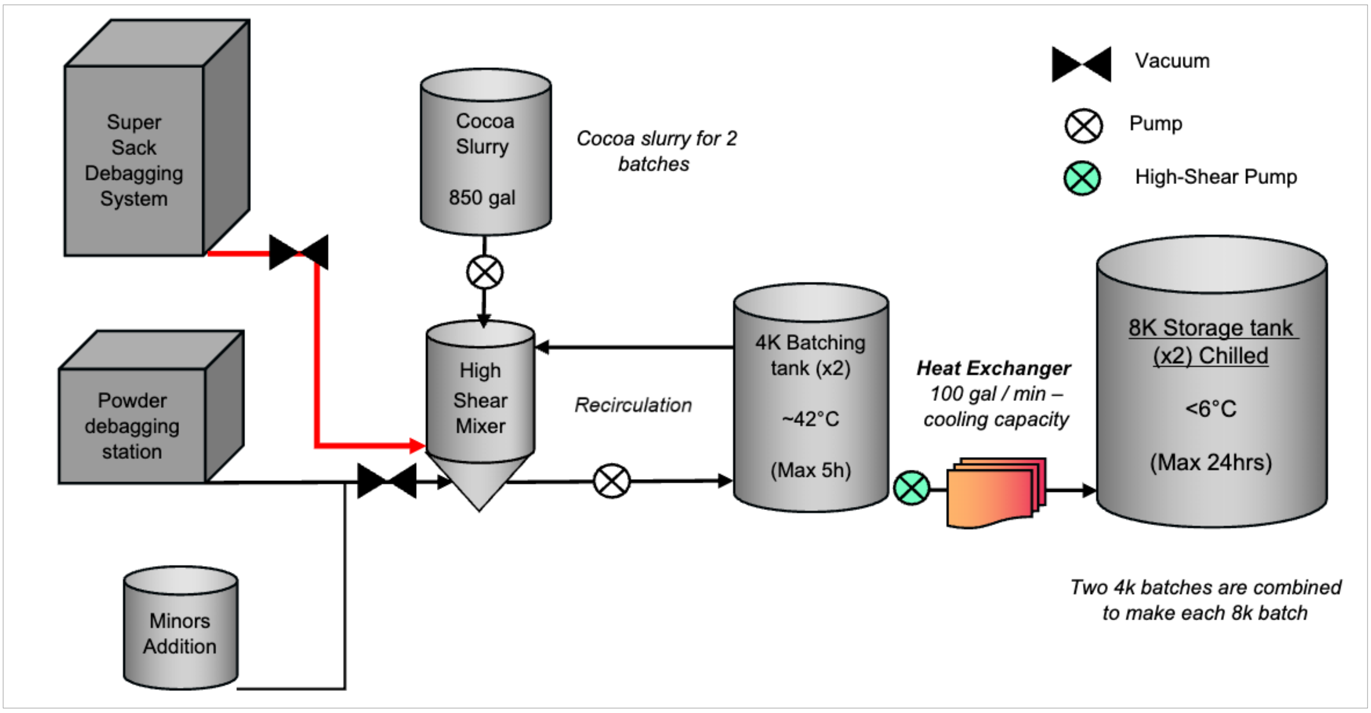

Figure 1: Batching equipment layout / overview

6.1.2.2 Batching Challenges

Batching is a known bottleneck process when at least three fillers are operating as intended (e.g. not undergoing overhaul / unplanned maintenance). The current batching process takes ~241 min with the three major components comprising:

- Batch make-up (120 minutes) – From initial water addition to complete transfer of 4,000 gallons of product to the batch tank
- Standardization (82 min) – Includes first standardization, adjusting the batch, and the second lab measurements to confirm the success of the adjustment
- Transfer to the surge tank (40 min) – 4,000 gallons at 100 gpm transfer speed

Total throughput is 16.7 gallons / min with the 4,000-gallon batch tank system. This is a simplified analysis which excludes the buffering capacity and all nuances with CIP cycles on the raw / sterile side. In the current state, three fillers are operating at 44% OEE (February 2025), assuming a shut down 16% of the time for CIP cycles on the sterile side. This configuration will draw 17.07 gallons per minute over the course of an operating run, which exceeds the throughput of the current batching process.

Description	Value	Units
Downstream Equipment		
Filler Capacity	9,000	Cartons (hr)
# Fillers	3	Each
OEE	44%	
Available Time	100%	
Total Throughput	11,880	Cartons (hr)
Total Throughput	1,019.97	Gallons (hr)
Total Throughput	17.00	Gallons (min)
Batching Process		
Batching Time	240.0	min
Batch Tank Capacity	4000	gal
Batch Throughput	16.67	gal / min
Surplus / Shortage		
Batch Production	(0.33)	gal / min

Figure 2: Current OEE with 3 fillers operating at February performance level (OEE = 44 %) at the current batching process speed indicates a shortage in gallons per minute of -0.33

In the most optimistic case (see section 6.1.5), where all the batching opportunities listed in this document are successful implemented and the benefit is completely realized, an additional filler could be operating and the OEE could increase by 18%, and the batching process would maintain pace the downstream throughput (Figure 3). Again, this is a straight-line analysis that does not include possible advantages and disadvantages with buffering and offset CIP cycles from the raw and sterile side.

Description	Value	Units
Downstream Equipment		
Filler Capacity	9,000	Cartons (hr)
# Fillers	4	Each
OEE	62%	
Available Time	100%	
Total Throughput	22,186	Cartons (hr)
Total Throughput	1,904.76	Gallons (hr)
Total Throughput	31.75	Gallons (min)
Batching Process		
Batching Time	126.0	min
Batch Tank Capacity	4000	gal
Batch Throughput	31.75	gal / min
Surplus / Shortage		
Batch Production	(0.00)	gal / min

Figure 3: Most optimistic case with all benefits realized resulting in a 126 min batch time will match the pace 4 fillers operating at 62% OEE

Given the likely result will land somewhere between current state and the most optimistic, a sensitivity analysis was created to understand the relationship between various batching time (min) relative to filler OEE performance (see Figure 4). When numbers (shortage or surplus gal/min) in the table are negative, the batching process will be a limiting factor for the factory. For example, the current batch time of 240 minutes is a limiting performance factor for all OEEs above ~30%, assuming four fillers are operating.

		Batch Shortage / Surplus Capacity (gal / min)					
		Batch Time (Min)					
	(0.00)	120	140	160	180	200	240
Filler OEE	30%	17.9	13.1	9.5	6.8	4.5	1.2
	35%	15.3	10.5	7.0	4.2	2.0	-1.4
	40%	12.7	8.0	4.4	1.6	-0.6	-3.9
	45%	10.2	5.4	1.8	-1.0	-3.2	-6.5
	50%	7.6	2.8	-0.8	-3.5	-5.8	-9.1
	55%	5.0	0.2	-3.3	-6.1	-8.3	-11.7
	60%	2.4	-2.3	-5.9	-8.7	-10.9	-14.2
	65%	-0.2	-4.9	-8.5	-11.3	-13.5	-16.8

Figure 4: Sensitivity analysis of batching speed (min) to filler OEE *(4 filler operating) – Note: The approximate current state is outlined in dark black*

6.1.3 Contributing Factor to Bottleneck: Rate of Ingredients Addition

MFI shared detailed process steps for chocolate recipe batching. Using this data, we created a mathematical model which indicates how solids concentrations change through the batch process in both the High Shear Mixer (HSM) and Batching Tank (BT), which operate with a recirculation loop. The purpose of the model to game different rates of ingredient addition while the batch remains under a certain threshold (< 20%) for total solids throughout the batching procedure. The model allows rates and order of ingredient addition to be optimized within the process constraints.

6.1.3.1 Key Findings from Modelling

The model outputs a chart (Figure 5) which has process milestones mapped to alphanumeric codes which can be interpreted using Table 1. The model of the current 119-minute batching process model realistically showed:

- Final solids concentration in BT (chocolate): 12.8%
- Peak solids concentration in HSM: 18.7%
- PNC shared guidelines from Tetra Pak indicating solids should not exceed 20.0% for a short period of time (time limit not established)
- Indicated headroom exists for accelerating solids addition rates to reduce total batching time (see future state model proposed below)

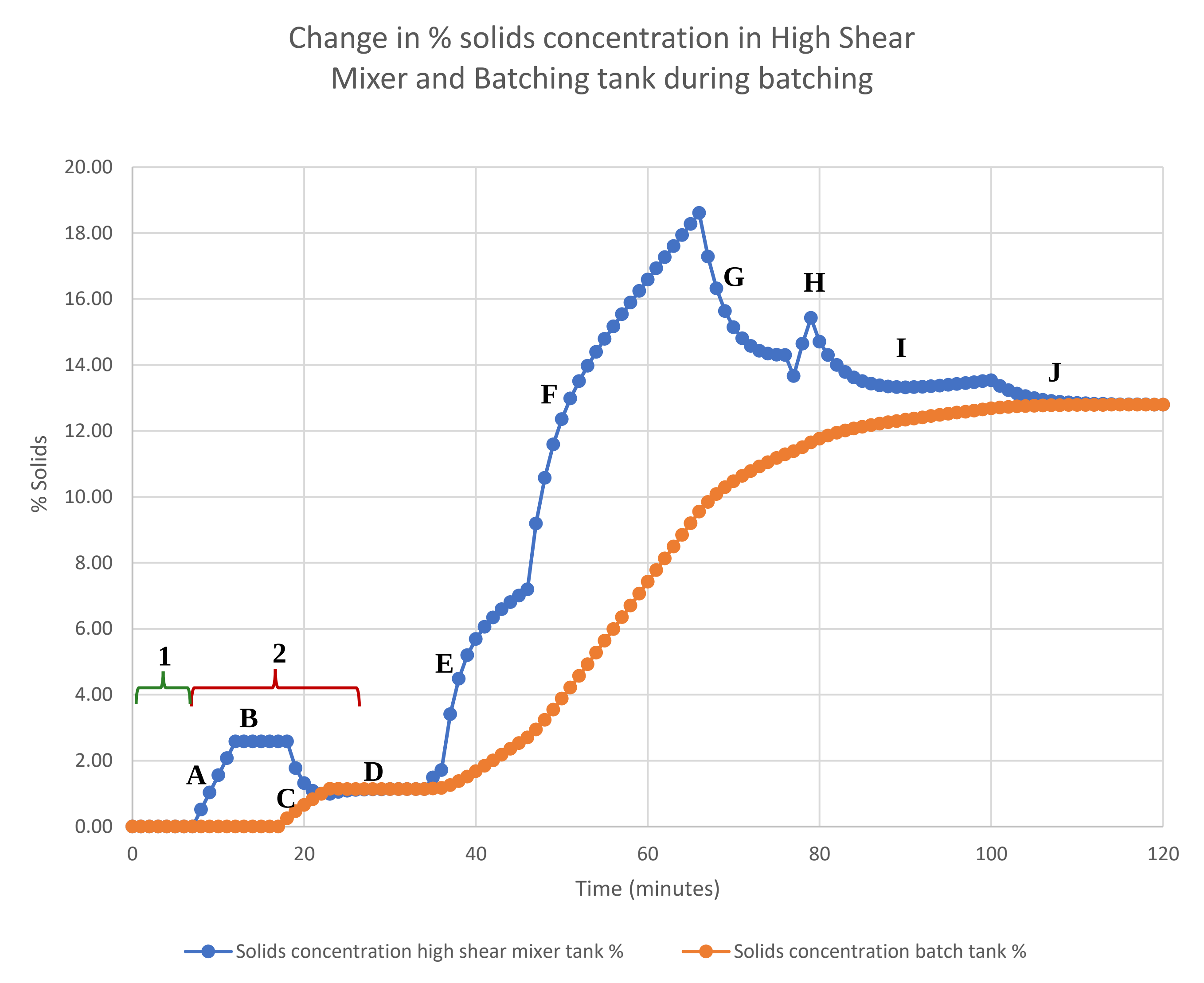

Figure 5: Current state – change in % solids concentration in HSM during *119-minute* batching process*. Note: 119 minute batch process includes 15 minutes of staging which is not shown in the graph above.*

Table 1: Legend for interpreting change in solids graphs

Step	Description	Rate of Addition – Before (kg/min)
1	Water addition to High Shear Mixer (HSM)	TBD
2	Water addition to Batch Tank (BT)	TBD
A	Gums addition (HSM)	7.5
B	Gums hydration (5min timer) (HSM)	N/A
C	Recirculation started between HSM and BT and Coca slurry addition (BT)	N/A
D	Recirculation between BT and HSM 20 min timer	N/A
E	Manual caseinate addition (HSM)	25.3
F	Milk protein Super Sack addition (HSM)	60
G	Milk protein manual addition (HSM)	25.3
H	Oils addition (HSM)	39.3
I	Minors additions (HSM)	16.3

J	Recirculation between BT and HSM 5-10 min.	N/A

6.1.3.2 Model Benefits

This mathematical modeling approach allows proposed changes to be rapidly assessed 'in silico', quantifying:

- Peak solids concentrations in both vessels
- Differential solids concentration between HSM and BT
- Impact of process modifications

An example of how the model can be beneficial for process optimization can be seen in Table 2 below, which demonstrates that lower recirculation rates risk the max solids concentrations exceeding the 20% max threshold (highlighted in red). The model can then be used to find an optimal recirculation rate for a given solids addition rate.

Table 2: Impact of recirculation rate on residence time (HSM), equilibration time (HSM:BT) and max solids (HSM) (Using 90-min batching protocol from March 18, 2025)

Recirculation Rate (l/min)	Mean residence time in HSM (min)	Time to equilibrate tanks within 5% solids (min)	Max Solids in HSM (%)[2]
200	7.2	32	32.1
300	4.8	27	25.6
400	3.6	10	22.0
568[1]	2.5	6	18.7
600	2.4	5	18.2
800	1.8	3	16.4
1000	1.45	2	15.4

[1]*Current recirculation rate: 568 l/min*

[2]*Solids in HSM should not exceed 20% for extended periods*

6.1.3.3 Process Optimization Results

Multiple process modifications were tested to ensure peak HSM solids remained below 20.0%, which resulted in:

- A reduction in batching time from 119 minutes to 60 minutes is made possible in part with optimization of ingredient addition (see Figure 6).
- Peak solids for optimized 60-minute process: 19.9%, exceeding 19.0% for only 3 minutes.
- Process change: water addition to BT now occurs concurrently with super sack bulk solids additions due to the elimination of the 10-minute wait while recirculation occurs after the gym hydration 'D' – see section 6.1.3.4 (point 3) for detailed explanation for removal of this step.
- Given all water will have been added to the system before peak solids concentration is reached, no significant impact on peak HSM solids during batching is anticipated.

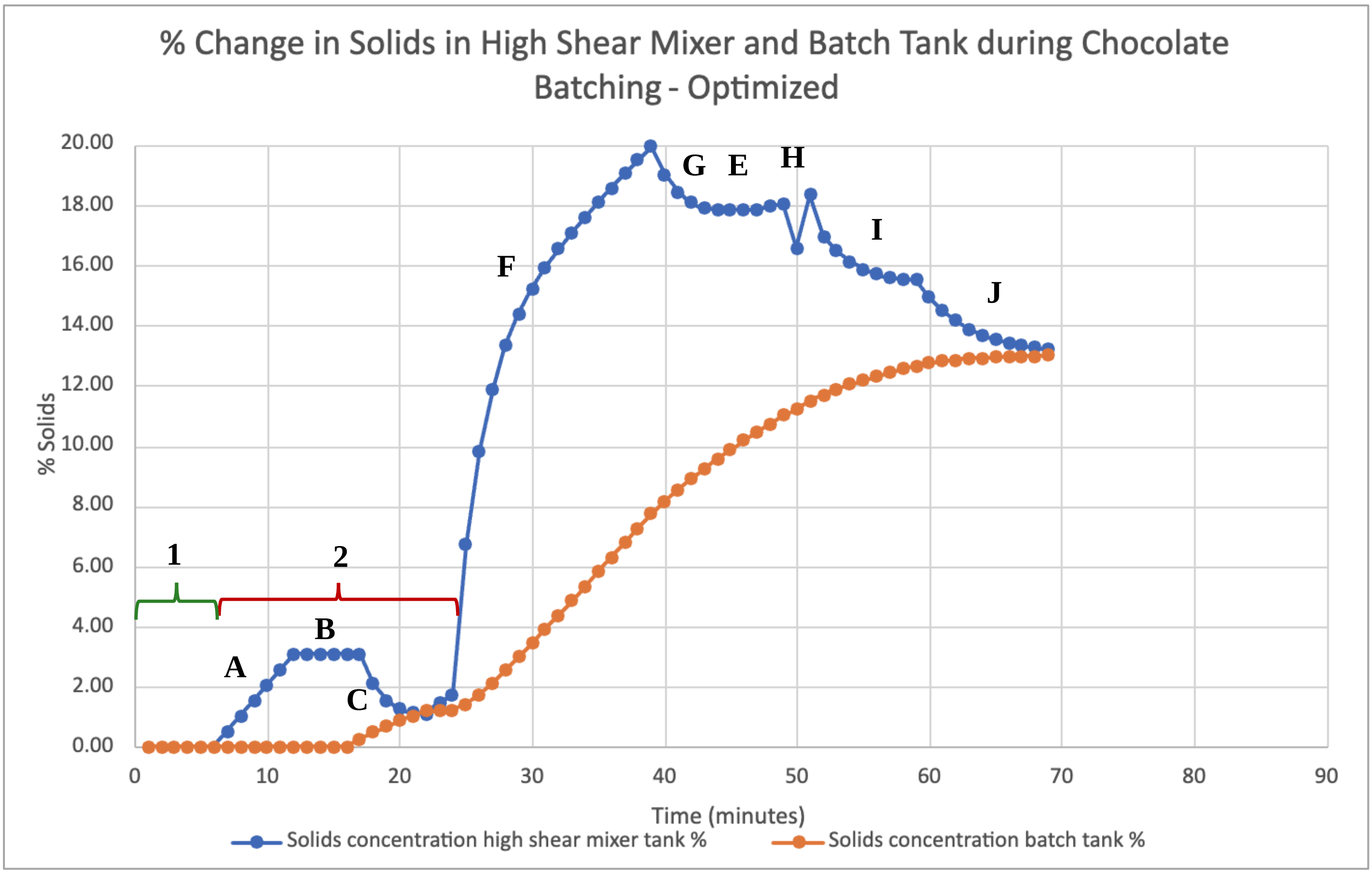

Figure 6: Future state – change in % solids concentration in HSM during optimized batching process

Table 3: Legend for interpreting change in solids graphs

Step	Description	Rate of Addition – Before (kg/min)	Rate of Addition – After (kg/min)
1	Water addition to High Shear Mixer (HSM)	TBD	TBD
2	Water addition to Batch Tank (BT)	TBD	TBD
A	Gums addition (HSM)	7.5	7.5
B	Gums hydration (5min timer) (HSM)	N/A	N/A
C	Recirculation started between HSM and BT and Coca slurry addition (BT)	N/A	N/A
D	Recirculation between BT and HSM 20 min timer	N/A	N/A
E	Manual caseinate addition (HSM)	25.3	44.3
F	Milk protein Super Sack addition (HSM)	60	80
G	Milk protein manual addition (HSM)	25.3	44.3
H	Oils addition (HSM)	39.3	78.5
I	Minors additions (HSM)	16.3	16.3
J	Recirculation between BT and HSM 5-10 min.	N/A	N/A

6.1.3.4 Process Optimization Insights

Several key discoveries emerged from the modeling:

- Ingredient addition order matters
  - Changing the order of bulk solids additions (without changing addition rates) significantly impacts peak solids concentration in HSM
  - Making rapid super sack additions first, followed by manual 20kg and 25kg sack additions, resulted in lower peak solids. This is due to the super sack system being able to incorporate MPC at twice the rate of manual debagging (~30 kg/min vs 60kg/min) and the batch tank being highly concentrated with water.
  - This allows for a more aggressive addition schedule which could reduce the super sack addition time from 20 minutes to 15 minutes and save an additional
- Understanding recirculation dynamics
  - BT maintains lower solids concentration than the HSM
  - Recirculation loop dilutes the HSM from the BT
  - Rapid initial solids addition to the HSM increases the solids differential between tanks
  - Greater differential increases dilution effect from the BT, reducing the peak solids in the HSM
  - This insight was revealed from modeling the different powder addition sequences to reduce the number of separate operations performed by the batching crew during powder addition
- Eliminating unnecessary hold times
  - The model showed that the 10-minute hold time (to allow water addition to complete and gums/cocoa slurry to equilibrate) was unnecessary due to the solids contents in both tanks being almost identical, meaning this step would not impact peak solids in the HSM. Further, there was more than ample time over the rest of the batching process for all ingredients to be homogenized and equilibrated between the tanks. These reasons are summarized below:
    1. Solids differential between tanks at this point was minimal
    2. Mean residence time in HSM was only 2.5 minutes
    3. Sufficient liquid movement throughout the remainder of the batching process ensured homogeneity of cocoa and gums

6.1.4 Contributing Factor to Bottleneck: Standardization

The standardization process was estimated to take 25 minutes in the original line design and capacity modeling created by Tetra Pak and shared with MFI. The actual time to standardize is ~36 minutes in the current process workflow.

6.1.4.1 Current Standardization Process

The current standardization process at MFI follows this sequence (Table 4):

- Once batching is completed, a request for sample is logged, notifying the Quality team. A timer is started to allow ingredient mixing in the batch tank (15 minutes)
- Sample collection and return to analytical lab (~6 minutes)
- Sample preparation (~2 minutes)
- CEM testing for solids and pH testing (~13 minutes)
- The results are reported to the batching operator along with recommended water and KOH volume required to standardize the batch
- The testing is completed a second time to verify the product is within the specification range, and the product is then transferred to the surge tank

Table 4: Expected timeline for standardization process steps and accumulated times

Process Step	Min. Step Duration	Min. Accumulated Time
Request sent to perform standardization testing (15-minute countdown)	15 min	15 min
Sample collection from line	6 min	21 min
Sample preparation	2 min	23 min
2 CEMs run in parallel +pH testing performed	13 min	36 min

6.1.4.2 Potential for Standardization Elimination

If initial variations in both solids and pH could be reduced, it may be possible to eliminate the standardization step entirely. The testing would still be required to verify the product meets the specifications required for total solids and pH, but with a 6σ process, the testing would infrequently result in out-of-specification results.

- This would involve calculating ideal amounts of raw ingredients, water, and KOH required for each recipe to achieve the center of their target ranges.
- Some co-mans in the PNC network successfully streamlined this process
- PA has developed a data-driven approach to identify such opportunities

6.1.4.3 Sample Collection Improvement

The sampling procedure needs to ensure the ‘dead leg’ between the tank and the valve is properly flushed before taking samples. The current process at MFI calls for 10 seconds of drain prior to sample collection but not all operators follow this requirement. Options include:

- Filling two sample bags and discarding the first (risk of mixing up samples)
- Hanging a small bucket or waste receptacle at the valve to capture 2-3 seconds of product flow before sampling (clean any waste receptacle once per shift to prevent microbial build up)
- Most importantly: training operators on the importance of clearing the dead leg to prevent non-representative samples from being tested and potentially destroying a batch.

6.1.4.4 Variation in Total Solids

Prior to the visit, PA and MFI collaborated on measuring and characterizing the variation in total solids and pH seen during the standardization process. MFI shared a minimum of 30 samples for each flavor produced (Caramel, Vanilla, Café Latte, Chocolate) which included initial measurements of total solids / pH, water addition, KOH addition, and results after standardization. Assessment of variation in solids values post-batching revealed:

- Ingredient addition accuracy is not likely responsible for the bulk of variation, based on measurement accuracy (confirmed by the supplier and in-house) and minimal powder waste (confirmed in the waste analysis by PA during site visit)
- A dedicated, calibrated batching flow meter is recommended, with results compared against the main RO meter

MFI provided PA with data from 179 separate standardizations for 4 different flavors. This data was analyzed and a summary showing the average solids before standardization and the standard deviation in the solids concentration before standardization.

The solids would be expected to vary by flavor and will be higher than target to allow for standardization and subsequent water pushes. The standard deviation was the same for all flavors, indicating that we are seeing consistent batching performance and that this is not influenced by flavor (Table 5).

Table 5: Solids variation analysis by recipe from MFI production data (October 9, 2024 – January 21, 2025)

Recipe	Number of Samples	Average Solids	Solids Std. Dev.
Caramel	63	12.97	0.11

Vanilla	50	12.84	0.11
Café Late	36	13.17	0.11
Chocolate	30	13.26	0.11

6.1.4.5 Water Addition - Accuracy Analysis

Two main factors which can be controlled during the batch makeup process are how accurate ingredients are added to the mixture and how accurate water is metered into the tanks. The below analysis shows there are challenges managing the water accuracy to the batch tank, especially when water additions are a smaller amount (<500 pounds). Additional information for water addition:

- All RO water is metered by a common Coriolis meter (±0.2% accuracy capability) from a common flow to the entire factory from the RO tank.
- No dedicated metering capability exists at the batching station
- System losses (e.g., leaking valves) at other fill points anywhere in the factory could disrupt the measured flow to batching system – leading to inaccurate standardization results.
- Tank load cells in the two batching tanks show inconsistent readings, preventing reliable liquid mass verification

The team took a multi-step approach to understanding variability associated with water addition at MFI:

- **Step 1:** Verify a predictable response to change in total solids is expected for a given mass of water added during standardization (see Figure 7). The trend line showed a very predictable result (R-squared of 0.98), meaning the response to water is consistent.

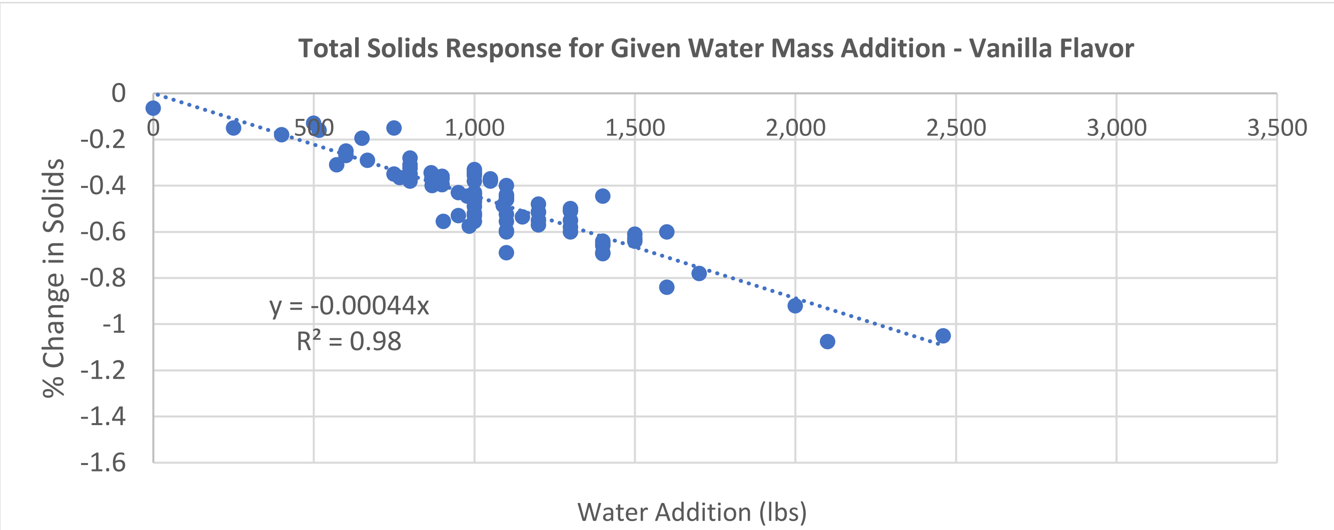

Figure 7: Impact of standardization water additions on solids for Vanilla recipe

- **Step 2:** Verify that water additions to correct for an initial solids reading are algorithm-calculated (see Figure 8). These results show due to high R-squared value than an algorithm / look up table is used. This was confirmed during the site visit at MFI.

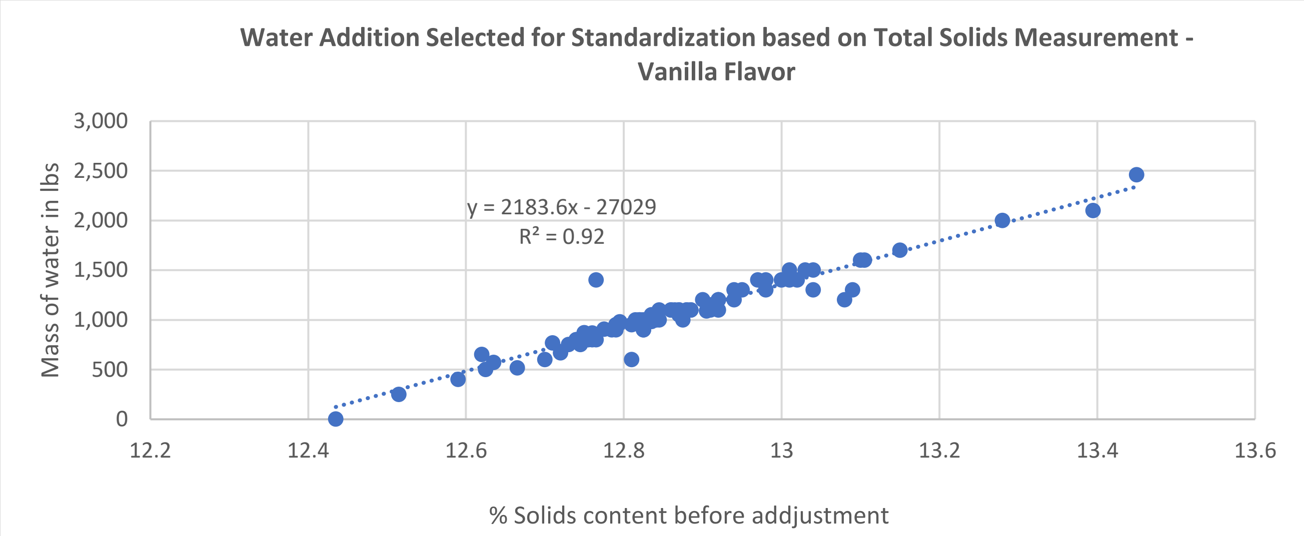

Figure 8: Water addition mass to adjust solids demonstrating tight adherence to the line of best fit

- **Step 3:** Understand the effect on samples stratified by weight of water addition. The data reveals greater solids variation when additions are <500lbs (see Figure 9). The standard deviation for a given stratified weight range of water shows that variation is nearly 10x higher at the lower end of water additions (see Figure 10).

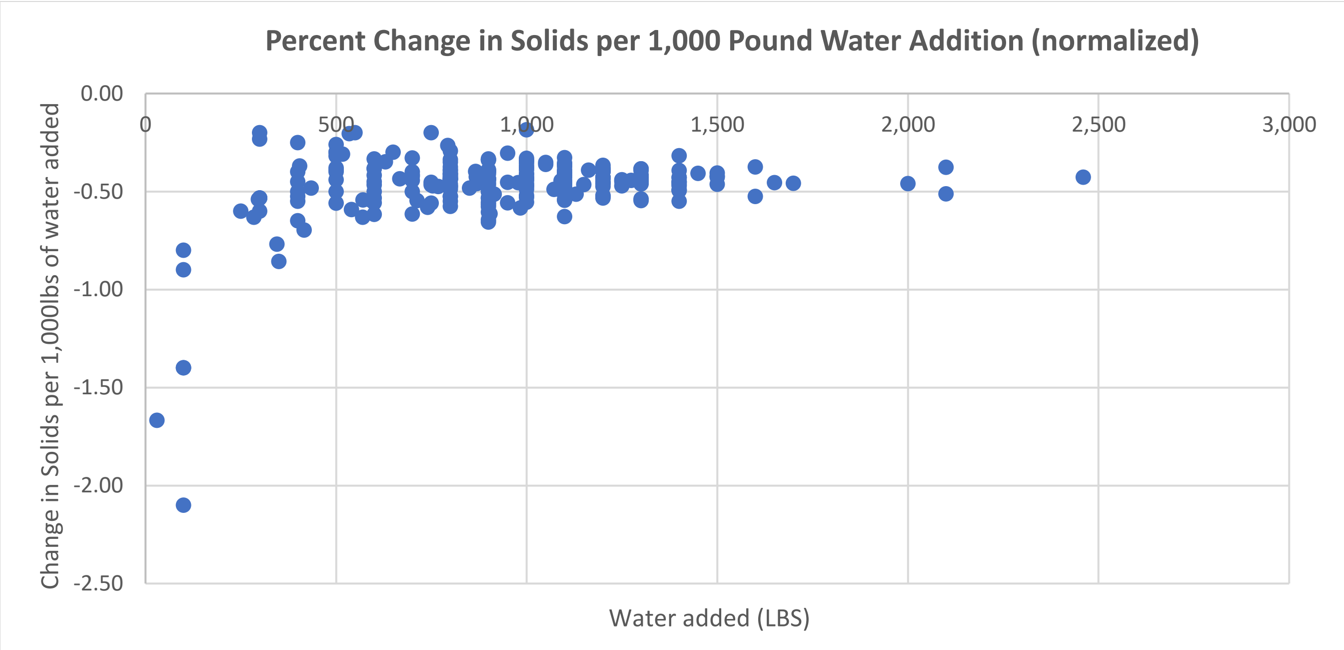

Figure 9: Normalized solids (change per 1,000lbs) for a given water addition, showing increased variation at lower addition volumes

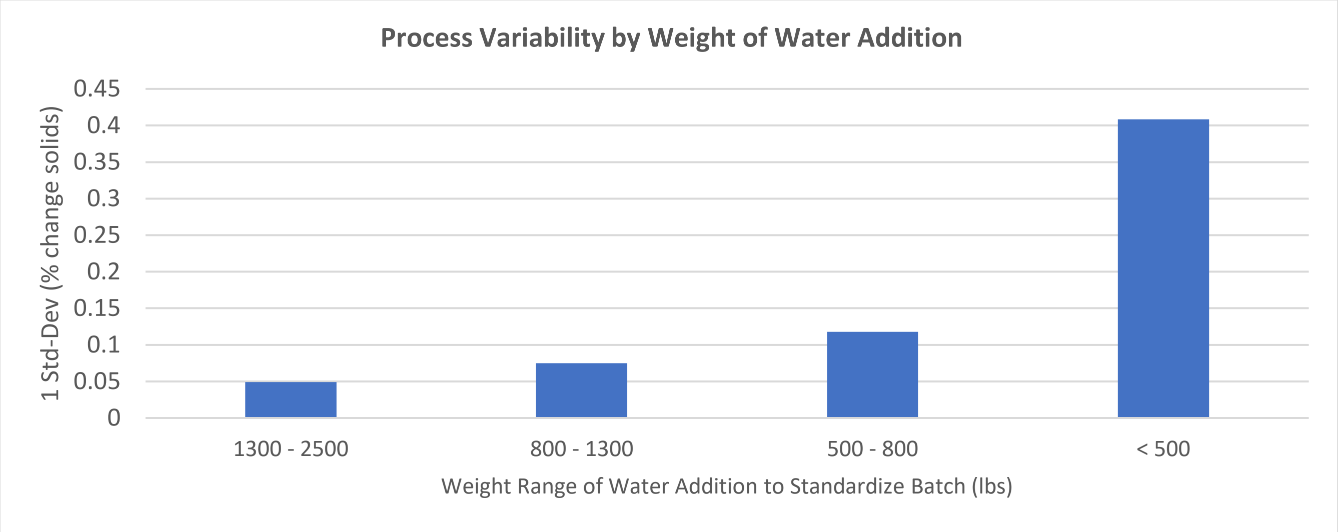

Figure 10: Process variability seen by stratified samples of water weight addition showing a 10x increase in variability as the weight in water added is less than 500 lbs

- This follows manufacturing/engineering principles: fixed water losses (valve leakage and residual water between valve and vessel) represent a larger percentage of small additions. For example, assuming 8lb residual water makes it to the tank after instructing the valve to close:
  - For a 400lb adjustment: 8/400X100 = 2.0% error
  - For a 1500lb adjustment: 8/1500X100 = 0.5% error
- Direct measurement of this residual water after valve closing would allow compensatory calculations to improve standardization accuracy:
  - Factoring in flow rate through the control valve
  - Subtracting this fixed amount from total water called for
  - Particularly beneficial for standardization adjustments below 500lbs

6.1.4.6 KOH Addition – Accuracy Analysis

The process for determining KOH requirements and measuring the pH value is consistent at MFI. The consistency of data around the best-fit line (see Figure 11) demonstrates that KOH additions during standardization are being calculated and executed based on an established algorithm at MFI.

From analysis of the standardization data shared by MFI from Oct 24 – Jan 25, we observe variation in the initial pH post batching would not conform to a 6σ process. The size of this variation is such that currently standardization elimination would not be possible until variation can be removed from the process (Table 6). Below, we have provided some guidance for reducing this variability.

Table 6: Standard deviation of pH during standardization of batches for all flavors

Recipe	Average pH (pre adjustment)	St Dev (pH units after batching)	St Dev (pH units per 20lbs KOH added)
Caramel	6.64	0.040	0.028
Vanilla	6.66	0.050	0.032
Café Latte	6.64	0.029	0.034
Chocolate	6.72	0.047	0.033

- For the target product pH range of 0.20pH units, the initial 6 sigma variation must be less than 0.033 pH units after initial batching to have a chance of meeting these targets. Currently only Café Latte with a variation of 0.029 pH units could meet this target.
- It is not currently known why we see differences in the variation between the flavors. The impact of the standardization (KOH) addition is very similar for all flavors, with standard deviations ranging from 0.028-0.034 pH units per 20lbs of KOH added. This indicates a consistent and predictable response to pH adjustments.

- The range in pHs between flavors is due to recipe, with chocolate being more alkaline than the other flavors. If standardization for pH were eliminated a recipe specific mass of KOH would have to be used for each flavor.

Several improvement opportunities exist to reduce process variability:

- Operator training and process consistency
  - The batching operator indicated to the team that the recommended weight of KOH to be added to the batch is sometimes not followed.
  - The operator is going off historical evidence that the value may push the batch out of specification and a slightly more conservative approach is taken (less KOH added).
- Residual peracetic acid from CIP cycles could potentially lower pH in first post-CIP batches
  - Current data does not identify first-CIP batches, preventing verification of any pH drop
  - Further analysis with CIP-batch identification would be valuable
- pH probe storage and maintenance recommendations
  - Store probes in 3M KCl (potassium chloride) solution rather than pH 7.0 buffer to maintain hydrogen ion concentration within the probe, giving more consistent and accurate readings over time.
  - Use pH 7.0 buffer only for calibration checks
  - Implement monthly protease cleaning (e.g., Pepsin-HCl) to remove protein buildup from the glass bulb of the pH electrode.
    - This buildup can decrease the responsiveness of the probes.
    - Adjust cleaning frequency if response time improves significantly after cleaning
    - Consult probe manufacturer for specific protease recommendations (e.g., sachets of protease powder).

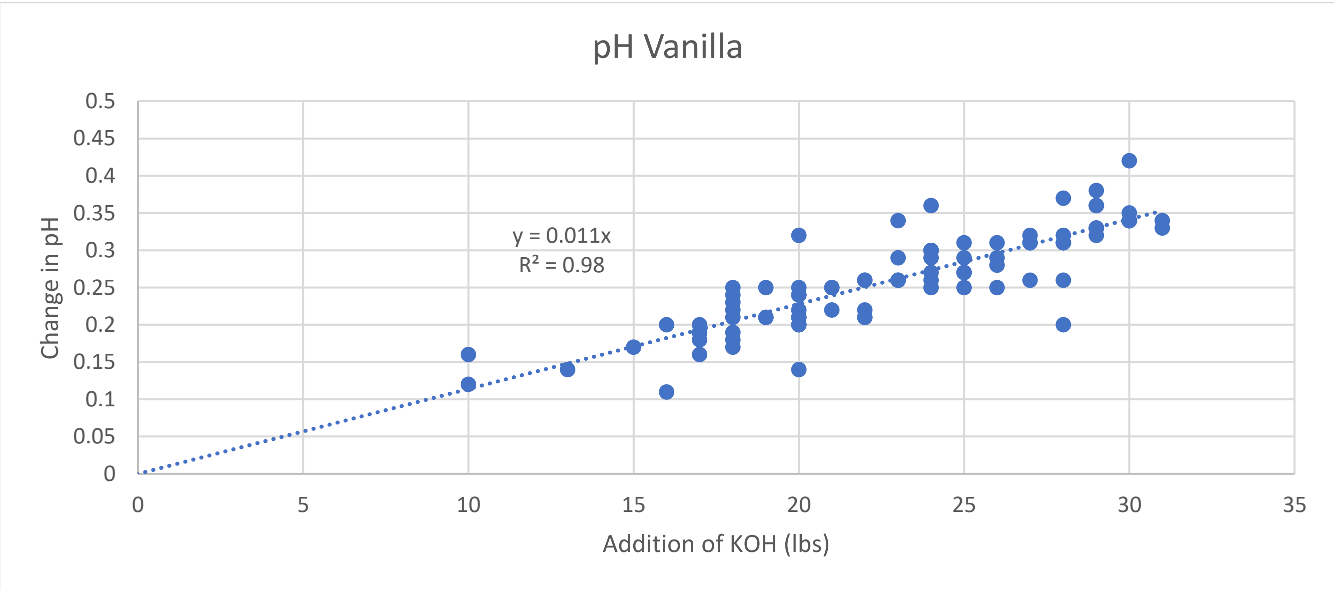

Figure 11: Impact of standardization additions on pH for *vanilla*

6.1.5 Contributing Factor to Bottleneck: Process Design

6.1.5.1 Current State Overview

The batching process design was evaluated for improvement opportunities from ingredients and water addition to transfer into the surge tank. The current batching time leads to product shortages at the fillers which forces production lines to go idle. It was necessary to develop a current state process model (Figure 12) to use as a baseline for developing an improved model.

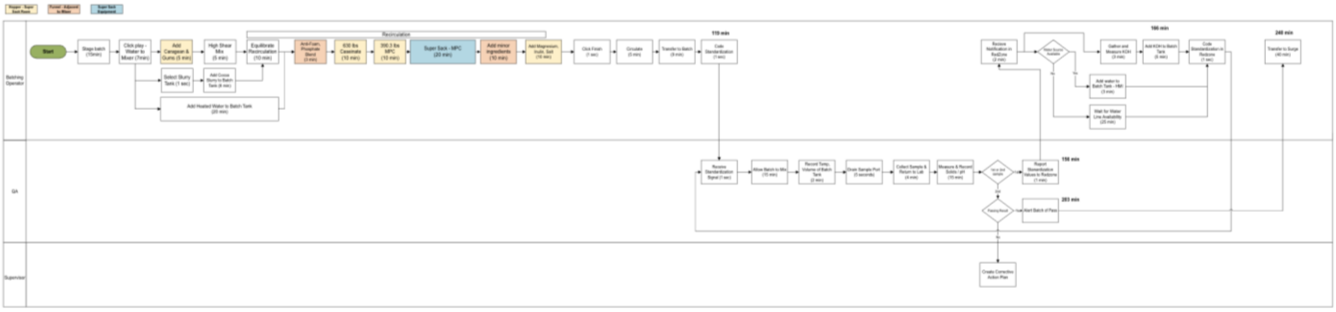

Figure 12: Current state process flow - 240 min end-to-end

The critical path in the process was measured to determine the total process time is approximately 241 minutes from batch make-up to transferred to the surge tank (see Table 7). The focus of the brainstorm primarily focused on the batch make-up process and utilizes the resources in the most efficient way.

Table 7: Current state – process times for batching milestones

Process Milestone	**Process Time (min)**	**Cumulative Time (min)**
Batch Make-Up (Start to Transfer to Batch Tank)	119	119
Standardization Values (e.g. KOH / Water) Reported to Batch Operator	36	155
Water & KOH Addition	10	165
Solids & pH Values Confirmed	36	201
Transfer to Surge Tank	40	241
Total Time	**241**	**241**

6.1.5.2 Future State Batching Process

The team collaborated with a cross-function group including members from MFI process engineering, quality, continuous improvement and production line operators to develop an optimized process which utilized the available production resources and equipment more productively (see Figure 13). The redesigned process does not require capital expense to be implemented but does require validation to ensure all finished product specifications are maintained within specification. For a detailed and clearer view of each process flow – please see the attachments in the ANNEX.

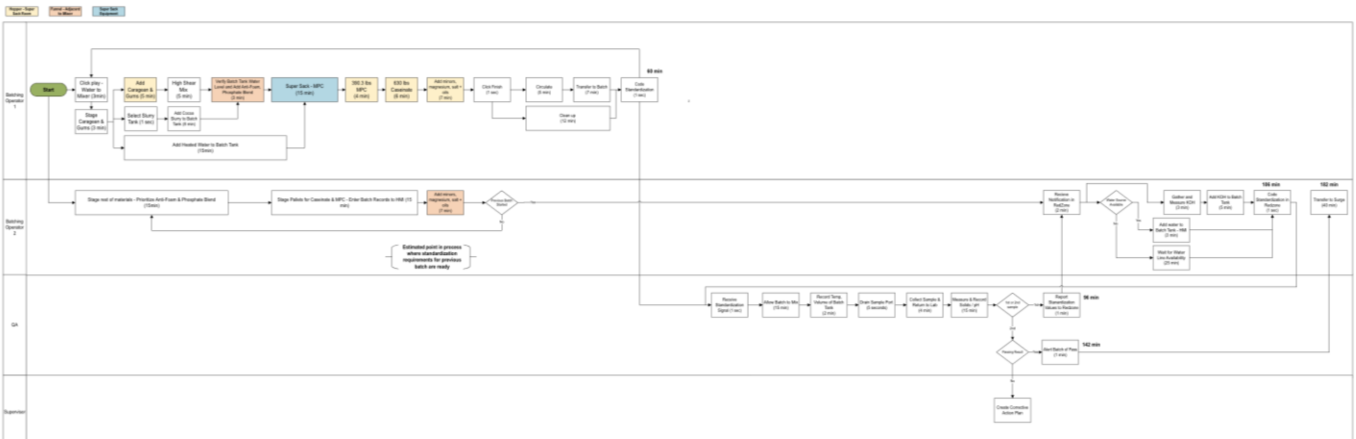

Figure 13: Proposed future state process flow - 182 min end-to-end

The waterfall diagram (see Figure 14) shows eight targeted initiatives to achieve the future state batch time. The detailed description of each process modification can be seen in Table 8.

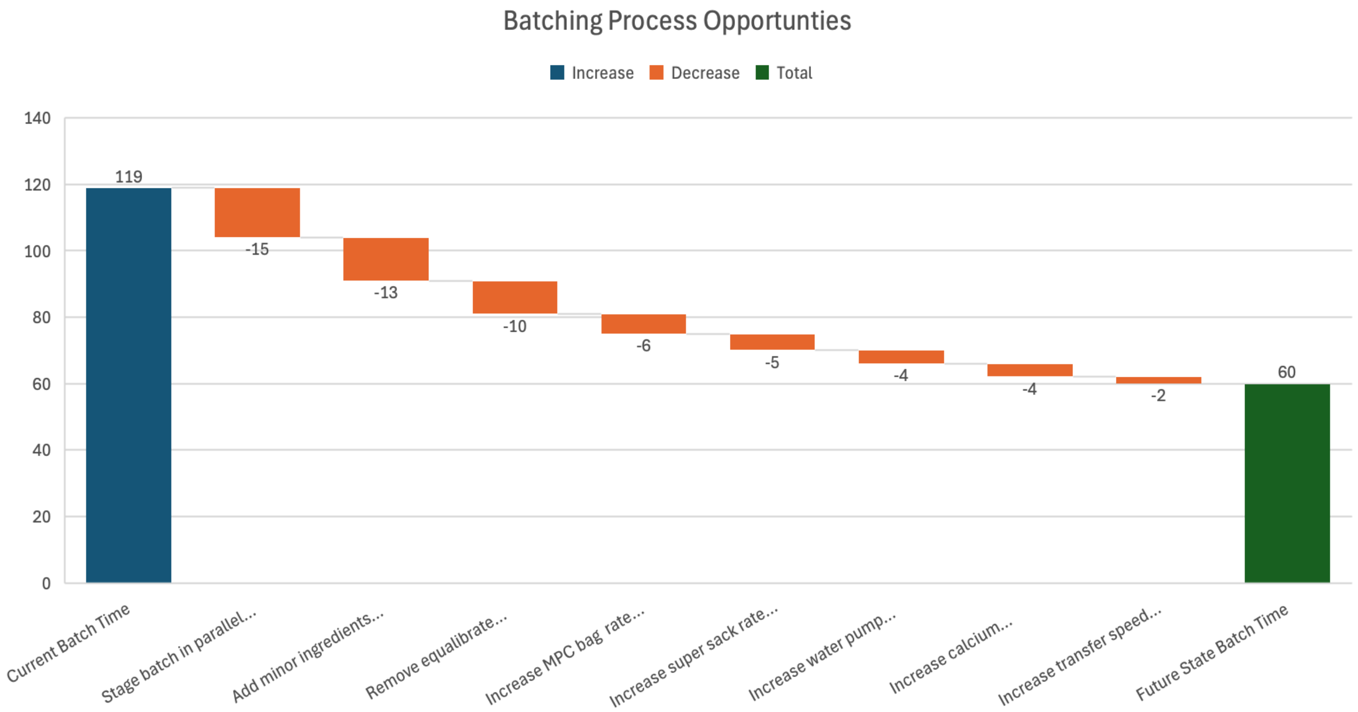

Figure 14: Waterfall diagram of batching process improvement opportunities

Table 8: Detailed breakdown of batching process improvements

Process Improvement	Time Savings (min)	Supporting Analysis
Stage batch in parallel with filling mixer	15	• Process change / training – MFI to evaluate feasibility
Add minor ingredients and oils in parallel using hoppers and funnels	13	• Process change / training – MFI to evaluate feasibility. • Section 6.1.3.3 shows a model indicating the rate of addition will not exceed design thresholds.
Reduce as much as possible equilibrate recirculation wait	5 - 10	• Section 6.1.3.3 shows a model indicating the rate of addition will not exceed design thresholds.
Increase MPC bag rate of addition	6	• Section 6.1.3.3 shows a model indicating the rate of addition will not exceed design thresholds.
Increase super sack rate of addition	5	• Section 6.1.3.3 shows a model indicating the rate of addition will not exceed design thresholds.
Increase water pump speed	4	• Process change – MFI to evaluate feasibility – Does not affect product quality
Increase calcium caseinate bag rate of addition	4	• Section 6.1.3.3 shows a model indicating the rate of addition will not exceed design thresholds.
Increase transfer speed from high shear mixer to batch tank	2	• Process change – MFI to evaluate feasibility – Does not affect product quality

The resulting proposed process removes an estimated 60 minutes from the end-to-end process, and additionally, there were opportunities identified in improving the turnaround time of quality checks and batch transfers to surge tank (see section 6.1.6). The detailed breakdown of where the proposed savings occur in the process can be seen in Table 9. It should be noted that any implemented and permanent process changes must be communicated to PNC through the Transfer Packet Form.

Table 9: Future state process milestones and improvements in time

Process Milestone	Cumulative Time (min)	Time Reduction (min)
Batch Make-Up (Start to Transfer to Batch Tank)	60	59
Standardization Values (e.g. KOH / Water) Reported to Batch Operator	36	0
Water & KOH Addition	10	0
Solids & pH Values Confirmed	36	0
Transfer to Surge Tank	40	0
Total Time	**182**	**59**

6.1.6 Additional Opportunities

The following additional opportunities came up during side-conversations but not vetted by the cross-functional group. If implemented, the maximum reduction in batch time would be 95 minutes (from the current state). These opportunities need to be discussed further and validated for feasibility.

6.1.6.1 Reducing mixing time in batching tank prior to lab samples collected

Exploring opportunities to reduce mixing time prior to standardization sample is collected. This process is currently 15 minutes (see Figure 15), and any reduction would create a direct minute-for-minute benefit in throughput. An analysis must be done to determine the point where additional agitation in the batch tank does not produce a more homogenous product mix.

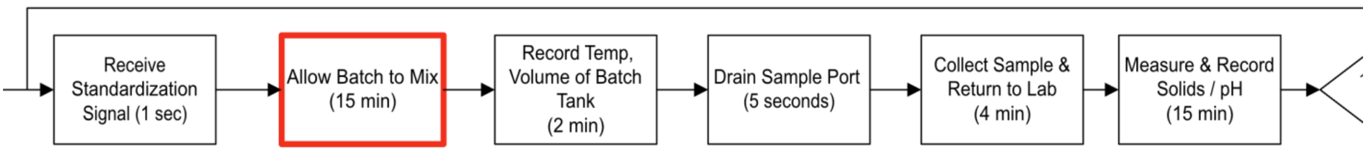

Figure 15: QA reporting lab values for total solids and pH

6.1.6.2 Sampling product from surge tank after standardization

Additionally, it may be possible to confirm the total solids and pH values after standardization is complete in the surge tank. This would save the 36 minutes required to do the testing as the sample could be drawn from the surge tank as the transfer is occurring instead of waiting for a 2nd round of test results (see red process line in Figure 16). It will be critical to ensure any samples collected in the surge tank are representative of the total batch and properly homogenous.

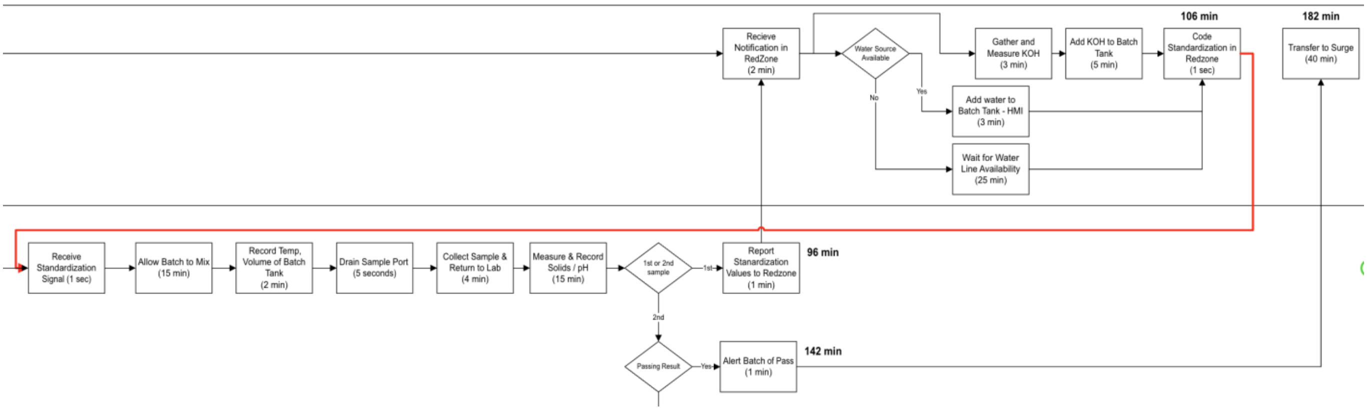

Figure 16: Process flow from standardization to second round of lab testing

6.1.6.3 Preload KOH into batches

The standardization data collected for pH shows a lower standard deviation compared to total solids measurements. It may be possible for a large majority of batches to pre-load the full amount of KOH into the initial batch makeup and still be within the pH specification range. Eliminating this downstream step would prevent the operators from measuring KOH and climbing a ladder to deposit into the batching tank. This would result in a net savings of 5 minutes (note: the full 8 minutes cannot be realized because there is 3 minutes of time where water is added in parallel). To remove this step, it would need to be validated that batches will consistently pass the final pH measurement.

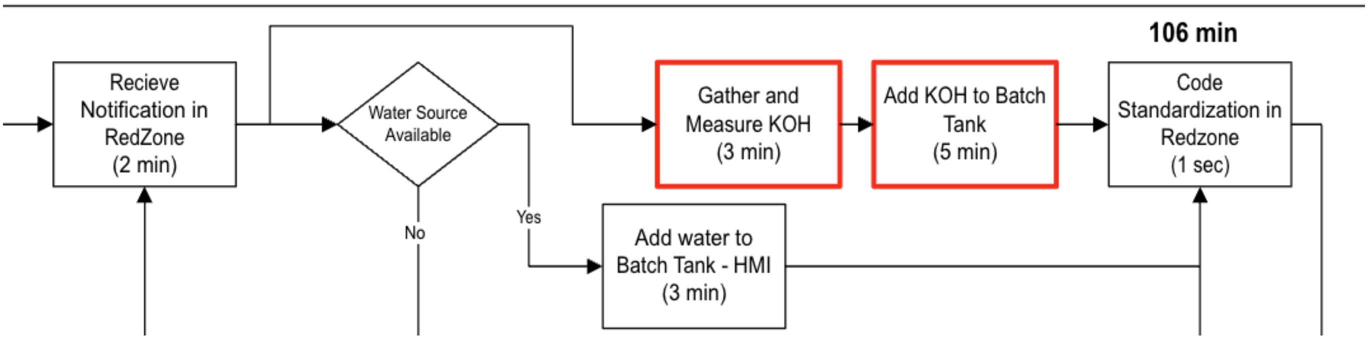

Figure 17: KOH addition steps

6.1.6.4 Increasing transfer speed from batch tank to surge tank

The batch to surge tank transfer occurs at 100 gallons per minute, and with 4000-gallon batches, that transfer is consistently around 40 minutes (Figure 18). It will be investigated into the maximum transfer rate could be increased to reduce the overall batch turnaround time. The transfer of liquid also includes a cooling step (product must be < 45F within 5 hours of the first introduction of water to an ingredient).

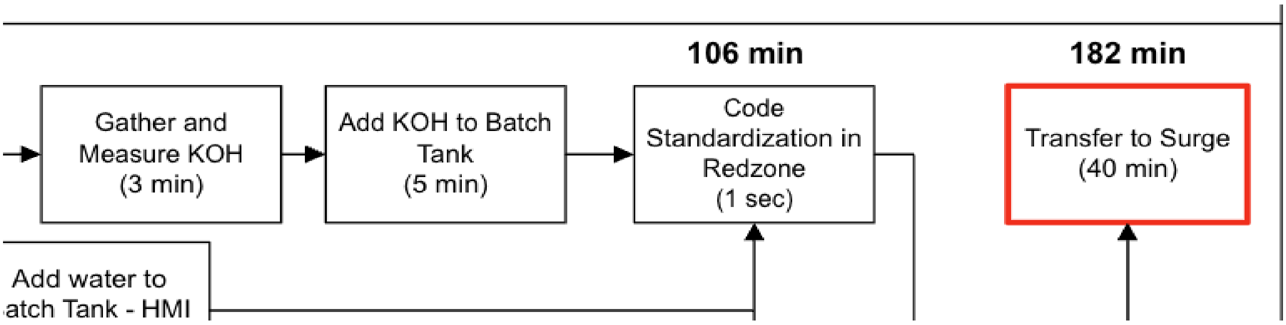

Figure 18: The final step in the batching process - transfer to surge tank

Table 10: Additional opportunities for time savings not vetted with cross-functional team

Process Milestone	Cumulative Time (min)	Reduction Time (min)
Batch Make-Up (Start to Transfer to Batch Tank)	60	59
Standardization Values (e.g. KOH / Water) Reported to Batch Operator	31	5
Water & KOH Addition	5	5
Solids & pH Values Confirmed	0	36
Transfer to Surge Tank & Solids & pH Values Confirmed	30	10

Total Time	**126**	**95**

6.1.7 Recommended Next Steps

Implementing these process changes require a multi-step approach to ensure quality and process requirements are maintained. The recommend next steps are the following:

- PNC to validate process changes will not adversely affect product quality and develop any required test results to ensure requirements are met
- Perform 5-10 time studies of a chocolate based flavor to validate the current state to ensure the time savings realized are objective
- MFI to evaluate the feasibility of each proposal and report back challenges, as needed
- Implement as many ideas as feasible and measure the result with 5-10 time studies
- Model the updated process with Tetra Pak simulation software to understand plant capacity and develop a roadmap for further process improvements (if needed)

6.2 Waste Analysis

6.2.1 Overview

A waste stream analysis provides a systematic approach to understanding and quantifying production losses in a manufacturing facility. By identifying where waste occurs, manufacturers can implement targeted process improvements, reduce costs, and increase operational efficiency. In this report, we leverage a loss tree analysis to map the sources of waste across all the production stages. This analysis focuses on three key areas—batching and processing, filler and packaging equipment, and quality hold—to assess material losses and identify potential opportunities for waste reduction.

The overall plant waste (Figure 19) was calculated as the sum of all waste streams detailed in the following sections. The months of August – December indicate waste levels beyond the production levels, and this is due to an effort to clear a backlog of quality hold inventory which required destruction from previous months. It is important to note that quality hold waste data from March – July was not included in the figure below, and this was assumed to be built into the backlog clearing events previously mentioned. The calculations measured by the PA team on site varied significantly from the MFI shrinkage calculations (orange bars). It is important to understand the variances between the two methods and reconcile.

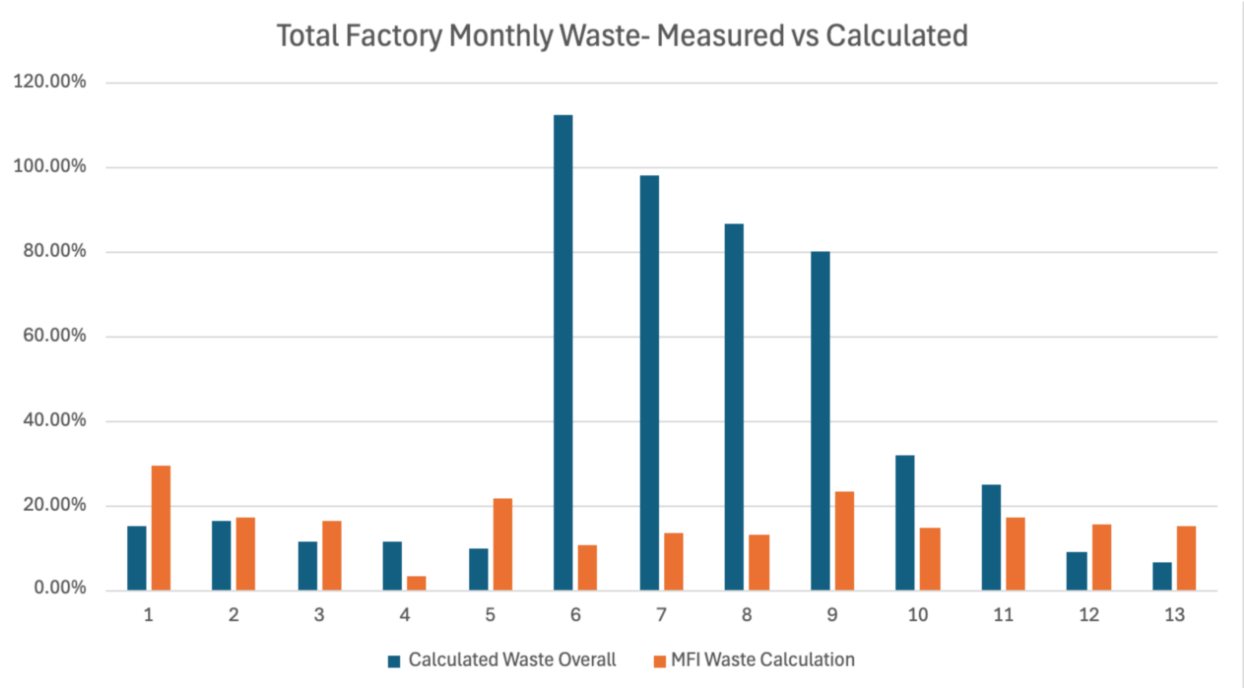

Figure 19: Comparison of calculated plant waste March 2024 - February 2025

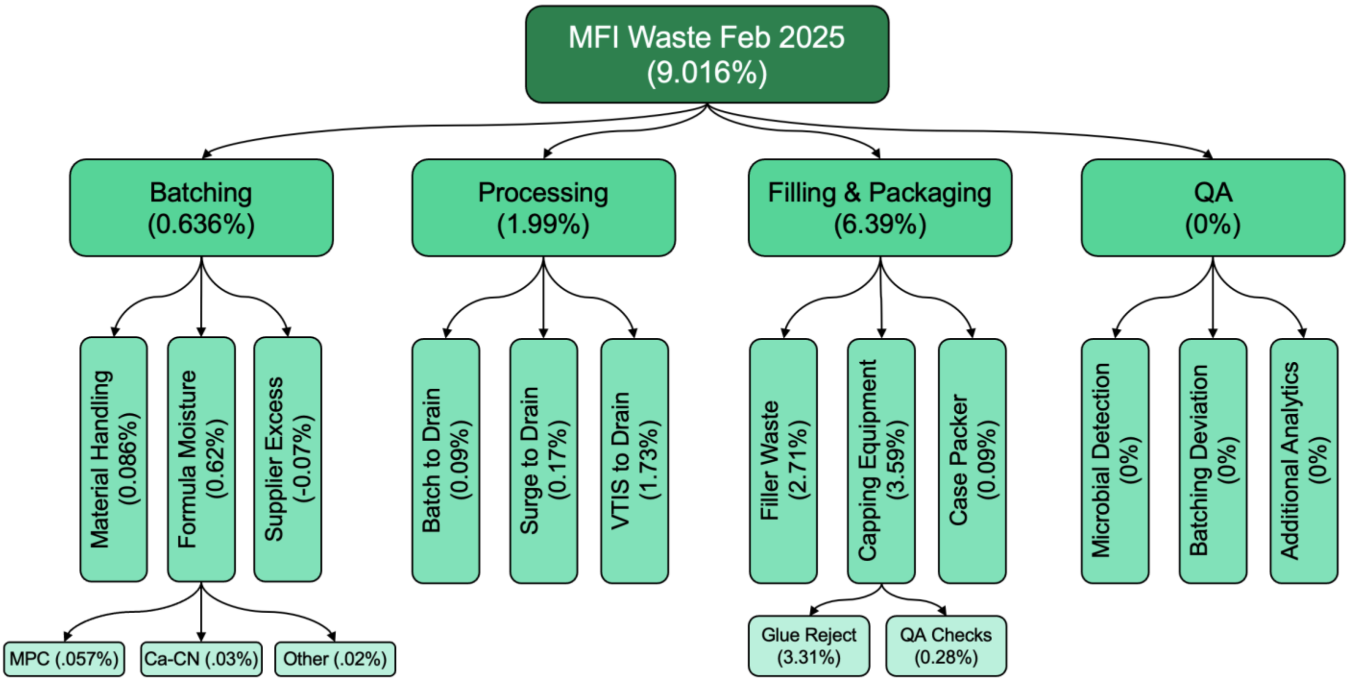

Figure 20: Loss Tree Analysis - End to End Waste for February 2025

6.2.2 Waste Stream: Batching

The batching and processing stage is a critical upstream phase in protein shake production where raw ingredients are combined, mixed, and prepared for aseptic filling. Waste in this stage can arise from ingredient handling inefficiencies, such as losses during air cyclone dumping, leftover powder in ingredient bags, and ingredients delivered from suppliers on the high side of total solids. A detailed breakdown of waste in batching can be seen below (Figure 22), but it's important to note that batching waste (0.636%) represents a small portion of the total waste seen in the facility (9.016% in Feb 2025).

6.2.2.1 Waste calculation methodology – Cyclone Losses

The cyclone is designed to capture powders which enter the air during debagging to prevent them entering the local atmosphere and creating hazards for workers. The discharge bin was weighed after completing a batch, and this weight (1.3lbs) was divided by the total powders entering the batch (3,665.8lbs) to give a waste value (0.04%). Table 11 shows the recorded values and measured waste.

Table 11: Cyclone discharge waste

Description	Weight (lbs)
MPC Added (Bags)	352.8
MPC Added (Kit)	37.5
Calcium Caseinate (Bags)	606.4
Calcium Caseinate (Kit)	23.6
Super Sack Add	2,645.5
Total Ingredient Weight	3665.8
Measured Discharge	1.3
Waste Percent	**0.04%**

6.2.2.2 Waste calculation methodology – Supplier Quantity Shipped

Although not a contributing factor to waste, the suppliers will typically ship above the nominal weight target (see Table 12). This excess amount was characterized for MPC and Calcium Caseinate bags. There was not an accurate enough measurement system for the MPC super sacks, but we assumed the excess in the super sacks to be the average between MPC and Calcium Caseinate (0.065%). Five samples for each ingredient type were measured with the bag weight subtracted from the total. This value was divided by the claimed weight of the manufacturer to calculate the excess shipment.

$$Excess\ Shipped\ Product = \frac{Claimed\ Weight - (Average\ (Measured\ Weight - Bag\ Tare))}{Claimed\ Weight}$$

Table 12: Average product excess of MPC and Calcium Caseinate

Ingredient Type	Sample #	Claimed Weight	Measured Weight	Excess Shipped	Excess %
MPC	1	44.0925	44.15	0.0575	0.13%
MPC	2	44.0925	44.17	0.0775	0.18%
MPC	3	44.0925	44.14	0.0475	0.11%
MPC	4	44.0925	44.11	0.0175	0.04%
MPC	5	44.0925	44.12	0.0275	0.06%
				MPC Average Excess	**0.10%**
Calcium Caseinate	1	55.1156	55.15	0.0344	0.06%
Calcium Caseinate	2	55.1156	55.11	-0.0056	-0.01%
Calcium Caseinate	3	55.1156	55.14	0.0244	0.04%
Calcium Caseinate	4	55.1156	55.14	0.0244	0.04%
Calcium Caseinate	5	55.1156	55.13	0.0144	0.03%
				Calcium Caseinate Average Excess	**0.03%**

6.2.2.3 Waste calculation methodology – Leftover Bag Waste

Leftover material during the debagging process (see Figure 21) is waste product and sample bags were retained after the batching process was completed. The excess material was extracted for weighing. Five samples were collected, and the excess weight was divided by the shipped weight.

$$Excess\ Shipped\ Product = \frac{Average\ (Leftover\ Waste)}{Claimed\ Weight}$$

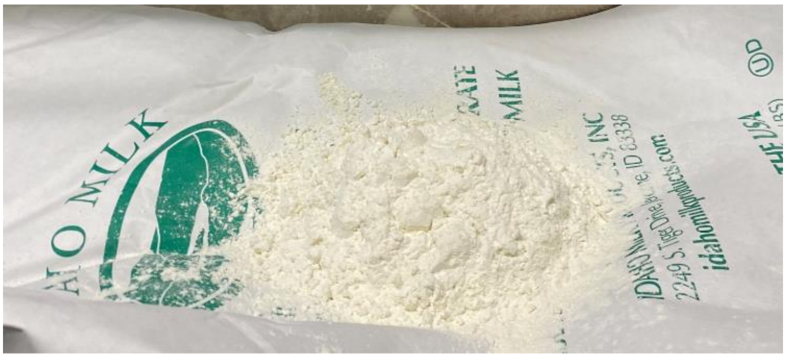

Figure 21: Representative sample of 1% MPC waste per 44 lb (20kg) bag (Note: for illustrative purposes only, not related to the excesses seen in the bag which is a much lower quantity)

Table 13: Leftover product in MPC and Calcium Caseinate bags

Type	Format	# of Sample	Weight	Shipped Weight	Average Waste	% of Total (all powders)
MPC	Bag	5	0.30	44.09	0.06	**0.015%**
Calcium Caseinate	Bag	5	0.47	55.12	0.09	**0.031%**

6.2.2.4 Batching Loss Tree Analysis

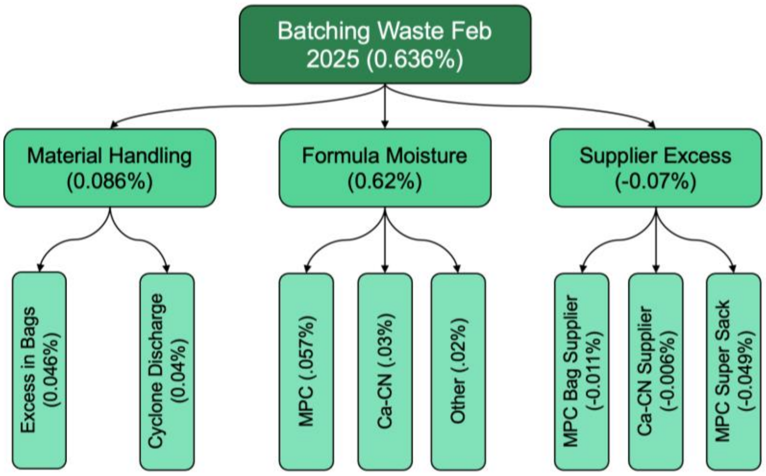

Figure 22: Batching loss tree analysis

6.2.3 Waste Stream: Processing

6.2.3.1 Waste calculation methodology – Example VTIS product drain

As the finished batch product moves through the process, there are programmed steps to send product to water and some product to drain. The process characterized includes mixer to batch tank, batch tank to surge tank, and surge tank to VTIS system. As the product was sent to drain, it typically begins as water and transitions to product by the end of the programed waste step (see Figure 23)

Figure 23: Waste product being sent to drain from VTIS

The team captured samples as the drain step was occurring and measured the total solids using the on-site CEM equipment to determine the “Product Equivalent Waste Gallons”. An example of this calculation can be seen in Table 14. The equivalent waste gallons can be calculated by taking the measured solids percent divided by the nominal target total solids (12.65% for chocolate) and multiplying this result by the gallons drained during the process step (see equation below). It was assumed that the solids percent could be linearly extrapolated for the time intervals the product was not measured.

$$Product\ Equivalent\ Waste\ Gallons = Gallons\ Sent\ to\ Drain\ \times \frac{Measured\ Solids}{Nonimal\ Solids\ Target}$$

Table 14: VTIS calculated waste during drain step

VTIS Calculated Waste – Chocolate product

Gallons	Solids	Measured / Extrapolated	Product Equivalent Waste Gallons
100	0.22	Measured	
90	3.45	Extrapolated	0.17
80	6.68	Extrapolated	2.73
70	9.91	Measured	5.28
60	10.37	Extrapolated	7.83
50	10.83	Extrapolated	8.20
40	11.29	Measured	8.56
30	11.41	Extrapolated	8.92
20	11.54	Extrapolated	9.02
10	11.66	Extrapolated	9.12
0	11.78	Measured	9.22
		Total Waste	**69.06**

6.2.3.2 Loss Tree – Processing

The losses measured during processing can be seen in the loss tree analysis diagram (see Figure 24). These are the only sources of loss which can occurring between the high shear mixer and aseptic tanks. The cumulative losses during processing are 1.99% of the batch.

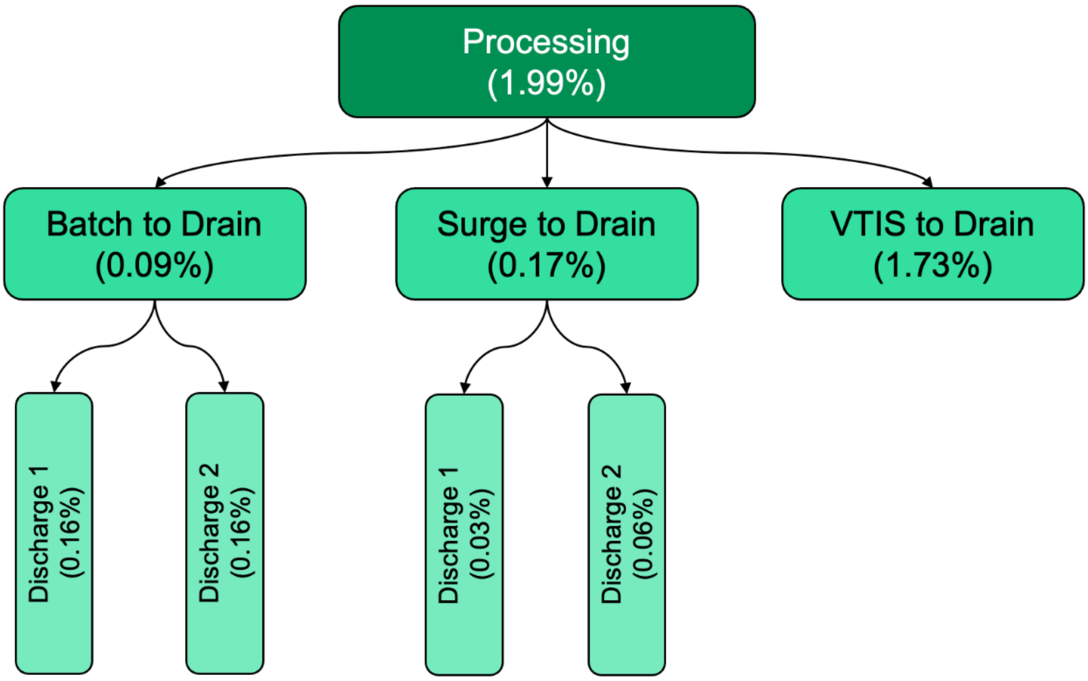

Figure 24: Loss tree analysis – Processing

6.2.4 Waste Stream: Filler and Packaging Equipment

Filler and packaging equipment are required in converting processed product into sealed, market-ready cartons. This stage can generate significant waste due to equipment restarts and subsequent programmed mechanical rejections. Improper capping, which can compromise package integrity, also leads to rejected cartons. In total, this process area is one of the largest contributors to the total waste and should be a focus area for improvement. See loss tree analysis breakdown for further detail (Figure 26).

6.2.4.1 Filler Waste Analysis

There are two factors which contribute to filler waste. The first, "line down events", occurs when a filler is shutdown, which requires certain numbers of waste product to be rejected to ensure package integrity and the subsequent QA inspection to verify the machine has been restarted correctly. The majority of waste is due to filler shutdowns which occur frequently due to issues with the filler or downstream equipment.

During normal operation, QA inspections are required to ensure package integrity. It should be clear that, inspections are not wasteful activities and are required to prevent substantially more waste from occurring, and as a percentage of total production, these samples represent a small portion, 0.11% on average (see Table 17). These are included in the waste metrics because it's product not shipped, not that it's recommended to change / stop inspections.

Line Down Events

Every time a filler is shutdown; two things must occur upon every restart.

- **Programmed Waste:** 60 packages are programmed by the machine to be rejected to waste because the packaging will fail integrity testing, and this could cause higher rates of microbial detections during lab testing.
- **QA Sample:** 12 packages are sampled for package integrity testing. 4 cartons are sampled line side, and 8 samples are returned to the QA lab.

The line down events where calculated using the downtime data from PLMS. The downtime events were totaled for each month (see Table 15) and the total waste was calculated (see Table 16) based on the programmed and planned waste (above bullets).

Table 15: Total downtime events Feb 2024 - Jan 2025 collected from PLMS data

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
Line 1	499	629	777	786	721	803	753	779	778	630	539	406
Line 2	41	147	474	396	779	312	0	0	13	28	0	6
Line 3	516	639	731	744	761	855	683	704	913	526	478	752
Line 4	498	496	194	0	0	43	346	434	483	599	683	696
Total	**1554**	**1911**	**2176**	**1926**	**2261**	**2013**	**1782**	**1917**	**2187**	**1783**	**1700**	**1860**
Daily Stops (per filler)	13	16	18	16	19	17	15	16	18	15	14	16

Table 16: Total waste product from programmed filler stops and QA samples (March 2024 to March 2025)

Date	QA Sample – Filler Stop	Reject – Filler Stop	Reject – Filler
Mar-24	22,932	114,660	6.44%
Apr-24	26,112	130,560	6.57%
May-24	23,112	115,560	4.21%
Jun-24	27,132	135,660	4.40%
Jul-24	24,156	120,780	3.48%
Aug-24	21,384	106,920	4.57%
Sep-24	23,004	115,020	5.30%
Oct-24	26,244	131,220	3.99%
Nov-24	21,396	106,980	3.21%
Dec-24	20,400	102,000	3.79%
Jan-25	22,320	111,600	2.77%
Feb-25	22,440	112,200	2.71%
Mar-25	-	-	0.13%
Total / Average	**280,632**	**1,403,160**	**3.97%**

QA Inspections

The following sampling is required during normal filler operation:

- **Shift start / end:** 4 samples are required at shift start and shift end. There are two shifts per day and every shift will have some level filler production. The total number of shifts were calculated by the number of days in a month multiplied by 2.

$$Shift\ Start\ or\ End = \ Number\ of\ Shifts\ x\ 4\ (samples)$$

- **Every 30 min:** 4 samples are required every 30 minutes. To calculate the total waste, PLMS data for total runtime on each filler was gathered, and the number of 30-minute intervals were collected and multiplied by the sample requirements.

$$[QA\ Sample - 30\ Minutes] = \frac{Total\ Hours\ of\ Filler\ Run\ Time\ x\ 4\ (samples)}{2\ (30\ \text{min}\ intervals)}$$

Table 17: Discarded product required for QA inspections (March 2024 - March 2025)

Date	QA Sample - Shift Start	QA Sample - Shift End	QA Sample - 30 min	Waste %
Mar-24	248	248	2,048	0.12%
Apr-24	240	240	2,272	0.11%

May-24	248	248	3,128	0.11%
Jun-24	240	240	3,472	0.10%
Jul-24	248	248	3,920	0.10%
Aug-24	248	248	2,672	0.11%
Sep-24	240	240	2,640	0.12%
Oct-24	248	248	3,872	0.11%
Nov-24	240	240	3,768	0.10%
Dec-24	248	248	3,064	0.11%
Jan-25	248	248	4,568	0.10%
Feb-25	224	224	4,680	0.10%
Mar-25	248	248	3,952	0.13%
Total / Average	**3,168**	**3,168**	**44,056**	**0.11%**

6.2.4.2 Capping Waste Analysis

The glue application and inspection system are designed to ensure accurate adhesive placement and proper cap alignment during the packaging process. Glue nozzles deposit adhesive onto incoming caps, with two nozzles working in tandem to apply a consistent amount. Cameras verify the cap meets performance requirements for alignment and glue volume. These cameras can issue a rejection signal, which removes the affected carton from the line. The combined actions of the glue volume monitoring, cap alignment verification, and rejection system help maintain quality control and ensure that only properly sealed and aligned cartons continue through the production process (see Figure 25).

- **Glue Nozzles:** Two nozzles deposit glue to incoming caps
- **Camera 1:** Captures an image and calculates the glue volume (length x width)
  - Out of specification glue volume (e.g. < 0.15g, > 0.23g) is kicked from the line
  - A signal is sent to the glue dispenser to adjust pressure up / down to meet target
- **Camera 2**: Ensures the cap opening is aligned on the carton – any misaligned caps will reject the carton from the line
- **Rejection System:** Signals from cameras 1 or 2 will reject selected cartons from the line

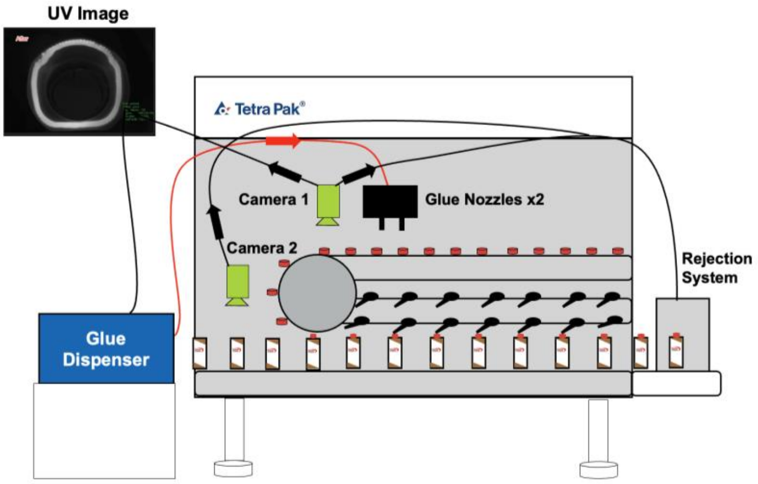

Figure 25: Capping equipment and camera detection systems for rejecting product

There are two types of waste which can come from the capping equipment, capper derived rejects and QA samples which occur on a regular cadence. These waste numbers can be seen in Table 18.

- **Capper Rejects:** A camera-based system which rejects cartons for glue or cap placement. This data can easily be extracted from PLMS.

- **QA Sample Rejects:** 12 samples are collected every 30 minutes to be tested for leaking caps. These are all waste products.

Table 18: Analysis of capping rejects - glue issues and QA samples (March 2024 – March 2025)

Date	Count of Capper Rejects	Reject - Cap / Glue Issue	QA Sample - Count	Reject - QA Sample
Mar-24	115,060	5.29%	6,144	0.28%
Apr-24	155,891	6.42%	6,816	0.28%
May-24	138,562	4.10%	9,384	0.28%
Jun-24	154,741	4.08%	10,416	0.27%
Jul-24	130,814	3.05%	11,760	0.27%
Aug-24	118,469	4.12%	8,016	0.28%
Sep-24	136,433	5.12%	7,920	0.30%
Oct-24	162,785	4.01%	11,616	0.29%
Nov-24	184,273	4.46%	11,304	0.27%
Dec-24	169,610	5.10%	9,192	0.28%
Jan-25	188,405	3.76%	13,704	0.27%
Feb-25	171,201	3.31%	14,040	0.27%
Mar-25	109,095	3.24%	11,856	0.35%

6.2.4.3 Case Packing Waste Analysis

The case packing equipment experiences waste due to cartons failing to feed correctly or being damaged (exploded) during processing, which can be caused by equipment / carton alignment issues. Since the system lacks Tetra Pak PLMS data or sensors to track waste, an estimated 80 cartons are rejected per shift. Monthly rejection data shows a range of 4,800 to 4,960 cartons per month (Table 19).

Table 19: Assumed number of rejects for the case packing equipment

Date	Reject	Reject - Case Pack
Mar-24	4,960	0.23%
Apr-24	4,800	0.20%
May-24	4,960	0.15%
Jun-24	4,800	0.13%
Jul-24	4,960	0.12%
Aug-24	4,960	0.17%
Sep-24	4,800	0.18%
Oct-24	4,960	0.12%
Nov-24	4,800	0.12%
Dec-24	4,960	0.15%
Jan-25	4,960	0.10%
Feb-25	4,480	0.09%
Mar-25	4,960	0.15%

6.2.4.4 Loss Tree Analysis: Filler & Packaging Equipment

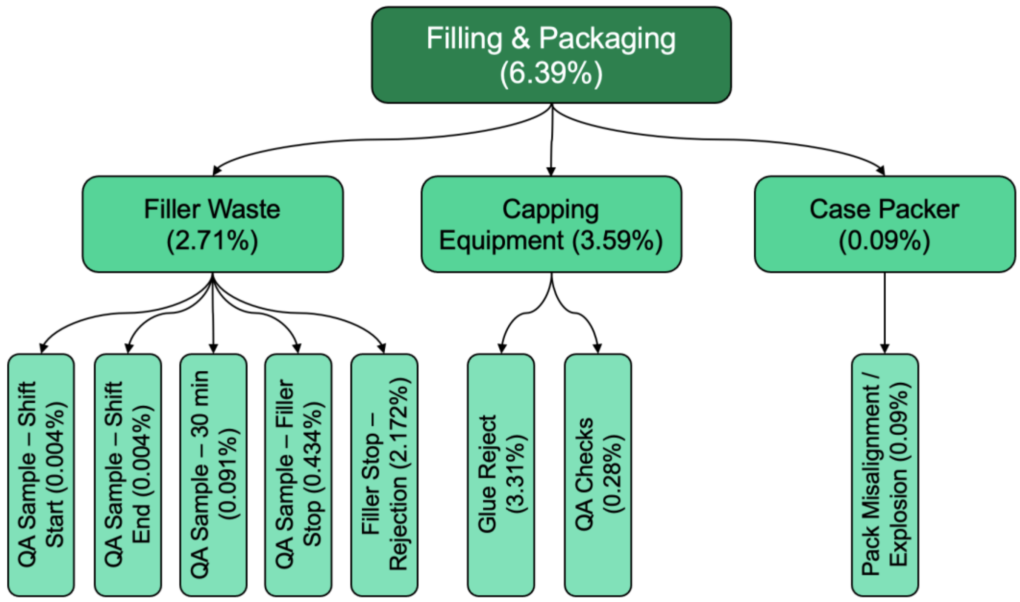

Figure 26: Filling and Packaging Waste Loss Tree Analysis - February 2025

6.2.5 Waste Stream: Quality Hold

Quality holds are implemented to prevent the release of product that may not meet established safety, regulatory, or specification standards. In an aseptic production facility, QA holds can occur due to microbiological detection, batching deviations, or additional analytics, and are natural parts of the production process which must be carefully monitored. These deviations may stem from extended surge tank hold times, out-of-spec temperature or pressure in the VTIS, or product inconsistencies like clumping, off-target total solids, pH fluctuations, or insufficient vitamin C levels. By analyzing the root causes of quality holds and the associated waste, we can enhance process control and reduce the frequency and volume of discarded product. QA holds dispositioned for destruction have shown the potential to represent a significant component of overall waste (e.g. >50 %), so tracking and improving the production processes which could lead to holds is critical to plant financial performance.

6.2.5.1 Microbiological detection

A micro detection can occur during any of the product sampling events at the filler. The sampling plans are listed in section 6.2.4 which describes the intervals and cadence for collection. A micro detection can be isolated to a single filler line, but if multiple filler lines detect a micro issue from the same batch the whole line will be investigated. The samples required for testing and discard are controlled by the process authority (Doverbrook for MFI). The investigation includes:

- Discarding product made within +/- 5 minutes of the micro detection
- Beginning, middle and end pallets from the affected line or all lines are tested – 3,000 cartons are pulled for additional testing
- If there is a 2nd failure detected, again, the product made within +/- 5 minutes of the micro detection are discarded, and an additional 3,000 samples are held for additional testing.
- The batches of 3,000 samples held for testing are either accepted or rejected based on the findings from the QA lab

The waste for micro detection can be seen in Table 20 which spans from Mar 2025 – Mar 2025. The data for micro detection is not consistent month to month for the following reasons:

- **March – July 2024:** The data used to measure waste was not reliably tracked and was excluded from the numbers. It should not be assumed there was no micro detection waste during these months.
- **August – October 2024:** The data begins to reflect actual waste numbers, but it wasn't possible to trace whether this waste was attributed to backlog inventory from previous months.

- **November – Current:** The data truly shows a remarkable improvement in reduction of micro failures due to improved production protocols and stringent testing.

Table 20: Micro detection waste broken down by 12ct and 15ct cases (March 2024 - March 2025)

Date	Lost Cartons 12 ct - Micro Detection	Lost Cartons 15 ct - Micro Detection	Micro Detection Waste %
Mar-24	-	-	0.00%
Apr-24	-	-	0.00%
May-24	-	-	0.00%
Jun-24	-	-	0.00%
Jul-24	-	-	0.00%
Aug-24	-	324,390	11.27%
Sep-24	-	261,315	9.81%
Oct-24	156,900	6,450	4.03%
Nov-24	-	-	0.00%
Dec-24	-	-	0.00%
Jan-25	-	-	0.00%
Feb-25	-	-	0.00%
Mar-25	-	-	0.00%

6.2.5.2 Batching deviations

Deviations to the batching process as submitted to the regulatory authorities results in an investigation and potential wasting of product. A deviation is most likely to occur due to product being held in the batch tank greater than 5 hours, in the surge tank greater than 24 hours, or the aseptic tank greater than 48 hours. Additionally, there could be issues related to pressure / temperature, sanitation deviations, ingredients, or other unexpected and unapproved changes to the process.

- **March – July 2024:** The data used to measure waste was not reliably tracked and was excluded from the numbers. It shouldn't be assumed there was no batching deviation waste during these months.
- **August – October 2024:** The data begins to reflect actual waste numbers, but it was not possible to trace whether this waste was attributed to backlog inventory from previous months.
- **November – Current:** Like micro detection, there has been a massive improvement to batching failures due to improved production protocols and operator training.

The total waste numbers can be seen in Table 21. As mentioned above, the data was unreliable and excluded from March to July. There was an effort starting in August to clear a backlog of product under batching deviation hold, and for the last four months, there have been no product wasted to batching process issues.

Table 21: Waste from batching deviation broken down by 12ct and 15ct (March 2024 - March 2025)

Date	Loss Cartons 12 ct- Batch Deviation	Loss Cartons 15 ct- Batch Deviation	Batching Deviation Waste %
Mar-24	-	-	0.00%
Apr-24	-	-	0.00%
May-24	-	-	0.00%
Jun-24	-	-	0.00%
Jul-24	-	-	0.00%
Aug-24	-	429,585	14.92%
Sep-24	-	236,445	8.88%
Oct-24	16,176	968,550	24.27%

Nov-24	-	435,900	10.56%
Dec-24	-	-	0.00%
Jan-25	-	-	0.00%
Feb-25	-	-	0.00%
Mar-25	-	-	0.00%

6.2.5.3 Additional Analytics

All product undergoes additional analytics which would fall outside the scope of microbiological testing. This testing covers product attributes such as clumping, total solids percent, pH level, and nutrient levels (e.g. vitamin C). Cases are pulled from the top, middle, and bottom pallets where the affected product is detected. If there is a failure, the entire pallet is sent for waste.

- **March – July 2024:** The data used to measure waste was not reliably tracked and was excluded from the numbers. It should not be assumed there was no analytics testing waste during these months.
- **August – October 2024:** The data begins to reflect actual waste numbers, but it was not possible to trace whether this waste was attributed to backlog inventory from previous months.
- **November – Current:** November was especially bad month where there was a coordinated effort to clear the backlog of “additional analytics” failures. This number represented 59% of the product produced that month, although it is likely the product was produced in previous months. The previous month, February had zero waste related to additional analytics, showing a similar improvement trend.

Table 22: Waste from additional analytics broken down by 12ct and 15ct (March 2024 - March 2025)

Date	Loss Cartons 12ct - Analytics	Loss Cartons 15ct - Analytics	Analytics Waste %
Mar-24	-	-	0.00%
Apr-24	-	-	0.00%
May-24	-	-	0.00%
Jun-24	-	-	0.00%
Jul-24	-	-	0.00%
Aug-24	69,936	2,079,135	74.6%
Sep-24	745,224	1,007,475	65.8%
Oct-24	204,804	1,717,575	47.4%
Nov-24	-	2,435,100	59.0%
Dec-24	493,584	164,430	19.8%
Jan-25	192,768	581,415	15.5%
Feb-25	-	-	0.0%
Mar-25	-	-	0.0%

6.2.5.4 Loss Tree Analysis: QA Hold

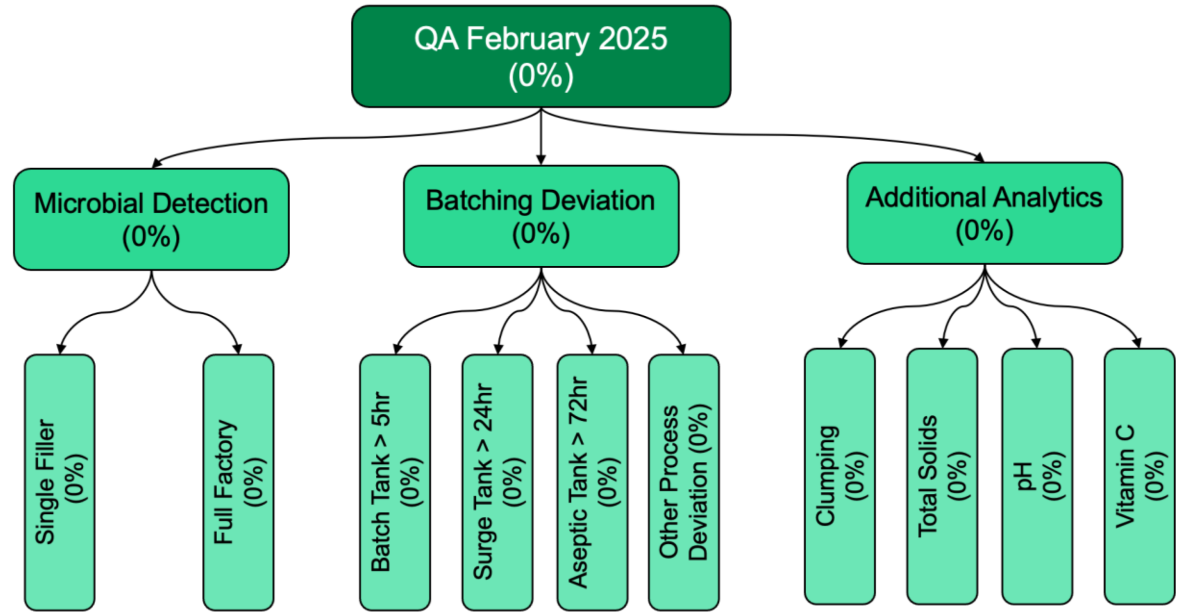

Figure 27: Waste Loss Tree Analysis - February 2025

6.3 Packaging Materials

6.3.1 Overview

Through a collaborative inspection of incoming materials, line-ready components, and finished packages, we identified several supplier manufacturing defects related to Menasha cases. These findings highlighted potential risks to both specification compliance and operational performance, demonstrating the value of systematic quality review procedures.

6.3.2 Transit Damage of Menasha Cases

6.3.2.1 Pallet Damage Causes and Implications

The primary cause of pallet damage was transit movement due to pallet instability – specifically from forward load shifting and collision with other pallets, leading to edge and corner damages. Several factors contribute to pallet movement:

- Inadequate strapping/wrapping, evident where the green straps appear non-vertical, causing stack of cases to shift, creating potential safety hazards (see Figure 28)
- Lack of strapping tension and inconsistent strap configurations – numerous strapping combinations proved unsuccessful in securing pallet contents (see Figure 29 and Figure 30)
- Strapping/stretch wrap failing to connect contents to the wooden pallet base (see Figure 31)

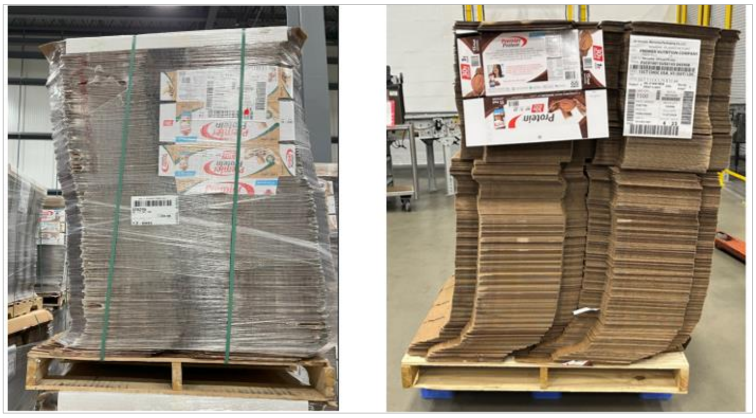

Figure 28: Pallet content slippage due to insufficient strapping/wrapping

Figure 29: Lack of *strapping* tension *and variation* in *configuration of* straps

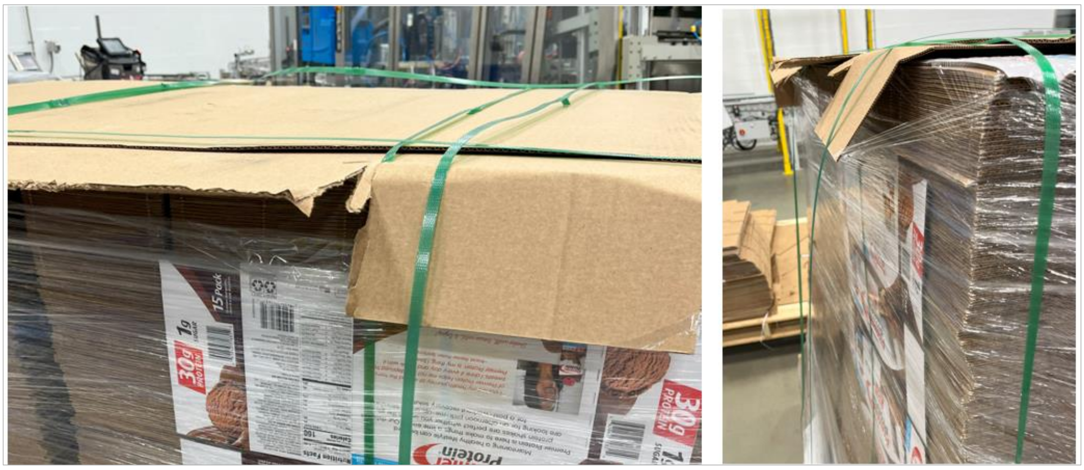

Figure 30: *Lack* of *tension in straps, creating an unsecure load*

Figure 31: *Strap and stretch* wrap not extending to the wooden pallet to secure the contents from movement

Another significant cause of damage involves inadequate protection from tensioned strapping and moisture at pallet tops and bottoms:

- Cases getting crushed and dented at strap contact points at pallet edges (see Figure 32)
- Some pallets lacked bottom protection, resulting in cases contacting the wooden pallet surface (see Figure *33*).
- White residue was observed between cases and wooden pallets, likely from pallet moisture – contamination that full pallet base coverage would prevent (see Figure 34)
- Moisture damage was observed on the base corrugate protection sheet, which then effected the bottom cases in contact with the protective sheet (see Figure 35). Since this was found already disposed, no pallet details remained to allow traceability.

Figure 32: Strapping-induced damages to cases at the top and base of the pallet

Figure 33: Pallet lacking corrugate protective sheet layer against wooden pallet

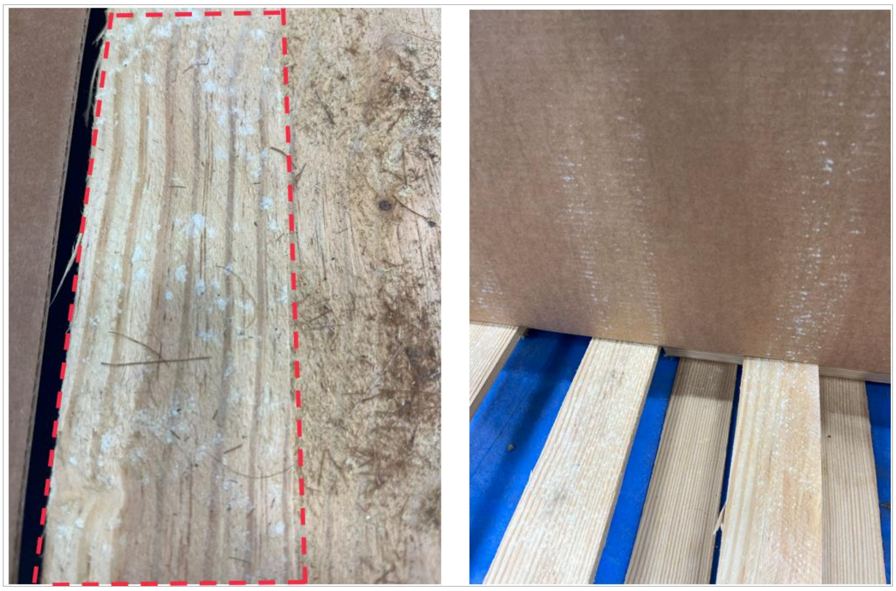

Figure 34: A white residue visible on the wooden pallet the layer pad and cases in contact with the pallet

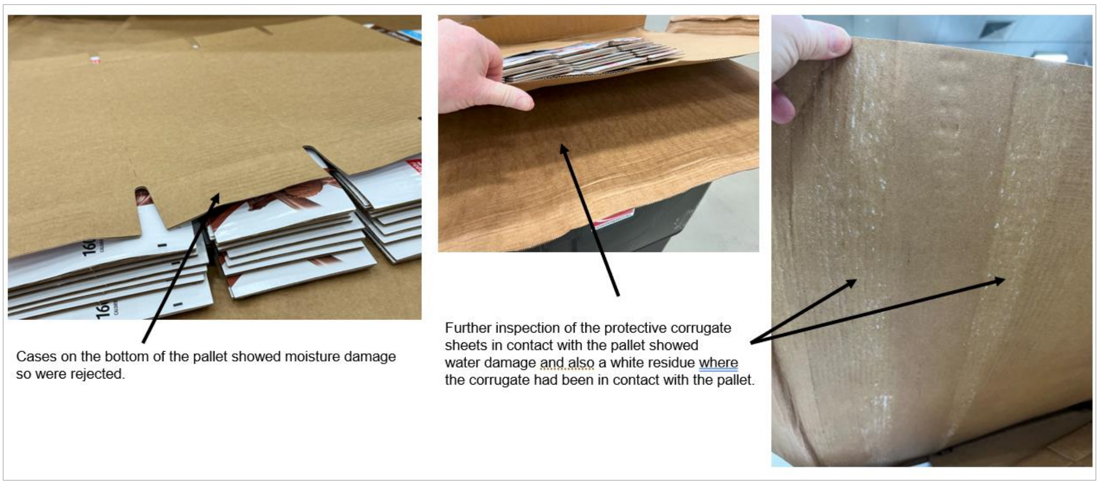

Figure 35: Moisture damage to protective corrugate sheet*, impacting corrugate cases at the bottom of pallet*

These combined issues – collision damage, tensioned strapping effects, and moisture exposure - result in significant waste. The case erector equipment cannot process materials with even minor damage, necessitating disposal of affected cases (see Figure 36 and Figure 37). Incoming packaging cases need to meet required case pallet quality to ensure proper functionality of the case erector (see Figure *38*).

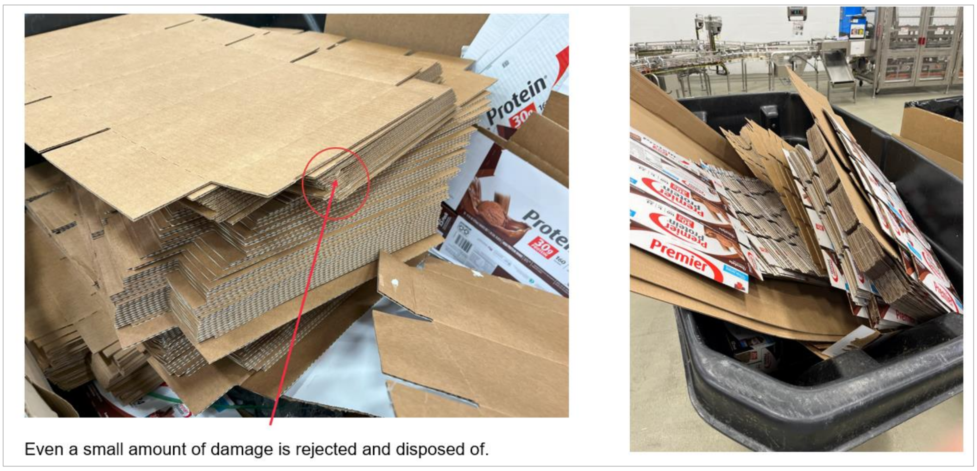

Figure 36: Rejected incoming packaging cases with minor damages

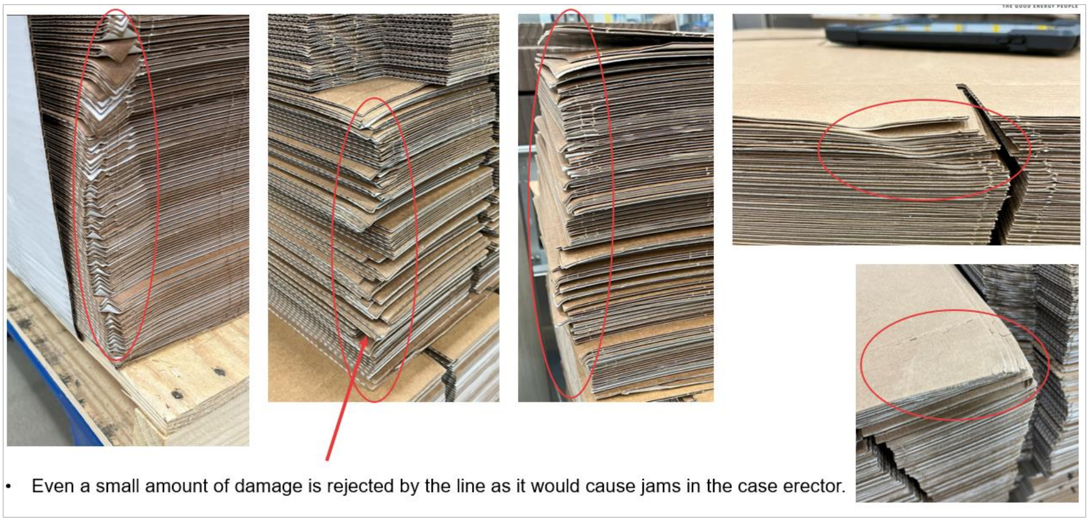

Figure 37: Additional minor damages found on incoming packaging cases requiring disposal

Figure 38: Required standard of cases for automatic case erector

6.3.2.2 Variations in Mitigation Approaches: Prevent Case Slippage

Menasha has attempted various methods to prevent the case slippage and damage during transit:

- Inserting white board sheets or corrugate layer pads between cases (see Figure 39)
- Numerous strapping combinations proved unsuccessful in securing the pallet contents (see Figure 40)

No separation A. White board sheets B. Corrugate layer pads

Figure 39: Variations in methods of separating layers to reduce movement of cases in transit

Figure 40*: Numerous strapping combinations, lacking strapping tension to secure load*

6.3.2.3 Variations in Mitigation Approaches: Improve Pallet Protection

Several methods were observed for improving protection against strapping damage and case-pallet contact:

- Applying corrugate sheet protection as top and bottom covers at strapping areas (see Figure 41)
- These approaches lack standardization, with no consistent method for applying top and bottom covers protection for the incoming cases (see Figure 42)
- Base corrugate sheets to separate cases from wooden pallets; however, some base covers were insufficient in size – they did not cover the full area of the pallet, allowing case-pallet contact and moisture contamination (see Figure 43 and Figure *44*)
- Bottom corrugate cover not fully protecting all sides of the pallet stack, leaving corners and sides vulnerable to strapping damage (see Figure 45)
- Some pallets showed optimal bottom and top case protection, effectively preventing both strapping damage and contact with wooden pallet (see Figure *46*)

Figure 41: A variation of a protective corrugate sheet as a pallet top cover to prevent strapping damage

Figure 42: Variations in protective corrugate sheets used at pallet top to prevent strapping damage

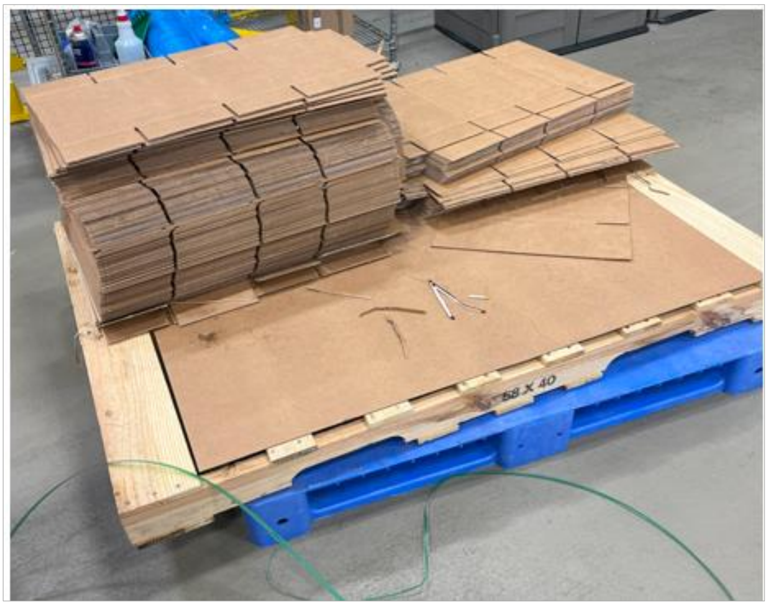

Figure 43: Base corrugate sheet not covering the entire wooden pallet

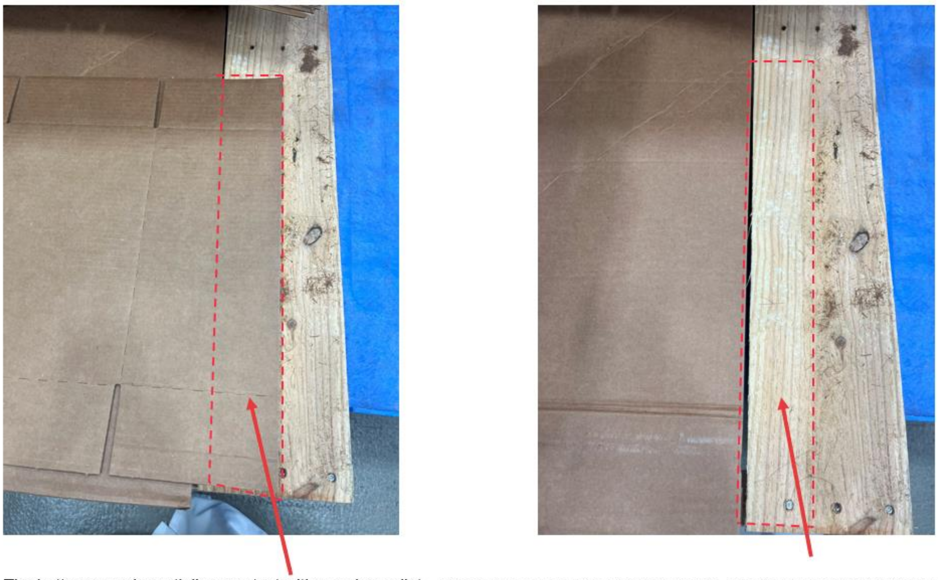

Figure *44*: Bottom cases in contact with pallet and white residue due to lack of corrugate sheet coverage

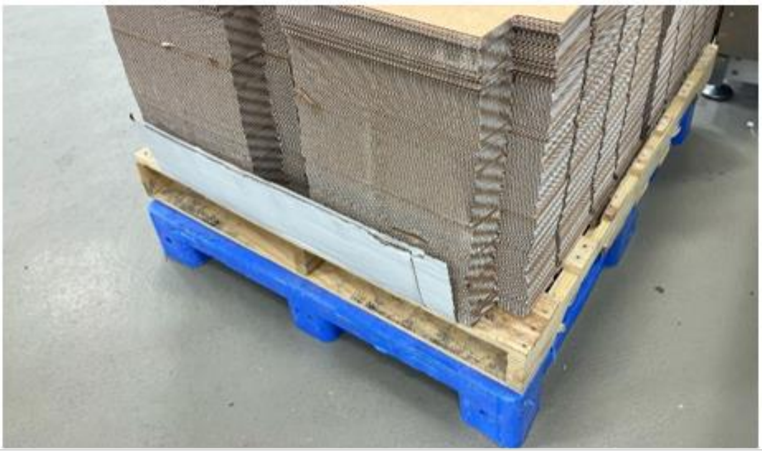

Figure 45*: Bottom corrugate cover not protecting all sides and corners of the pallet*

Figure 46: Best current method of bottom (left) and top (right) case coverage

6.3.3 Unvarnished Glue Area Variation

6.3.3.1 Variation Cause and Implications

The case design requires unvarnished areas to ensure proper bonding of hot melt glue to the board surfaces for effective case closure. Inspection revealed inconsistent positioning of these unvarnished areas, compromising glue adhesion where it contacts varnished surfaces (see Figure 47, Figure 48 and Figure *49*).

Figure 47: Case glue tab varnish free area varying in position


Figure 48: Case glue tab varnish free area varying in position with glue applied

Figure *49*: Glue not bonding to the white gloss varnished areas of the case

This is evidenced by the distinct transition in glue appearance: proper bonding shows white fiber tear in unvarnished areas, while contact with varnished surfaces results in flattened, glossy glue indicating poor adhesion (see Figure 50).

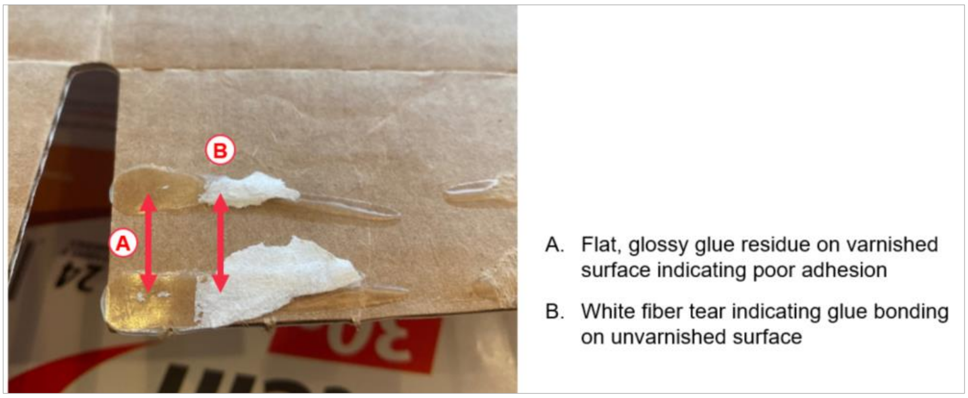

Figure 50: Case tab showing glue bonding patterns on varnished versus unvarnished surfaces

6.3.3.2 Mitigation Approach: Improve Consistency of Unvarnished Area

The 15-count case has been modified to include a completely unvarnished glue flap, improving adhesion reliability and reducing the impact of glue application inconsistencies (See Figure 51).

Figure 51: Large varnish free area on case glue flap of new 15-ct case

6.3.4 Date Coding Smudging on Case

6.3.4.1 Ink Smudging Cause and Implication

Some cases in the warehouse were observed with smudged date coding, which prevents essential product traceability (see Figure 52). This issue occurred when ink was placed on varnished case surfaces rather than the designated unvarnished areas. Affected cases were scheduled for reprinting using new equipment and a quick-drying ink system.

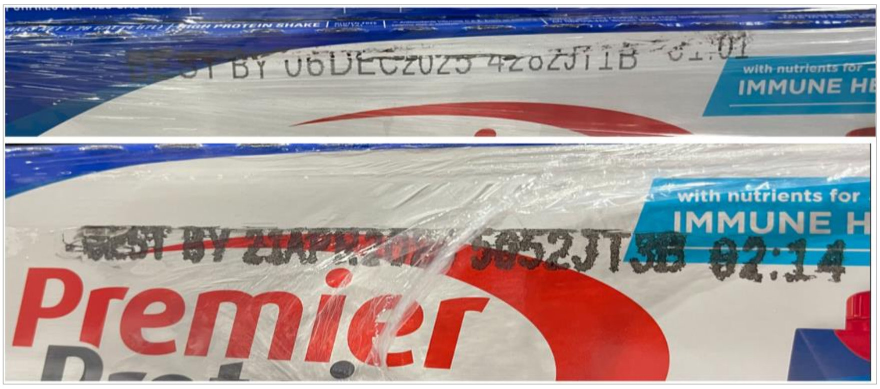

Figure 52: Coding smudging as it was not on unvarnished area on case

6.3.4.2 Mitigation Approach: Prevent Ink Smudging

More recently produced cases demonstrate significant quality improvement and elimination of ink smudging through:

- Implementation of new printing equipment and quick-drying ink system at MFI
- More precise placement of date codes within unvarnished areas (see Figure 53)

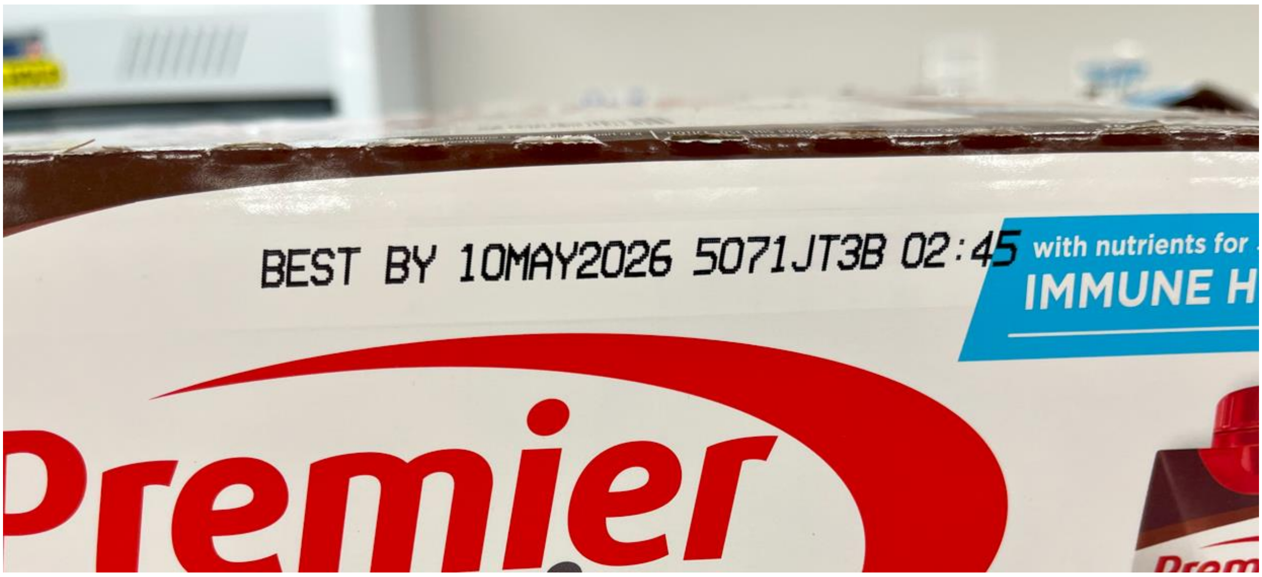

Figure 53: An alternative inkjet printer and a new ink has solved the issue with smudging

6.3.5 Pallet Label Visibility

6.3.5.1 Hidden Label Cause and Implication

Several Menasha pallets were observed with pallet labels obscured by protective packaging or incorrectly positioned (see Figure 54). This compromises warehouse efficiency and inventory management, as warehouse staff cannot readily identify pallet contents without removing or manipulating protective cover. Lack of visible labeling also creates challenges for proper stock rotation and increases handling time. Menasha to be informed that this is not acceptable as an incoming packaging standard.

Figure 54: Menasha Pallet labels partially covered with protective cover or folded making it unreadable

6.3.5.2 Mitigation Approach: Improve Pallet Visibility

Menasha to be informed that current label positioning does not meet incoming packaging standards. A revised specification should require:

- Consistent positioning of pallet labels in highly visible locations
- Labels to remain fully viewable even with protective packaging in place
- Standardized placement to improve warehouse scanning efficiency

6.3.6 Recommended Next Steps

- **Transit damage prevention:**
  - Evaluate current strapping configuration effectiveness:
    - Compare performance of 2 versus 3 and 4 PP strap configurations
    - Assess strap tension specifications
    - Ensure straps are connected to the wooden pallet
  - Note that non-slip varnish on 15-count cases demonstrated some effectiveness in preventing slippage movement
  - Implement consistent and adequate strap protection at top and base of cases
  - Add edge protection for cases using 90-degree board angled protection
  - Establish clear specifications for top and bottom corrugate protection sheets, ensuring full coverage of pallet footprint
- **Case glue area inconsistency:**
  - Investigate cause of varnish registration inconsistency, as each case should be identical
  - Address potential weakening of case structure on pallets and premature opening in store
  - Consider extending successful unvarnished glue flap design from 15-count case to other formats
- **Ink Jet coding smudging on case:**
  - Issue already resolved with the implementation of new printing equipment and quick-drying ink system at MFI
  - Develop a date code verification protocol which includes an ink smudge quality check
- **Pallet label visibility:**
  - Request Menasha to ensure all pallet labels remain visible without removing protective top covering
  - Standardize label placement position across all pallet configurations
- **Process improvements:**
  - PNC's ongoing efforts to develop clear escalation process for packaging quality issues
  - Establish photographic documentation standards for incoming packaging defects
  - Implement tracking system for packaging-related waste and operational impacts

6.4 Plant Performance Metrics / KPIs

6.4.1 Overview

The PA team introduced a KPI framework developed using industry standards and designed to leverage existing data reporting capabilities. This initiative was undertaken to enable fair network comparison across co-mans and provide benchmark data on similar products. The framework covers four categories: Operational Performance, Quality, Delivery, and Sustainability (see Figure 55).

After collaborating with various MFI functions (Continuous Improvement, Tetra Pak on-site, Food Safety Quality, and Plant Controller), the team compiled a KPI scorecard and gathered documentations to test, validate, and refine baseline understanding of performance data reporting capabilities and challenges.

Figure 55: Co-man KPI framework overview

6.4.2 PLMS System Capabilities

MFI team provided a detailed walkthrough on extracting KPIs from Tetra Pak's PLMS system. Various learning and training documents were leveraged during discussions (see ANNEX), revealing:

6.4.2.1 Multidimensional Analysis

Reporting outputs can be configured by the following performance analysis features (see Figure 56 and Figure 57):

- Machine vs Lines: analyze by machine or the general line
- Group vs Compare: analyze many machines / lines as a single entity or to compare them
- Time base of Analysis: by days, weeks, months or years
- Parse by Recipe: filter equipment performance data by recipe
    - Can be leveraged to create reports specific to PNC production only (applicable to co-man sites with multiple customers besides PNC)
    - MFI's recipes set up by: [Line] [Case Configuration] [Pack Configuration] [WASF?] [Sleever] [Flavor]

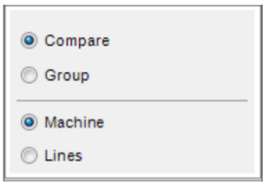

Figure 56: Analysis Focus features under the Performance Analysis Module in PLMS

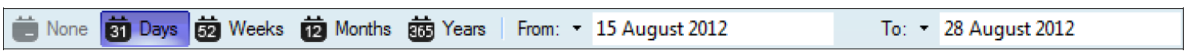

Figure 57: Time Period features under the Performance Analysis Module in PLMS

6.4.2.2 Available Report Outputs

We generated the following reports most relevant to this initiative to evaluate the outputs and limitations.

- OEE Report: OEE and components data for all PNC 330mL production can be extracted.
  - Data includes OEE, components, packages produced, production time, and other equipment events and metrics. These fields can be customized.
  - The User Manual indicates that it is possible to use Available Time (includes planned downtime) or Planned Available Time (excludes planned downtime) for OEE analysis. However, we were unable to validate the process on-site due to user access limitations.
  - The recipe filtering option is not available for OEE reports.
- Stops Report: A full list of equipment / all stop occurrences exportable for downtime analysis.
  - Data includes stop duration, frequency counts, and packages wasted.
  - Additional analysis required to categorize each stop by equipment.
  - The recipe filtering option is available for stop reports.
- Production Report: A complete overview of production data and efficiencies available for additional line performance insights.
  - Data includes production time, downtime metrics, waste metrics, reliability metrics, and other equipment/line efficiency metrics.
  - The recipe filtering option is available for production reports.

6.4.2.3 Breaking Down OEE Calculations

The team investigated on how to calculate OEE without the OEE report by leveraging other PLMS reports, such as the production report. Two goals were in mind for this investigation:

- Identify other KPIs that could serve as proxies for each component in case the co-man cannot generate a PLMS OEE report.
- Understand what factors drive the result of each component, which can inform areas for improvement.

Based on one month of production data, investigation revealed no clear correlation between the OEE report and the production report KPIs. Findings disproved our hypothesis that metrics like Time Utilization or Line Efficiency could serve as OEE Availability or Performance proxies respectively. Figure 58, Figure 59 and Table 23 outlines the differences between definitions and calculations for Time Utilization and OEE Availability:

- Time Utilization uses Production Time: when equipment performs primary required function
- OEE Availability uses Running Time: when line could perform required function without stops
- Both reference Available Time: when necessary operations for producing units are performed

12.4.13 Time Utilisation (TU)

How well the equipment is utilised during the Available Time.
Unit = %

Single Side Machine
$TU = \dfrac{\text{[Production Time]}}{\text{[Available Time]}}$

Figure 58: Time Utilization Calculation from PLMS User Manual

Availability rate
The availability rate indicates how much of the available time the line is available for production (Running Time).
Unit = %

Single Side Machine
$Availability = \dfrac{\text{[Running Time]}}{\text{[Available Time]}}$

Figure 59: OEE Availability Calculation from PLMS User Manual

Table 23: Terminology for Time Utilization and Availability Rate from PLMS User Manual

Impacted KPI	Variable	Definition
Time Utilization	Production Time	The time during which the equipment is performing a primary required function.
Availability	Running Time	The time during which the line could have been performing a required function if no equipment or other stop had occurred.
Both	Available Time	The time during which the necessary line operations for producing packages have been performed. *Calculation:* Production Time + Equipment Stops + Other Stops + Outside Production Stops

6.4.3 OEE Reporting Systems Comparison

MFI leverages SAP's OEE results as their primary source for internal reporting. MFI plans to internally report an OEE that factors in both planned/unplanned downtime into calculations, whether through SAP or another system, providing a more comprehensive performance measure. Three different systems provide varied OEE results (see Table 24):

- RedZone (lowest OEE result):
  - Captures activities from batching to palletizer
  - Uses integrated data from PLMS, count sensors within equipment PLCs, and operator inputs for downtime capture
  - Can export a top stop report for granular visibility
  - Only considers planned production time, excluding planned downtime
  - Includes significant human interaction and manual data input
  - Incorporates more process steps and potential failure points
- PLMS (moderate OEE result):
  - Captures activities from filler to case packer
  - Considers planned and unplanned downtime (e.g., unavoidable planned changeover)
  - Can export a top stop report for granular visibility
  - Can be reconfigured on PLMS DB Management to use Planned Production Time instead of Available Time
  - Balances automated data collection with operator inputs
- SAP (highest OEE result):
  - Captures activities from filler to robot palletizer to finished product scan.
  - Only records performance when production starts and stops
  - No stop reports available for granular visibility into actual production challenges
  - Does not distinguish between planned vs unplanned downtime as it is not aligned to production schedule
  - Overlooks delays that occur before production officially starts (e.g., if planned sanitation exceeds allocated time frame into planned production time, the system will not register this as unplanned downtime)

Table 24: Comparing OEE results from different systems

Month	RedZone	PLMS	SAP
February 2025	37%	44.17%	53.80%

6.4.4 KPI Validation through Data Collection

Extensive assessment and testing with the MFI team confirmed data availability and reporting for most KPIs. The validation revealed both capabilities and challenges specific to MFI's systems environment (see Figure 60).

6.4.4.1 Operational Performance KPIs:

- Aligned with stakeholders to report monthly
- OEE metrics:
  - Available through Tetra Pak PLMS
  - No difference in OEE results when extracting from the filler machine versus the overall line due to the filler driving line performance
  - OEE Availability (primary driver of OEE) includes both unplanned and planned downtime for realistic assessment and better identification of improvement areas
  - OEE's Quality rate calculated as 100% - total waste %, verifiable through the line summary report
- Downtime by Equipment:
  - Available through Tetra Pak PLMS
  - Downtime data collection incomplete due to time constraints for extensive analysis of stop code list
  - Exported list does not clearly identify each stop's associated equipment
  - Further investigation into Stop Code Structure and User Manual (see ANNEX), along with Tetra Pak PLMS specialist support to identify efficient methods for categorizing stop codes by equipment

6.4.4.2 Quality KPIs:

- Aligned with stakeholders to report monthly
- Provides insights on end-to-end process quality, downstream checks, incubation period, risk management, and final release performance
- Incubation period (7-9 days) considerations:
  - Incubation period affects timing of quality results
  - Actual quality performance lags production (by approximately 2 months to be truly reflective) – a common reporting limitation
- First Pass Quality:
  - Available through SAP system and internal Hold Log
  - MFI experienced high holds in November-December 2024, leading to delays in clearing holds and production reporting
- Extended Hold:
  - Available through SAP system and weekly PNC MFI Extended Hold List
  - Reflects orders held beyond 15-day from production date, aligning with Quality contract requirements
  - Data only available from September 2024 onward
  - Historical hold data will take additional time to normalize due to backlog

6.4.4.3 Delivery KPI (OTIF):

- Could not identify key stakeholder for data collection or align on monthly reporting
- Data source (internal or manual tracking systems) remain unconfirmed

- Recommendation to report on production month basis rather than actual delivery month to account for incubation period
- OTIF should reflect completed production orders stored as available finished goods, excluding 3PL logistics activities

6.4.4.4 Sustainability metrics:

- Total Waste:
    - Aligned with stakeholders to report monthly
    - Developed from multiple data sources
        - Total units produced sourced from internal SAP
        - Waste generated data (raw materials and finished goods) from waste collection company
        - Monthly rates calculated through Finance's Shrink Variance Analysis
- Energy Usage, Water Usage:
    - Available at plant level through the utility bill via Plant Controller
    - Investigation needed for Tetra Pak's equipment-specific usage reporting capabilities
    - Excluded from monthly reporting initiative to avoid duplication with PNC's ESG survey (18-24 month distribution)

Category	KPI	What it measures	Calculation	Cadence	Data Source
Operational Performance	OEE (%)	Overall equipment effectiveness combining availability, performance, and quality	Availability * Performance * Quality	Monthly	Tetra Pak filler
	OEE Availability (%)	Percentage of production run time compared to available time, which includes planned and unplanned downtime	Production Run Time / Available Time	Monthly	Tetra Pak filler
	OEE Performance (%)	How well the equipment is running compared to its designed speed	Actual Units Produced / Ideal Produced Units	Monthly	Tetra Pak filler
	OEE Quality (%)	Percentage of units that meet specifications at the filler without any defects/reprocessing, indicating initial production quality	Good Units at Filler / Actual Units at Filler	Monthly	Tetra Pak filler
	Downtime by Equipment (%)	Percentage contribution of each equipment's stop time to total downtime, showing impact of individual machines on overall line stoppages	Sum of Stop Times by Equipment / Total Downtime	As requested[1]	Filler, capper, sleever, packaging, palletizing equipment
Quality	First Time Quality (%)	Percentage of units that meet all specifications first time without any rework/reprocessing	Units Meeting All Specs First Time / Total Production Units	Monthly	Quality Team
	Quality Extended Hold (%)	Percentage of production placed on extended hold for longer than 15 days from production date	Products on Extended Hold / Total Production Units	Monthly	Quality Hold Report
Delivery	On-Time In-Full (OTIF) (%)	Orders delivered completely and on schedule to co-man warehouses (excluding 3PL logistics)	Total Orders Made On-Time & In-Full / Total Orders	Monthly	Internal system / manual tracking
Sustainability	Total Waste Rate (%)	Combined waste as % of production, which includes product and packaging wastes	Waste Generated / Total Production Units	Monthly	ERP system
	Water Usage Ratio (gal/gal)	Total water used per gallon produced, which includes process water, CIP/sanitation, cleaning, utilities	Total Water Used / Total Gallons Produced	Annual	Plant Controller
	Energy Usage Ratio (kWh/1000gal)	Total energy consumed per 1000 gallons, which includes processing, HVAC, refrigeration, compressed air, utilities	Total Energy Consumed in kWh / Total Production Volume in thousands of gallons	Annual	Plant Controller

1. Monthly data, last 12-month period to support initial baseline

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Figure 60: Co-man KPI framework with agreed cadences and data sources at MFI

6.4.5 Recommended Next Steps

Overall, MFI can report on most KPIs (OTIF and downtime by equipment pending) and provide 12 months of historical data for most metrics (Extended hold data limited to post-September 2024). Key next steps include:

- MFI to report data on OTIF, downtime by equipment and any feedback/challenges
- Tetra Pak's PLMS specialist to:
  - Create a customized downtime by equipment report
  - Identify automation opportunities for future-state reporting
- Investigate alternative OEE calculation methods using existing PLMS metrics and reports to:
  - Develop deeper understanding of performance drivers through component analysis
  - Enable root cause identification for efficiency losses through detailed breakdowns
  - Support targeted improvement initiatives with more granular performance data
- Validate recipe filtering methodology to:
  - Accurately isolate PNC-specific production data
  - Ensure consistent reporting across time periods
  - Leverage production schedule data to correlate time windows with specific products
  - Establish recipe format standard across the network
- Collect data and documents from Tetra Pak:
  - Complete list of stop reasons with associated equipment (if available)
  - Network benchmarks for OEE, components, and planned downtime
  - Equipment-specific energy/water usage reports (if available)

7 NEXT STEPS

Action	Owner	Status
• Review report details between MFI, PA, and PNC	MFI / PNC / PA Consulting	Open
• Review variances between shrink calculation from MFI and waste calculations from PA	MFI / PNC / PA Consulting	Open
• Create implementation plan for batching process improvements identified during the visit	MFI / PNC / PA Consulting	Open
• Develop approach to reducing batching variation with the target of eliminating standardization process	MFI / PNC / PA Consulting	Open
• Follow up with packaging suppliers for issues identified in this report	PNC	Open
• Share OTIF and Downtime by Equipment Data	MFI	Open
• Share Stop Reasons List	MFI / Tetra Pak	Open
• Share Equipment Energy/Water Usage Reports	MFI / Tetra Pak	Open
• Develop Process Batching Improvement Model	MFI / PA Consulting	Open
• Share Current and Future State Process Flows	PA Consulting	Complete
• Share Batching Capacity Analysis	PA Consulting	Complete
• Share Waste Analysis	PA Consulting	Complete
• Share Solids Calculator for Batching	PA Consulting	Open
• Share Downtime Report	PA Consulting	Complete
• Share KPI Framework (prep pack) and MFI Consolidated Historical Data	PA Consulting	Complete
• Discuss Automated Reporting with Tetra Pak PLMS Specialist	PNC / PA / Tetra Pak	Open

8 ANNEX

Note: the following documentation is stored on the PNC SharePoint. The content below has already been distributed to MFI, but can be requested from PNC, as needed.

Document Name	Document Description
MFI - Current Process Flow (Cocoa Base) - Current State.vsdx	MFI's current batching process flow
MFI - Process Flow (Cocoa Base) - Future State.vsdx	Ideal batching process flow
Batching Capacity Analysis.xlsx	Current batching capacity analysis
Batching Process Improvements Outlined.xlsx	A model on the optimized batching process
Standardization at MFI.pptx	Standardization troubleshooting presentation
Solids Calculator – In-Process	Model to calculate total solids in batching tank and high shear mixer during ingredient addition
Waste Calculations - MFI.xlsx	Waste analysis including downtime report
Updated Shrink Variance Report - Final PY 12 2024.xlsx	MFI's shrinkage analysis determining material/product loss in FY2024
Updatd Shrink Variance Report - FY2025 PY 06.xlsx	MFI's shrinkage analysis determining material/product loss in FY2025
Co-man KPI Distribution Pack_final.pdf	KPI framework, definitions, and reporting instructions
KPI Data Report_Historical_MFI.xlsx	MFI's KPI historical data consolidated with raw data/analyses
PLMS Centre - User Manual (1).pdf	Tetra Pak PLMS user manual
PLMS tutorial.pdf	Tetra Pak PLMS tutorial document on set up, generating reports, and production KPIs
PLMS Training.pdf	Tetra Pak PLMS training guide on system overview, production and OEE KPIs and formula definitions
PLMS_Codes_Structure.pdf	Tetra Pak PLMS guide on event and state code structure