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Smart Processing and Multi-Stage

Agenda

1. Motivations and Objectives
2. Design of Experiment (DoE)
3. Smart Processing Team
4. Multi-Stage Experiments
5. Exploratory Data Analysis
6. Understanding the Drivers
7. The Two Prediction Models
8. Recommendations



Motivations

- Simulate industry workflow
↳ Merge sub-processes
- Improve the production
- Minimize the losses
- Control the process for stabilized production



Objectives

- Use optimal parameters from previous sub-processes
- Maximize Half Kernel Yield percentage production
- Track and monitor Sticktight
- Develop models to predict Half Kernel Yield and Discharge Throughput



Design of Experiment (DoE)

Environmental and Initial Conditions

Moisture Team

Cracking Team

Shelling Team

Multi-Stage		
Environmental Conditions	Range	Units
Water Temperature	-	°F
Room Temperature (for air drying)	69.60-74.30 (avg=71.46)	°F
Room Humidity	0.14-0.440 (avg=0.440)	%
Initial Conditions	Range	Units
Variety	Desirable	Name type
Batch Age	5-54 (avg=25)	days
Pecan Diameter	0.971-1.11 (avg=1.05)	in
Initial Shell Moisture	10-16 (avg=12)	%
Initial Kernel Moisture	2.5 – 3.5 (avg=3)	%
Pin Material	Steel Gradient	Name type



Design of Experiment (DoE)

Independent Variables

Moisture Team

Cracking Team

Shelling Team

Multi-Stage		
Independent Variables	Range	Units
Soaking Time (post-conditioning kernel moisture)	5 – 35	hours
Air drying	15	minutes
Input Feed Rate	12 – 38	pecan/sec
Entry/Exit Height Diff	-0.1 – 0.09	in
Crush Amount	0.07 – 0.18	in
Plate Contact Frequency	30 – 60	Hz
Ring Gap	0.39 – 0.51	in
Paddle Shaft	400 – 800	RPM
Drum	30	RPM



Design of Experiment (DoE)

Dependent Variables

Moisture Team

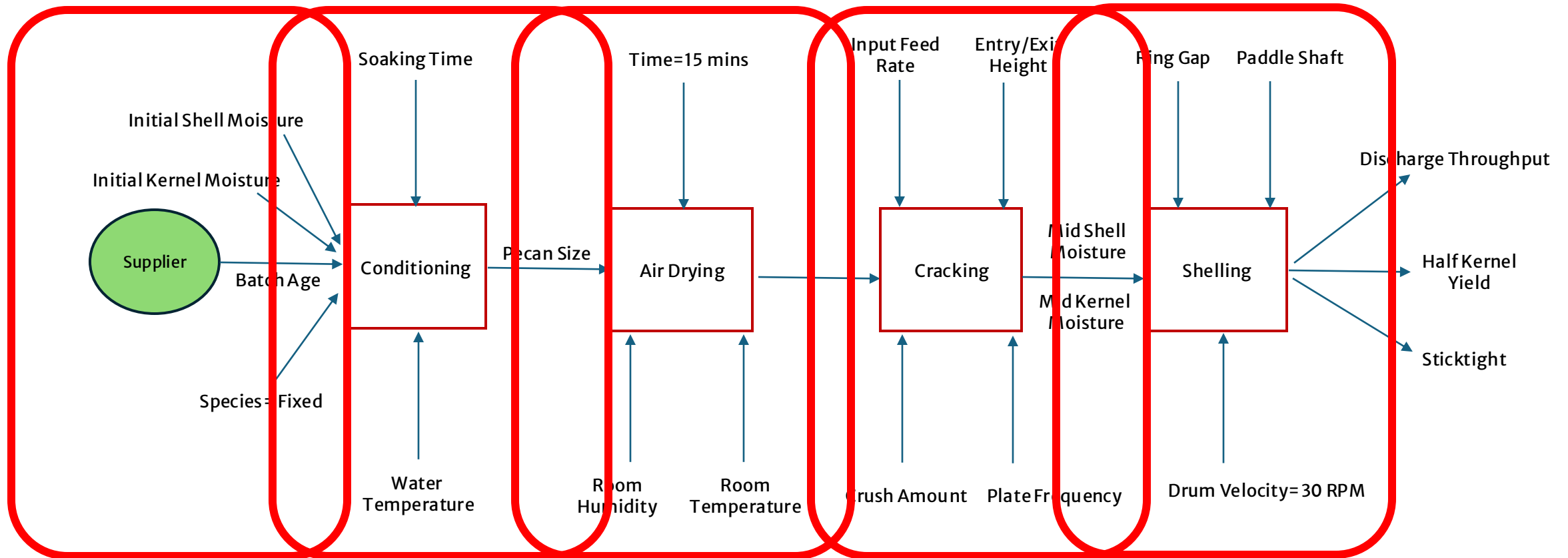
Cracking Team

Shelling Team

Multi-Stage	
Dependent Variables	Units
Change in the moisture (for conditioning process)	%
Processing Time	minutes
Sticktight Occurrence	%
Override Chute (Discharge Throughput)	%
Half Kernel Yield	%



Flow Diagram of Pecan Processing: Key Inputs and Outputs across Stages



Smart Processing Team in the Pecan Project

Design of Experiments (DoE)

Develop efficient experimental designs for each processing team

Data Analytics

Analyze experimental data, identify key process factors, and evaluate process performance

Multi-Stage Processing Methodology

Develop an integrated analytical framework for Multi-Stage experiments, DoE, predictive modeling, and optimization.

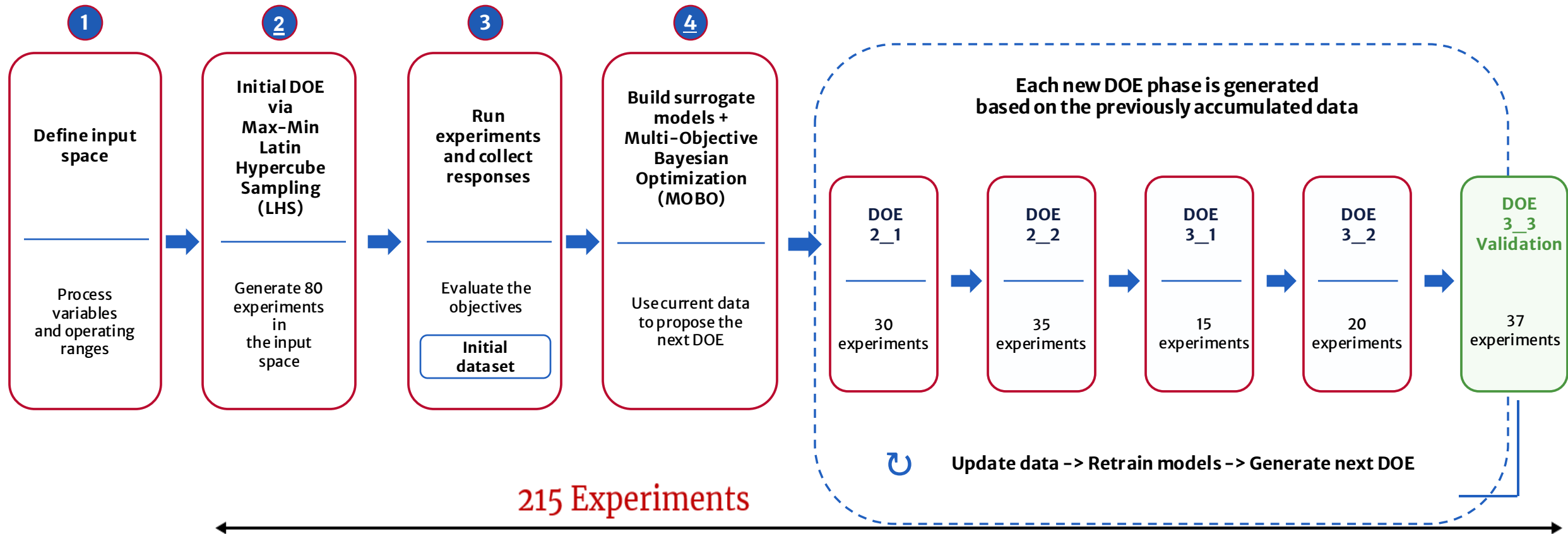


Multi-Stage Experiments



Sequential Experimental Design and Optimization

Procedure



Savings with LHS and MOBO Methodology

Full Factorial Experiments

3-Level Full Factorial –
No replication

- 2,224 experiments

2-Level Full Factorial –
3 replications

- 421 experiments

LHS and MOBO

- 217 experiments

Saved by using LHS and MOBO

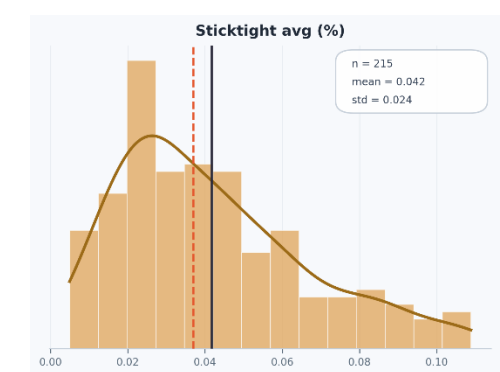
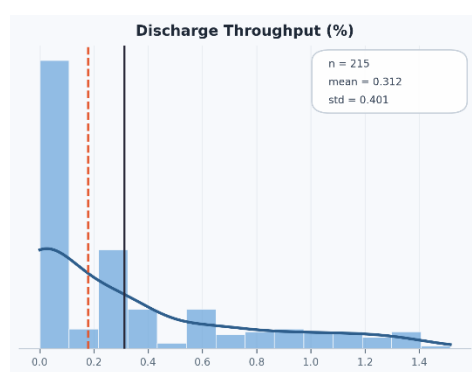
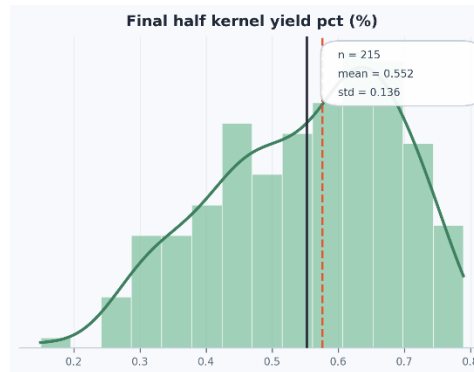
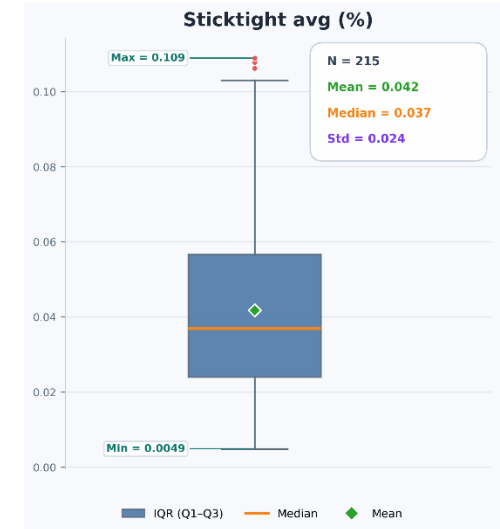
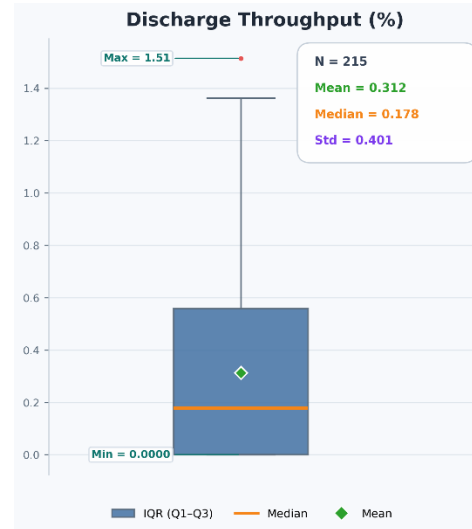
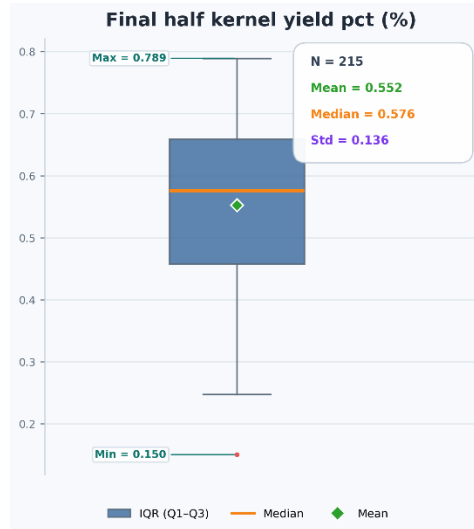
3-Level	2-Level	Units
2,509	255	Experimental hours
66,231	6,732	lbs of pecan
205,668	20,905	dollars



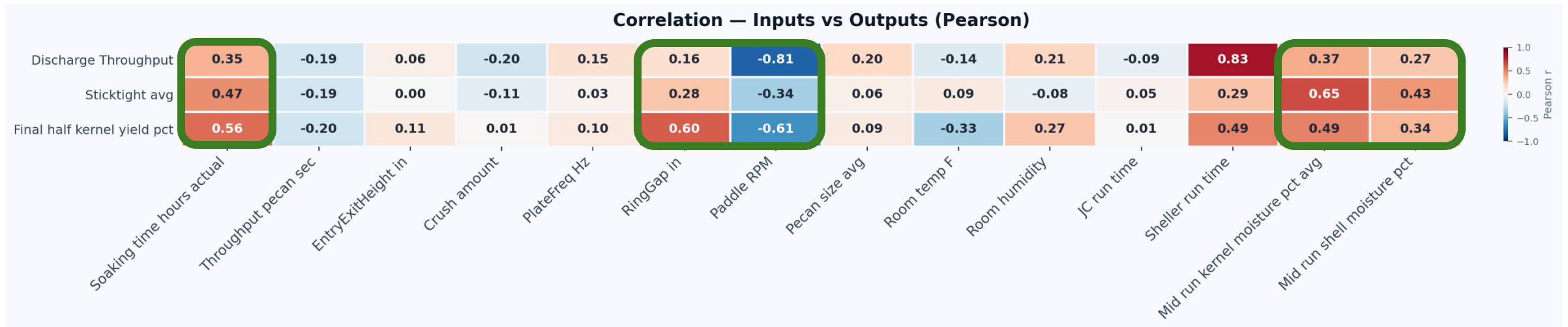
Exploratory Data Analysis



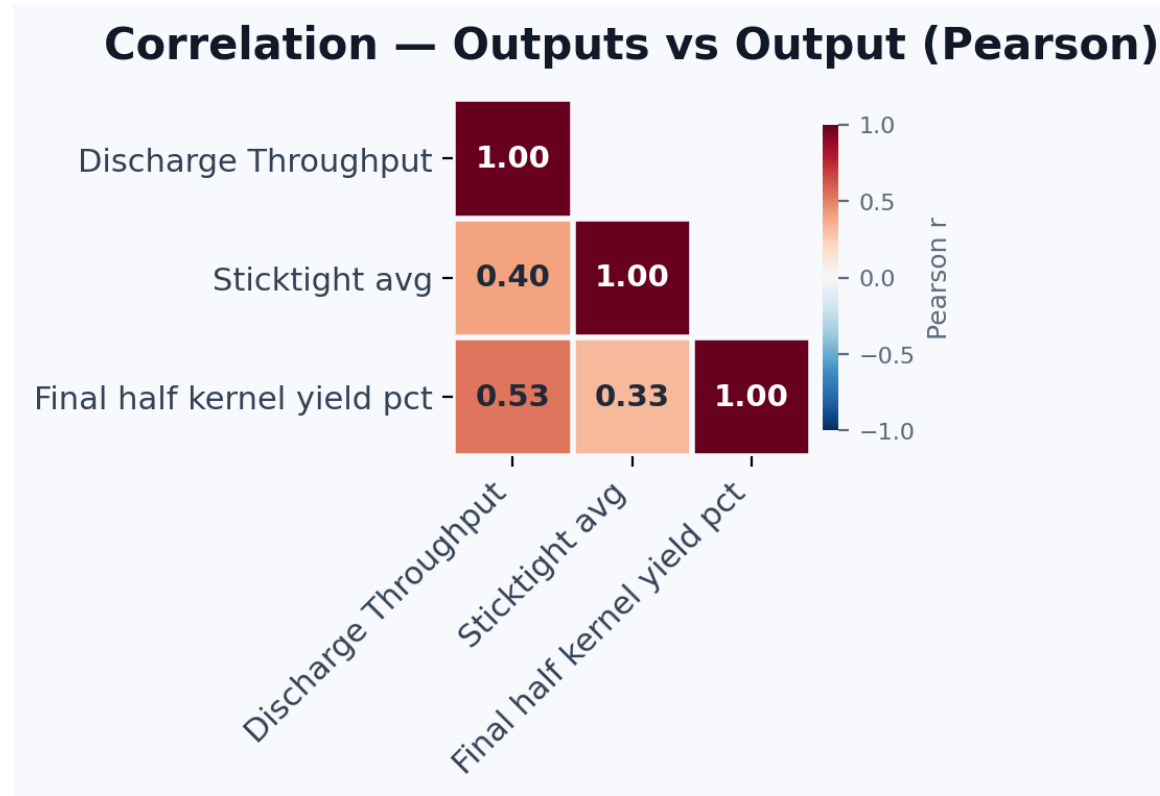
Output Distribution



Correlation- Inputs vs Outputs



Correlation- Outputs vs Outputs



Understanding the Drivers (which settings matter)



Understanding the Drivers (which settings matter)

Half Kernel Yield (%)

Discharge Throughput (%)

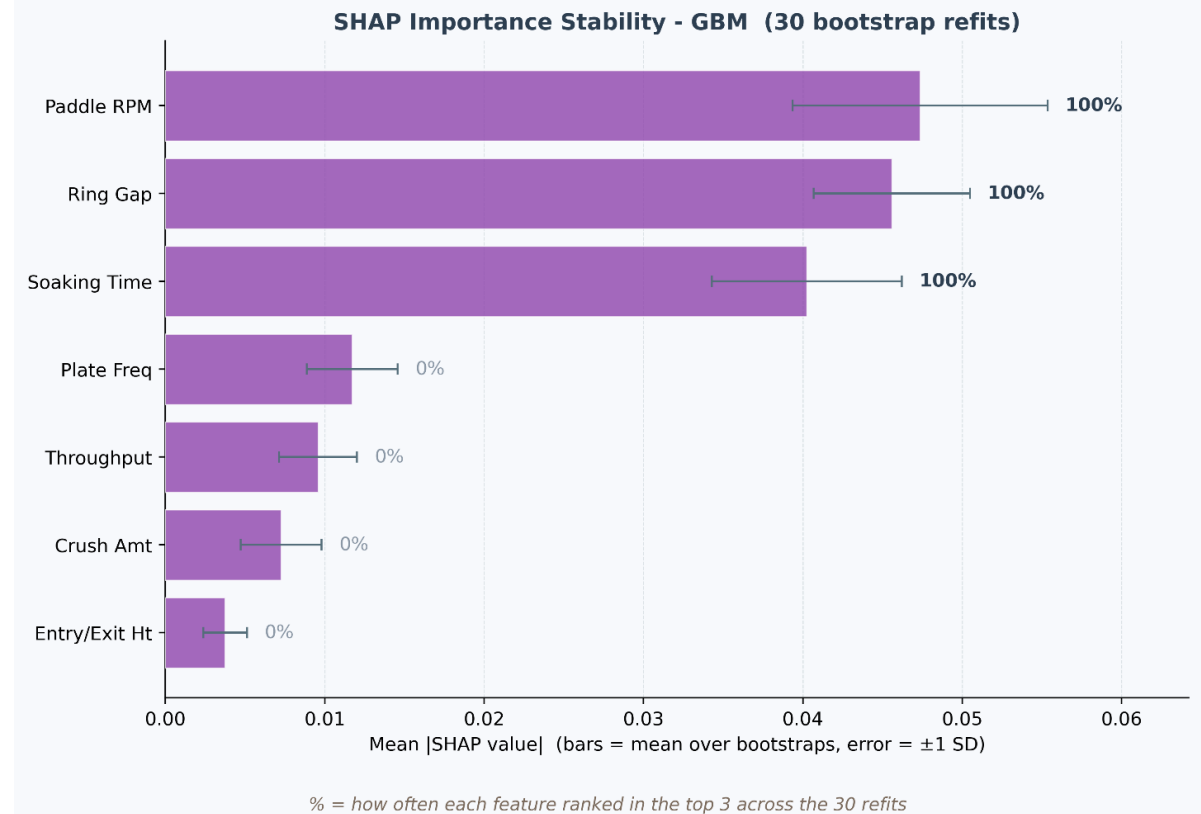
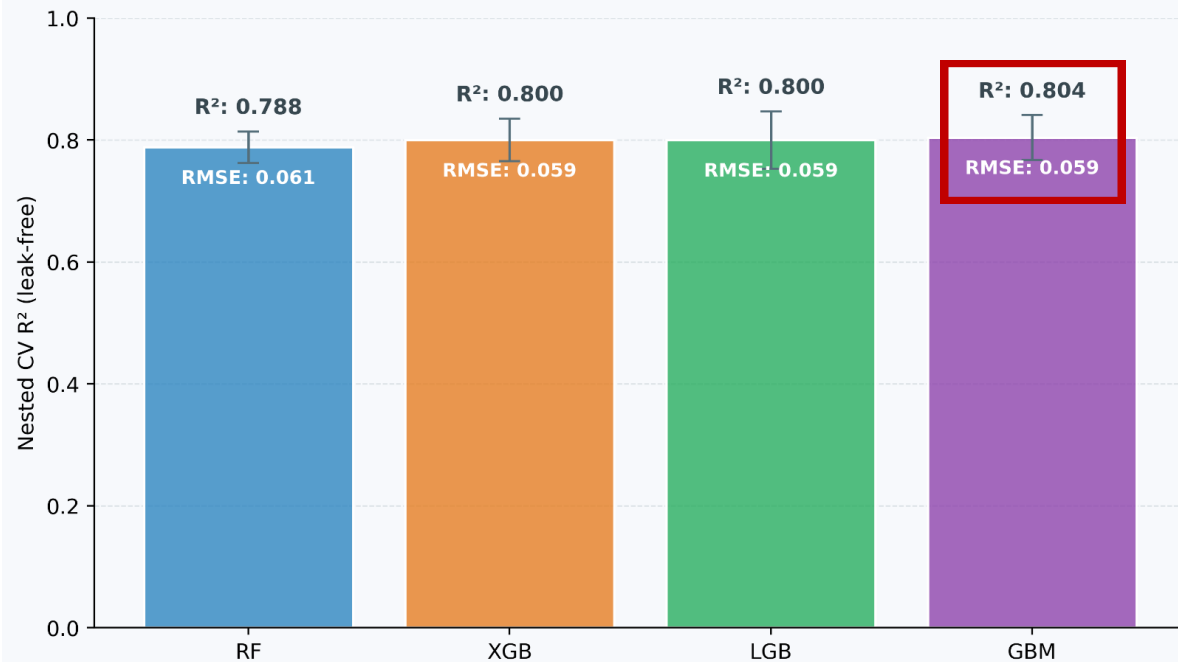
Sticktight (%)



Main drivers of Half Kernel Yield (%)

- Mean |SHAP| = average magnitude of a feature's effect on model prediction
- % = frequency the feature ranked in the top 3 across 30 bootstrap refits

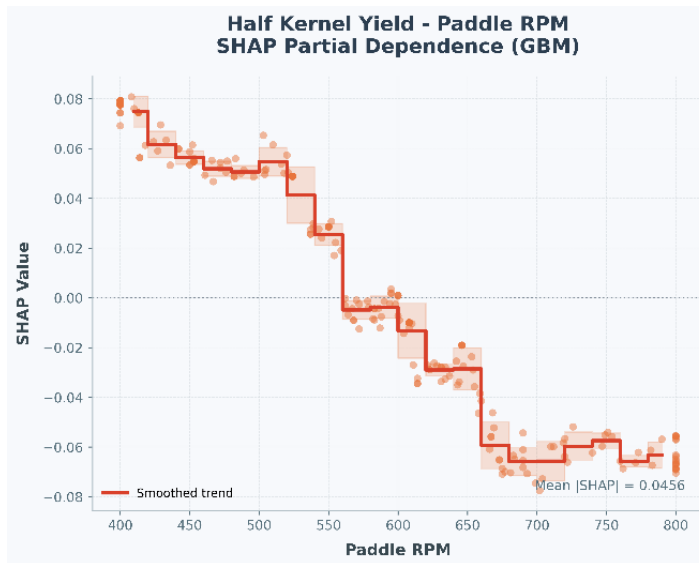
Half Kernel Yield - Model comparison - Nested cross-validated accuracy



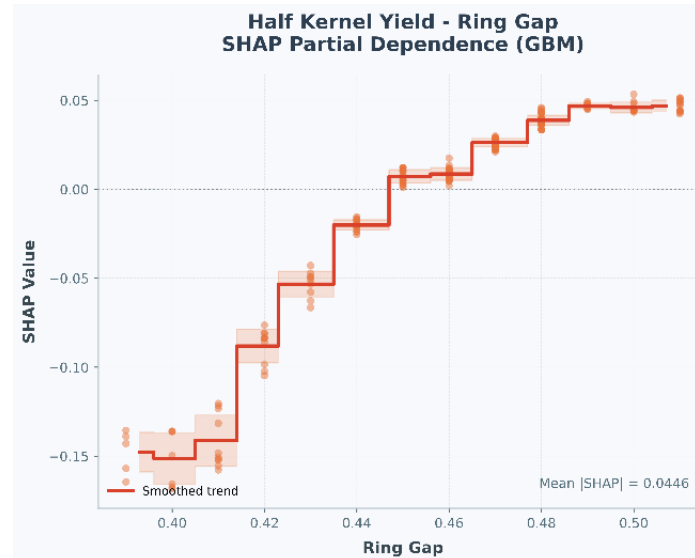
What is the direction of each factor's effect on Half Kernel Yield?

How much dependent variables pushes the GBM prediction of Half Kernel Yield up or down from its average prediction.

↓ Paddle Shaft -> ↑ Half yield



↑ Ring Gap -> ↑ Half yield



↑ Soaking Time -> ↑ Half yield

