Cracking Update

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Motivation

- Efficient optimization of cracking process will significantly impact pecan post-harvesting process.
- Implement advanced technologies to provide smarter machines and fine-tune cracking processes to control pecan half-yields and to promote overall effectiveness.
- Recommendations to have a greater half-yield following cracking process.

Research Objectives

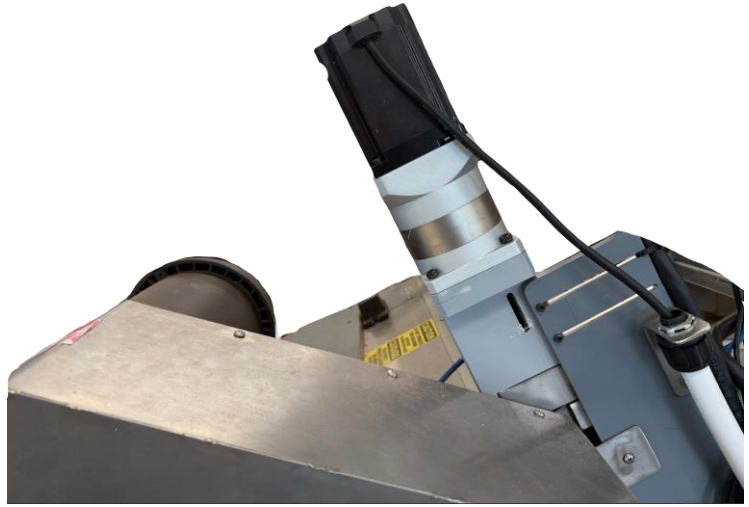
1. Optimize Half Yield and improve controllability in pecan post-processing.

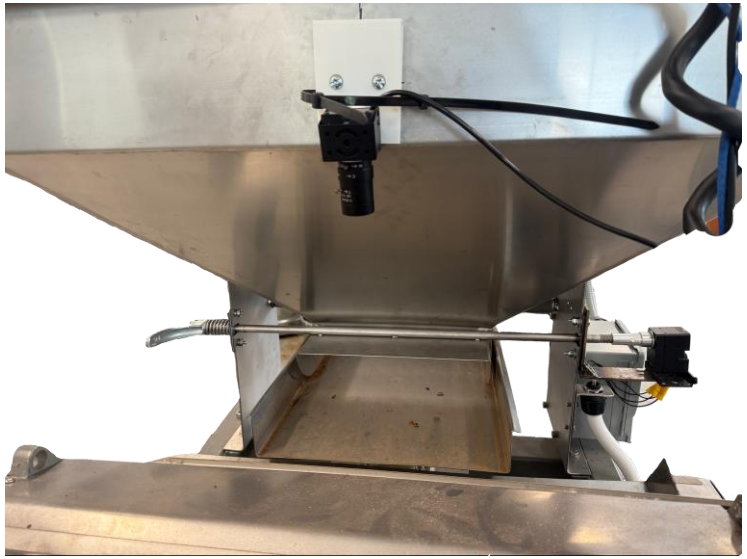
2. Determine impact of moisture on crack quality during the cracking process.

Equipment

System Updates

- **Actuators** added to motors to adjust entry and exit height difference.
- **Feed rate controller** added to the system to control the number of pecans entering the JC.





Assumptions

- **Disclaimer:** we are doing this in a controlled lab environment. The trends we present are valid, but the absolute numbers you see in your facility will likely not be the same.
- Results are based on our environment, pecan variety, and machine parameters.
- All sheller settings remain constant throughout our testing.

Cracking Parameters

- **Plate contact Frequency:** Vibratory frequency of the plate feeding into the JC (Hz).

- **Throughput rate:** Number of pecans entering the JC per second (pecans/sec). This should represent machine's productive output.

- **Crush amount:** Change in height to crush the pecan (in inches), impact for the 0 setting plus/minus the given value.

- **Entry/exit height difference:** Vertical change (in inches) between the opening and exit of the JC due to tilt of the crush plate.

- **Pecan diameter average:** Sets the average origin of the impact plate relative to the JC base for smooth pecan movement.

- **Mid-run kernel/shell moisture:** Kernel/shell moisture after cracking, before shelling

DOE

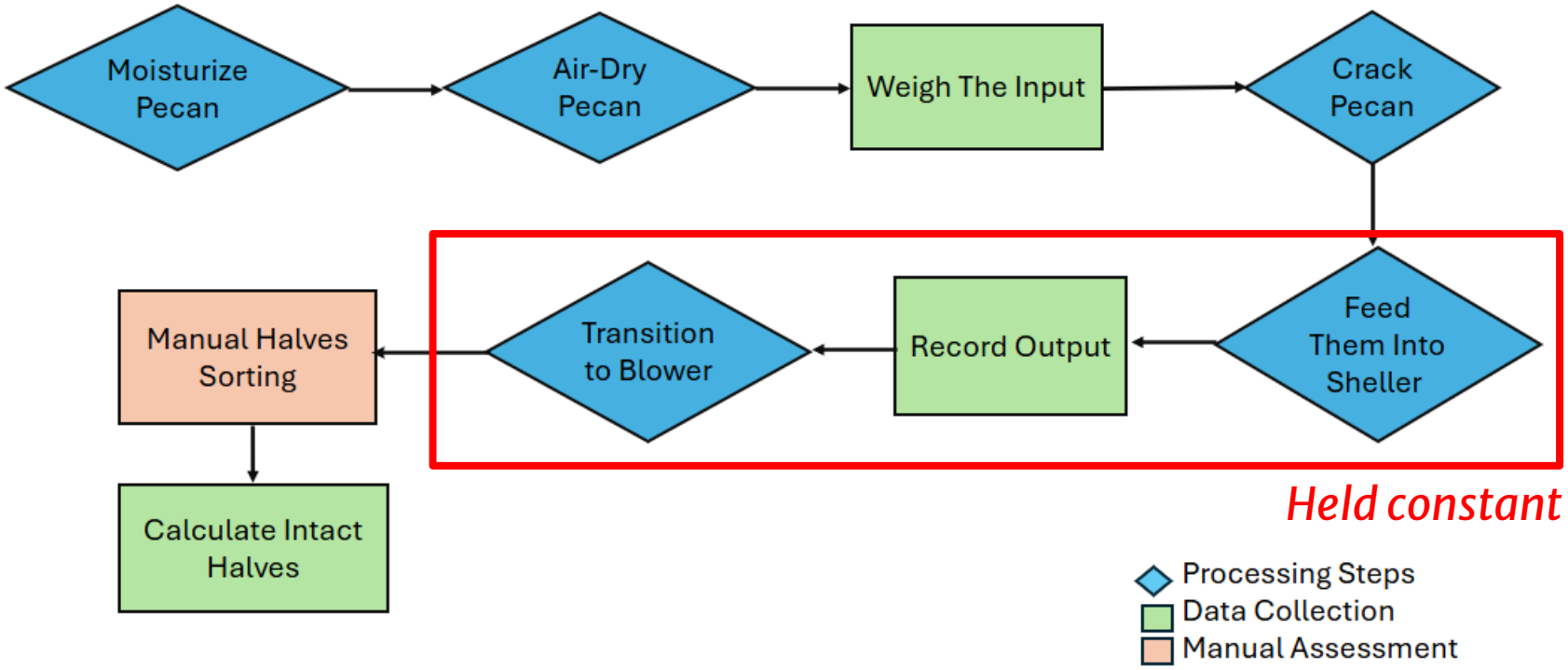
Later referred to as *Phase 1*

Independent Variables	Variables Range		Units
	Minimum	Maximum	
Moisture	4	11	%
Plate Contact Frequency	30	60	Hz
Throughput Rate	12	38	Pecans/s
Crush Amount	25	125	Thousands of an in
Entry-Exit Height Difference	-3/32	3/16	in

Methodology

- With a scientific standard, we would have run 243 experiments.
- A strategic decision was made to use **a Latin Hypercube Sampling (LHS)** and run **40 experiments.**
- Based on the current capability of the machine, we tested a wide range of **variables.**
  - Plate Contact Frequency
  - Throughput Rate
  - Crush Amount
  - Entry and Exit Height Difference
  - Pecan Diameter
  - Shell and Kernel Moisture

Experimental Procedure



Data Structure

Independent Variables

Dependent Variables

run_id	Plate contact frequency [hz]	Throughput rate pecans per [sec]	Crush amount [in]	Entry exit height diff [in]	Pecan diameter inch [avg]	Mid run shell moisture [%]	Mid run kernel moisture [avg %]	Final half kernel yield [%]
1	53	28	0.05	0.09	1.02215	27.18	11.5	45.98
2	34	29	0.03	0.01	1.02765	24.79	8.98	49.35
3	37	23	0.06	-0.08	1.0082	27.04	8.86	49.32
4	41	38	0.05	0.03	1.02875	22.66	6.28	59.80
5	38	35	0.07	-0.08	1.0045	23.68	7.56	53.65
6	30	24	0.07	0.02	0.9985	25.40	6.78	47.77
7	41	38	0.05	0.03	1.00855	24.16	6.78	47.54
8	30	24	0.07	0.02	1.0113	24.08	8.98	56.87
9	41	14	0.07	0.04	1.0185	25.05	7.86	62.46
10	45	17	0.07	-0.08	1.01455	28.72	9.72	55.23
11	60	28	0.06	-0.1	1.011225	26.98	10.28	50.59
12	30	36	0.05	-0.04	0.99463	27.86	9.04	61.09
13	42	13	0.07	-0.07	1.0318	24.70	8.36	48.00
14	60	28	0.06	-0.1	1.00355	27.45	10.76	47.65

Based on the tests guided by LHS, more tests on optimized variables were ran for new data ranges.

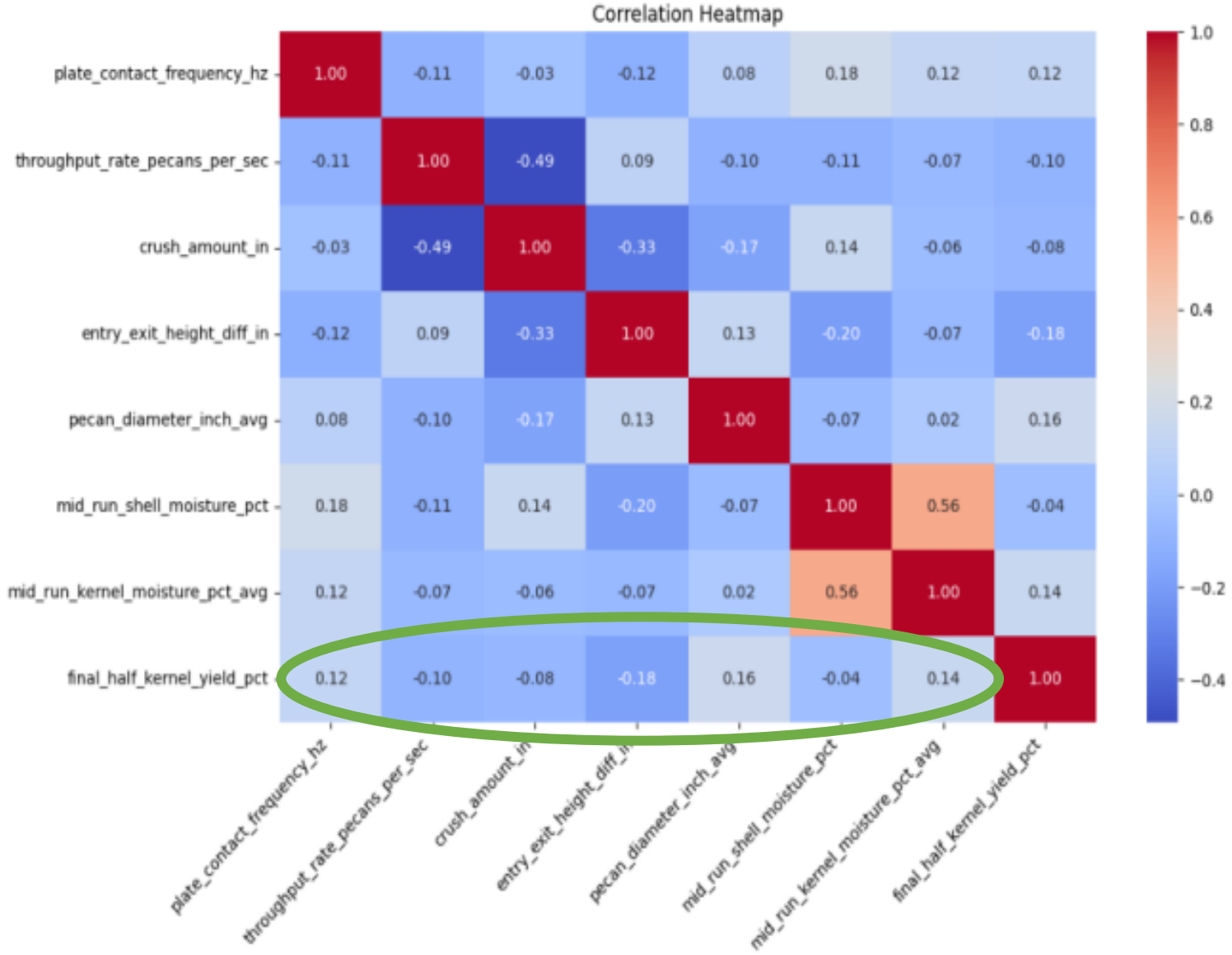
Phase 2 DOE

Sample size for each run was 33 lbs.

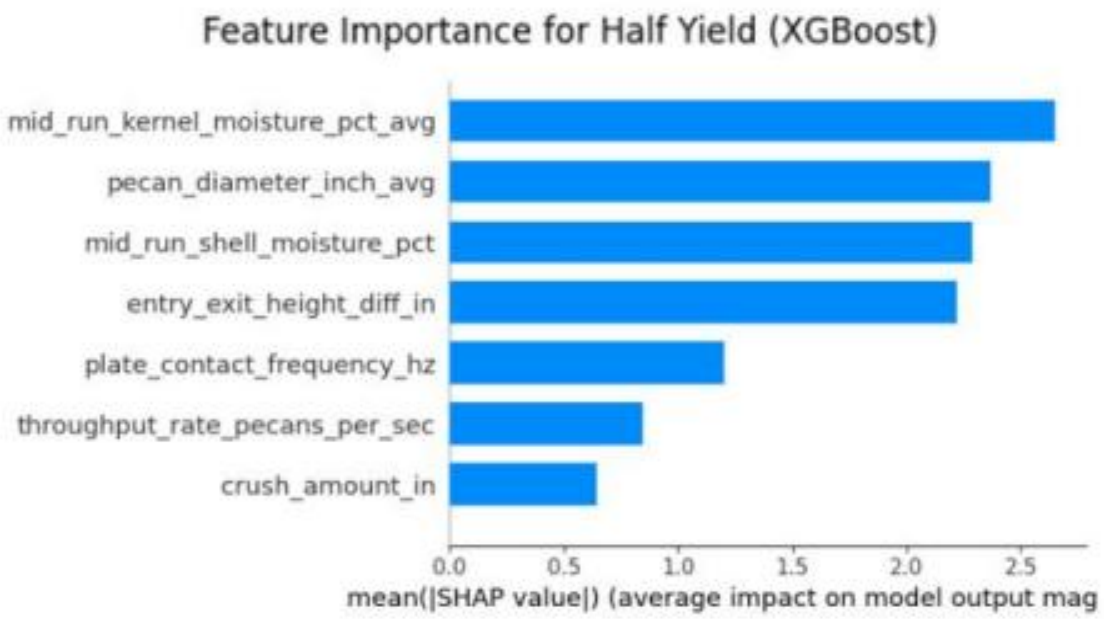
Independent Variables	Variables Range		Units
	Minimum	Maximum	
Moisture	2	11	%
Plate Contact Frequency	30	60	Hz
Throughput Rate	12	38	Pecans/s
Crush Amount	0.03	0.08	in
Entry-Exit Height Difference	-0.1	0.09	in

Correlation

- Half yield is driven by the combined influence of multiple features rather than one dominant variable.



XGBoost with SHAP (SHapely Additive exPlanation) Interaction Analysis



- **Kernel moisture :** Higher kernel moisture % increases yield.
- **Pecan diameter :** Larger average diameters improve yield.
- **Shell moisture:** Lower shell moisture % improves yield.
- **Entry exit height difference:** Negative tilt improves yield.
- **Plate contact:** Moderate-to-higher frequencies slightly improve yield.
- **Throughput rate:** Lower throughput preserve yield.
- **Crush amount:** Smaller crush amounts help preserve halves

This applies when other features are kept constant except this one feature.

PDP (Partial Dependence Plots) Recommendations

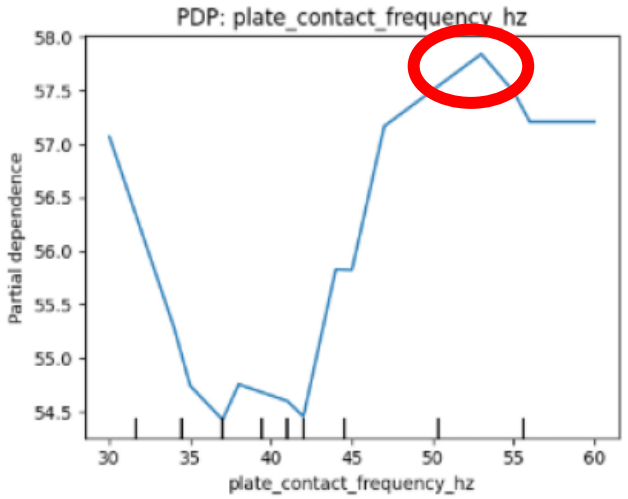
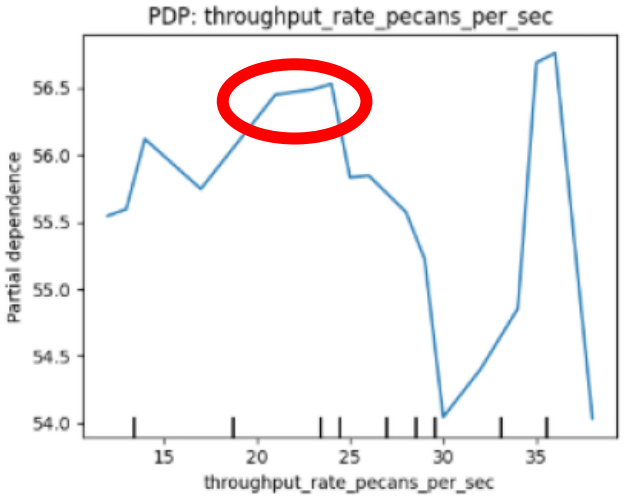


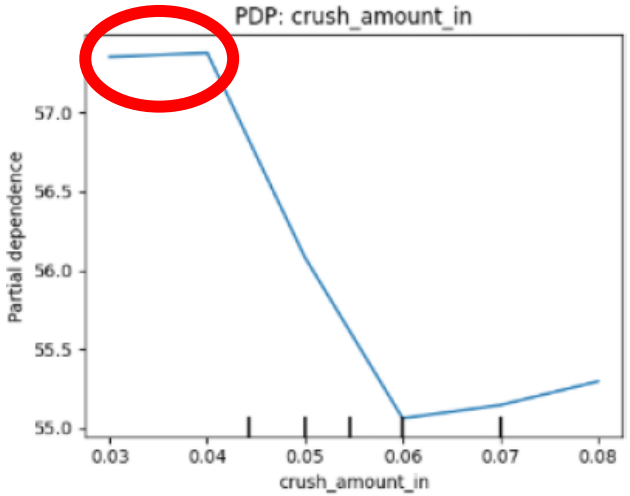
Plate Contact Frequency:

50 – 55 Hz



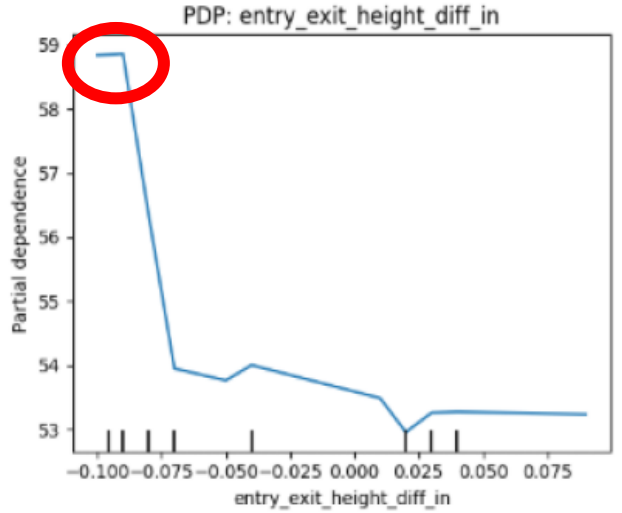
Throughput Rate:

20 – 25 Pecans/s



Crush Amount:

0.03 – 0.045 in

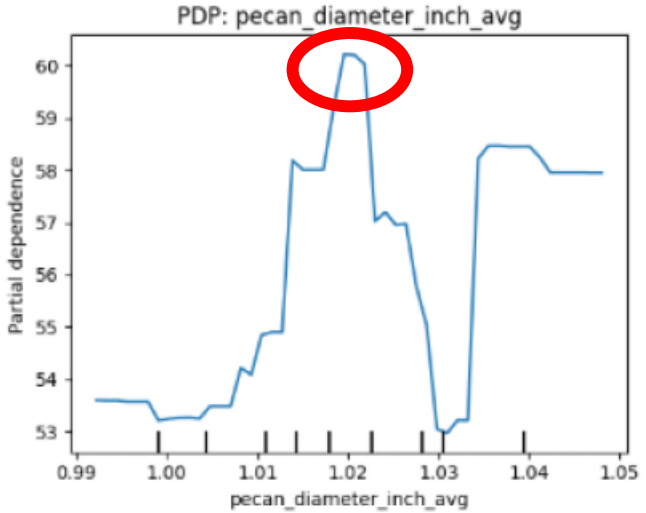


Entry-Exit Height Difference:

-0.10 – 0.08 in

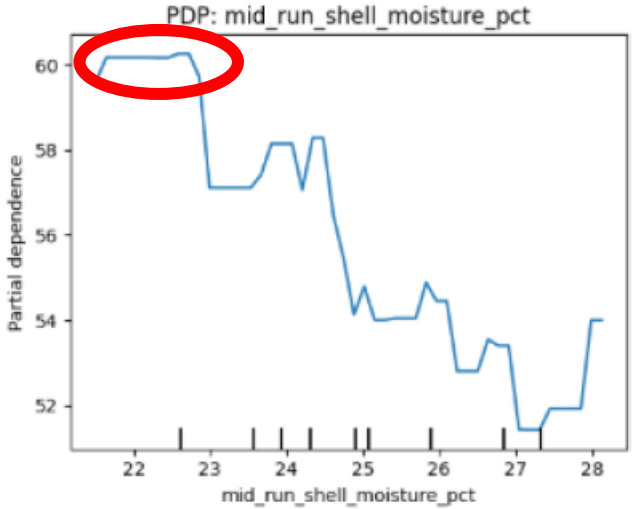
This applies when other features are kept constant except this one feature.

PDP (Partial Dependence Plots) Recommendations



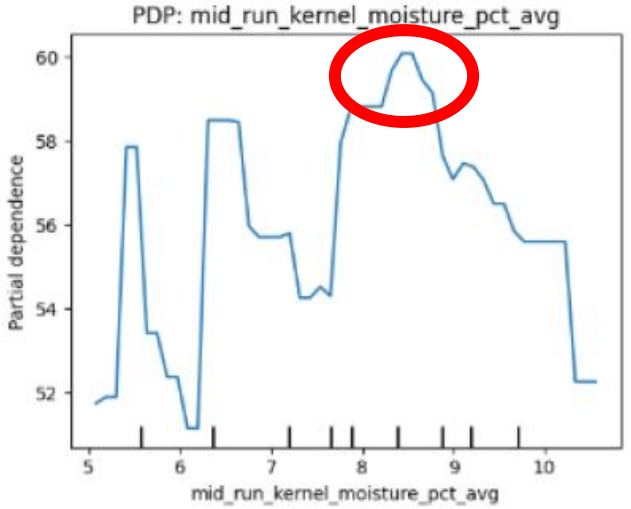
Pecan Diameter:

1.015 – 1.025 avg in



Shell Moisture:

22 – 23 %

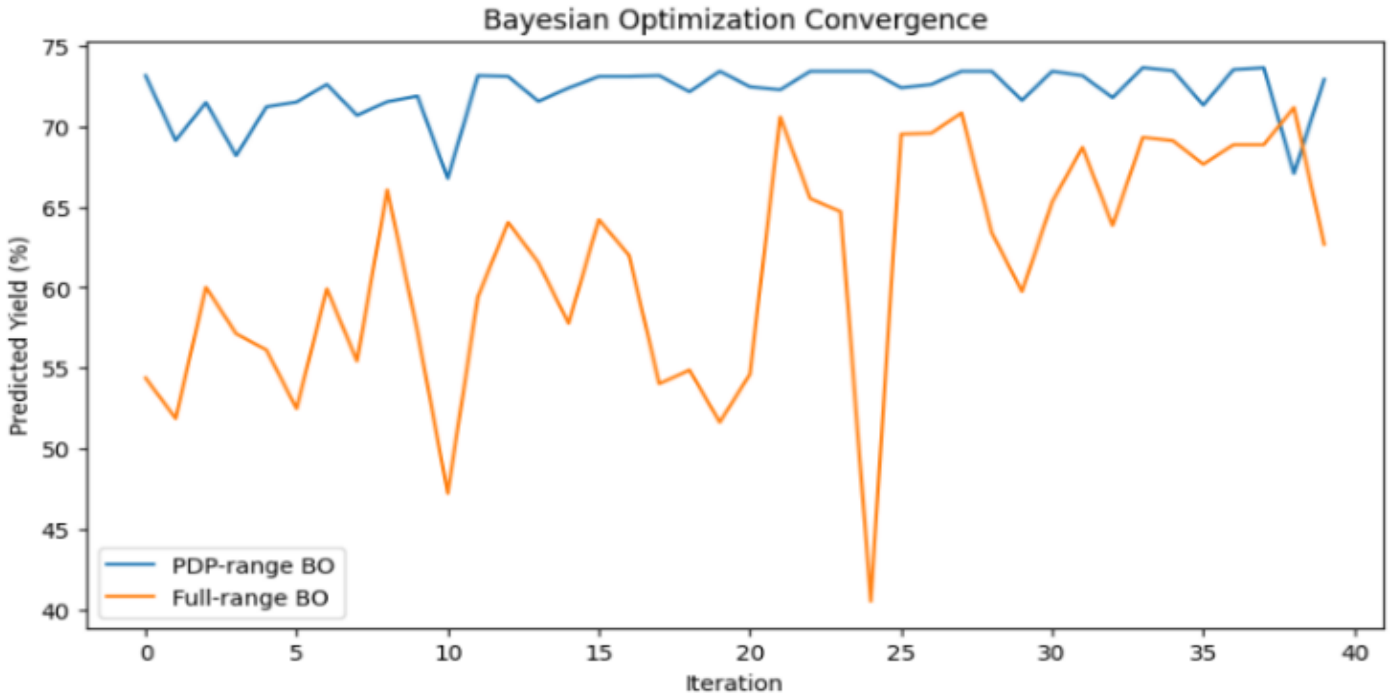


Kernel Moisture:

8 – 9 % avg

Bayesian Optimization (BO)

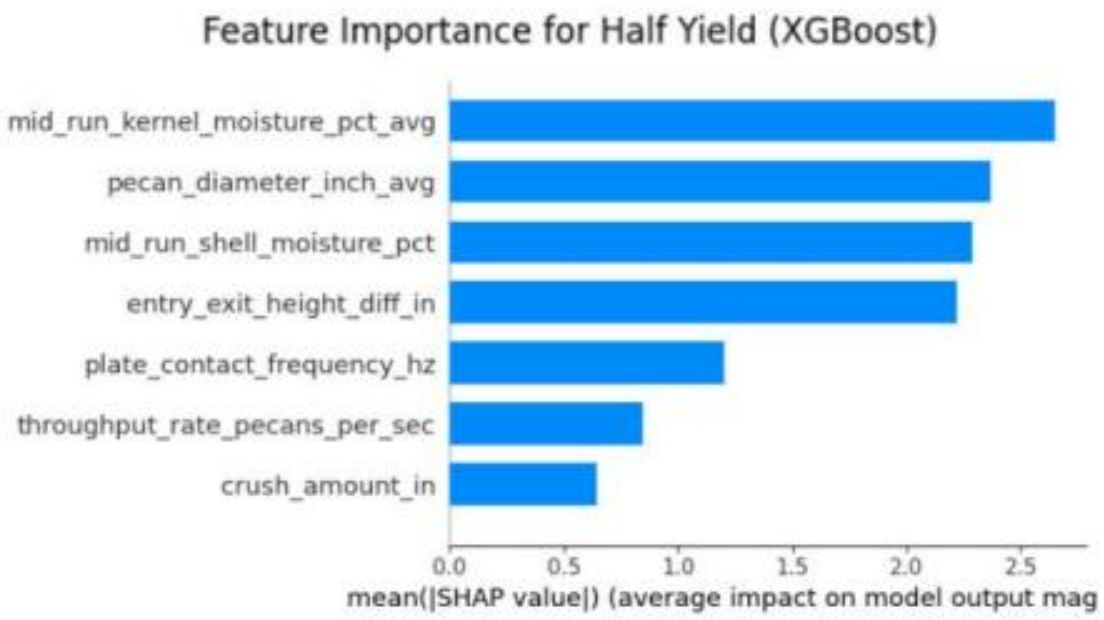
- Evaluate how these features interact when set within the PDP-based ranges.
- This approach also allows us to compare the predicted half yield from the PDP-based ranges against the predicted yield from the full observed data range.



Bayesian Optimization (BO)

Bayesian Optimization			
Variable	**Actual Value**	**Simulation Value**	**Unit**
Plate Contact Frequency	54	55	Hz
Throughput Rate	24	30	Pecans/sec
Crush Amount	0.042	0.043	in
Entry/ Exit Height Difference	-0.087	-0.081	in
Pecan Diameter	1.021	1.051	in
Shell Moisture	22.7	31.5	%
Kernel Moisture	8.5	8.5	%

Recap of Analysis



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- **Throughput rate:** Lower throughput preserve yield.
- **Crush amount:** Smaller crush amounts help preserve halves

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Summary

Parameters	Average Range Recommended for Max Half Yield
Kernel Moisture	8-9 (%)
Shell Moisture	22-23 (%)
Plate Contact Frequency	50-55 (Hz)
Throughput Rate	20-25 (pecans/sec)
Pecan Diameter	1.015 - 1.025 (avg in)
Crush Amount	0.03-0.045 (in)
Entry-Exit Height Difference	-0.10 – 0.08 (in)

Thank you!

Questions & Comments

Special thank you to Bruna Vialate (PhD Student).