DISCOVERY SUMMIT
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Using JMP® to Extend Wine Shelf Life

Timmy Sath Ka
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187mL PET Single Serve Package

Abstract

Oxygen Management & Wine Shelf Life

Proper oxygen management during the bottling of wine is critical to ensuring long shelf life. If the package contains too much oxygen at bottling, the wine's aromas, flavors and mouthfeel can be damaged due to oxidation reactions. **Total Package Oxygen (TPO)** is the term for quantifying the total amount of oxygen in the package. TPO therefore is directly determined by measuring the oxygen dissolved in the wine and in the package's headspace and adding these values together. Studies have shown that from 60 to 80% of the overall TPO can come from the oxygen in the package's headspace. Thus, measuring and controlling oxygen must be done at bottling to ensure the wine remains acceptable for extended periods. TPO is a crucial control factor in increasing a wine's shelf life.

G3 Enterprises' Mobile Bottling Division recently installed a new 187mL PET bottling line and used JMP 13 PRO to help visualize several key critical to quality characteristics, including TPO. Further analysis of the data helped to identify ways the bottling personnel could drastically reduce the process variation which, in turn, reduced TPO variation.

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Reducing Process Variation ("Pre" DOE Work)

Fill Volumes Measurements

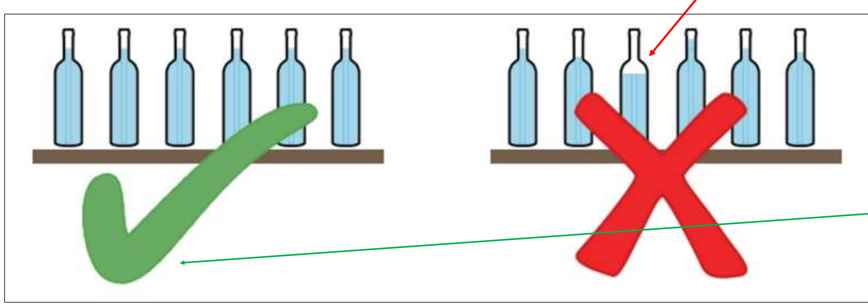
We decided to capture the "Current State" performance of the 187mL PET bottling line in regards to fill volumes. Since fill performance affect both headspace volumes and also (wine or product) fill volumes, the ability or inability to properly fill to target will affect the Total Package Oxygen (TPO)… (see formula shown below).

Total Package Oxygen TPO (mg/L) = HeadSpace Oxygen HSO (mg/L) + Dissolved Oxygen DO (mg/L)

Where HeadSpace Oxygen HSO (mg/L) = mg O2 in HeadSpace ÷ L of Fill Volume (wine)

By minimizing fill volume variations, we will be improving the noise to signal ratio during our DOE. Our goal was to be able to reduce as much variation in fill process as much as possible.

Picture shown below on left is our goal of consistent fill volumes and the one on the right is what we are trying to minimize prior to our DOE work.

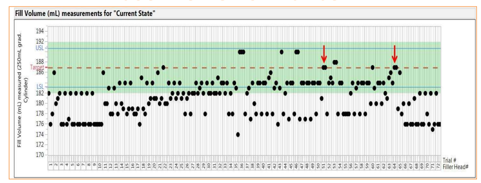


Current State vs. Future State#1 vs. Future State#2

Using JMP to Drive Down Fill Volume Variation

The following charts shown below illustrate the progression of fill volume measurements "before" and "after" adjustments were made. We utilized JMP to help us visualize how much variation was in our process by filler heads. We were able to identify "ideal" vs. "bad" filler heads which allowed us to correct the issue.

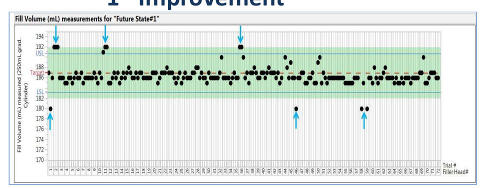
Baseline Performance



Current State

Analysis of data shows fill volumes are lower than target. Graphing data points allowed us to easily identify which filler heads (#54 & #64 shown in red arrows) were most consistent and close to fill volume target (shown in the red arrows). All other filler heads were "adjusted" to be similar to these two filler heads.

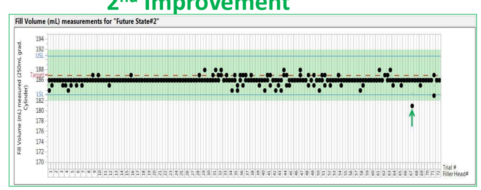
1st Improvement



Future State #1

Fill volume performance shows drastic improvement. Majority of data points fall within spec; although there are still a few data points (blue arrows) that appear to be out of spec, we used JMP again to identify which filler heads we still needed to adjust.

2nd Improvement



Future State #2

Latest round of fill volume testing showed almost all of the data points are within the spec limits. Overall, we saw huge reduction in process variation. The Operations Team was very thankful for the improvement we had achieved.

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Quantifying Results: Performance Capability Indexes

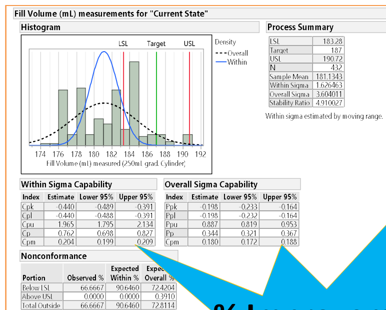
Process & Performance Capability (Cpk & Ppk)

Charts on right side show the fill volume results for the "Current State" vs. "Future State #1" vs. "Future State #2" in respect to the specification limits. Also included are the Cpk and Ppk values illustrating the significant improvements made.

Baseline Performance

Analysis of data shows fill volumes are lower than target. Graphing of data points allowed us to easily identify which filler heads (#54 & #64) were most consistent and close to fill volume target (shown in the red arrows). All other filler heads were "adjusted" to be similar to these two filler heads.

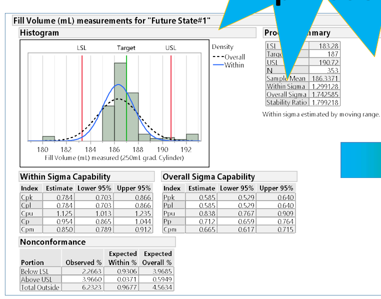
Cpk = -0.440
Ppk = -0.198



1st Improvement

Fill volume performance shows drastic improvement. Majority of data points fall within spec; although there are still a few data points that appear to be out of spec, we used JMP again to identify which filler heads we still needed to adjust.

Cpk = 0.784
Ppk = 0.585



% Improvement
Cpk: 278%
Ppk: 395%

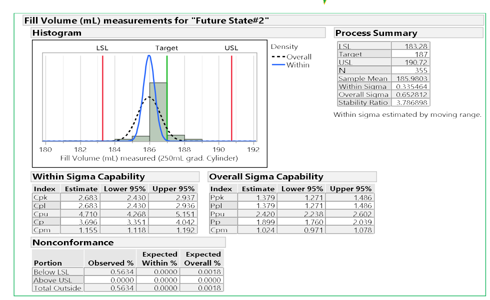
Conclusion: Huge Percentage Improvement Gained!

% Improvement
Cpk: 710%
Ppk: 796%

2nd Improvement

The latest round of fill volume testing showed almost all of the data points are within the spec limits. Overall, we saw huge reduction in process variation. The Operations Team was very thankful for the improvement we had achieved.

Cpk = 2.683
Ppk = 1.379



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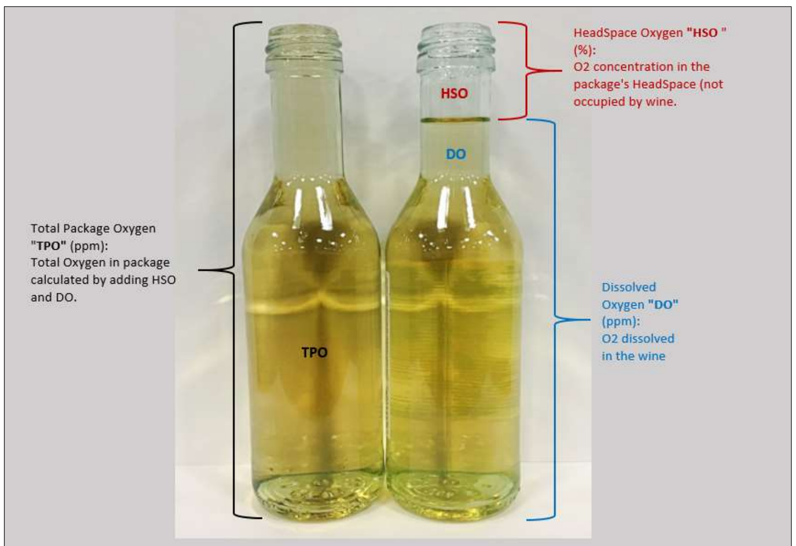
Total Package Oxygen (TPO)

What is Total Package Oxygen (TPO)?

- Term for the total amount of oxygen in the package (ppm or mg/L).
- TPO (Total Package Oxygen) = HSO (HeadSpace Oxygen) + DO (Dissolved Oxygen)
- Measured at bottling
  - TPO can be measured using non-destructive (OxySense) & destructive methods (shaken DO)

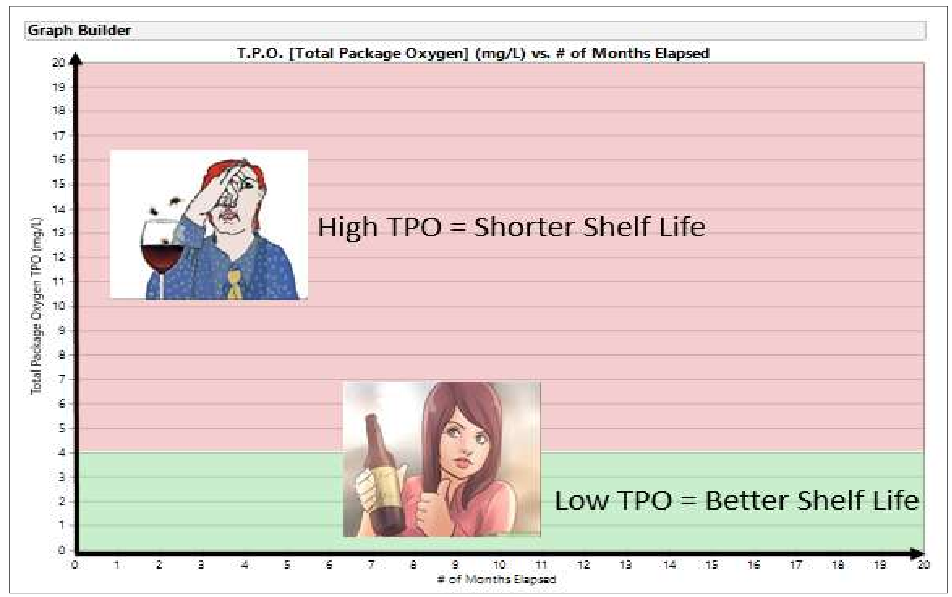


Total Package Oxygen **TPO** = Dissolved Oxygen **DO** + HeadSpace Oxygen **HSO**

TPO vs. Shelf Life Expectancy

Trend of TPO vs. Shelf Life

Studies have shown "Low" TPO values result in longer shelf life of products while "High" TPO values result in shorter shelf life.



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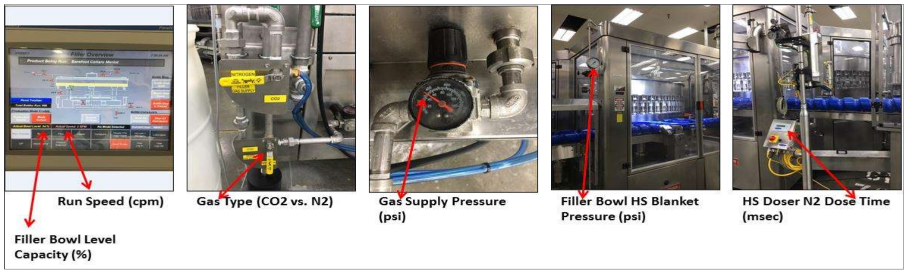
TPO Optimal Study DOE

Definitive Screening Design (DSD)

After we had completed our fill volume variation reduction study, we proceeded to run our TPO Optimal Study DOE using JMP's Definitive Screening Design platform.

Factors



After meeting with operators, mechanics, and engineers, we decided to evaluate 5 factors (shown above) that could potentially affect our TPO performance.

Responses

Responses

Shown on right were the responses we decided to capture for this study.

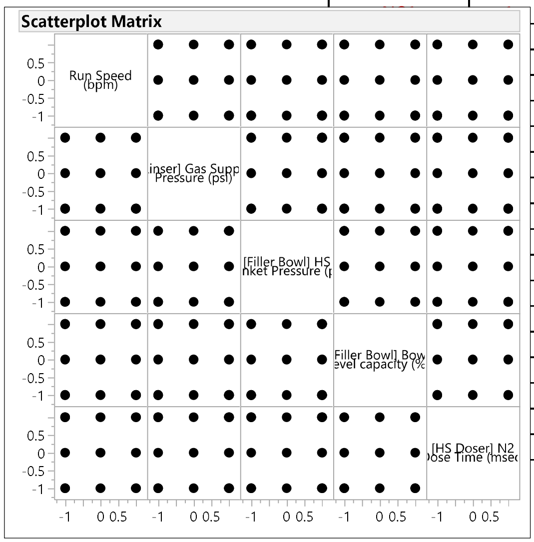
- HeadSpace Oxygen HSO (%)
- Dissolved Oxygen DO (ppm)
- Total Package Oxygen (ppm)
- Fill Volume (mL)
- Headspace Volume (mL)
- CO_2 (ppm)

Definitive Screening Array

DSD Array

Below is the Definitive Screening Design (DSD), one for CO_2 and N_2. The Scatterplot Matrix helps illustrate JMP's orthogonal DOE design (Factors).

	Factors					
Trial ID	Run Speed (bpm)	[Rinser] Gas Type	[Rinser] Gas Supply Pressure (psi)	[Filler Bowl] HS Blanket Pressure (psi)	[Filler Bowl] Bowl level capacity (%)	[HS Doser] N2 Dose Time (msec)
		N2	+1	-1	0	+1
		N2	+1	-1	-1	-1
		N2	-1	0	+1	-1
		CO2	-1	+1	+1	+1
		CO2	-1	-1	-1	-1
		CO2	+1	0	-1	+1
		N2	0	0	0	0
		CO2	0	0	0	0
		N2	+1	+1	+1	+1
		CO2	-1	+1	0	-1
		N2	-1	+1	-1	0
		CO2	+1	+1	+1	-1
		CO2	+1	-1	+1	0
		N2	+1	+1	-1	-1
		N2	-1	-1	-1	+1
		CO2	0	+1	-1	+1
		CO2	-1	-1	+1	+1
		N2	0	-1	+1	-1



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Initial Analysis for "CO_2" Only, No Prediction Modeling

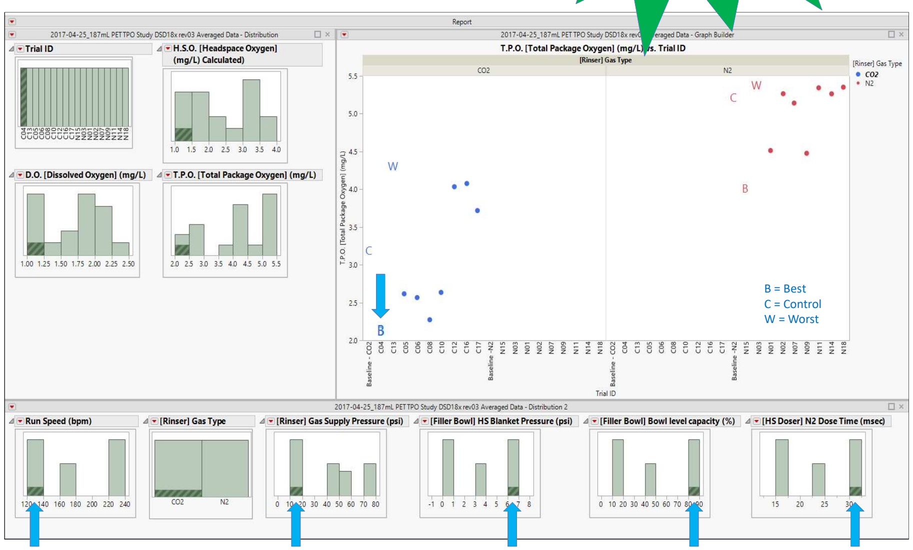
Visual Analysis / Distribution of Factors vs. Responses

Because of JMP's "dynamically linked" capabilities, we began our analysis by creating histograms of factors and responses. Our goal was to explore any hidden trends/patterns in the data set.

As seen above, the "CO_2" trials, it appears that low TPO results were obtained when running the bottling line using:

- Run Speed (bpm) = slower
- [Rinser] Gas Supply Pressure (psi) = low
- [Filler Bowl] HS Blanket Pressure (psi) = high
- [Filler Bowl] Bowl Level Capacity = high
- [HS Doser] Dose Time (msec) = high

TPO appears to lower when using CO2; also Best trial has lower TPO vs. Control (baseline)



Initial Analysis for "N_2" Only, No Prediction Modeling

Visual Analysis / Distribution of Factors vs. Responses

Similar to the analysis conducted on the DSD Array using the CO2 gas, we performed a similar visual analysis using the "N_2" trials. Low TPO results were obtained when running the bottling line using:

- Run Speed (bpm) = slower
- [Rinser] Gas Supply Pressure (psi) = high
- [Filler Bowl] HS Blanket Pressure (psi) = low
- [Filler Bowl] Bowl Level Capacity = low
- [HS Doser] Dose Time (msec) = high

Higher TPO results when using N_2; on positive note, we see the Best trial has lower TPO vs. Control (baseline) although overall TPO is higher than CO_2 trials

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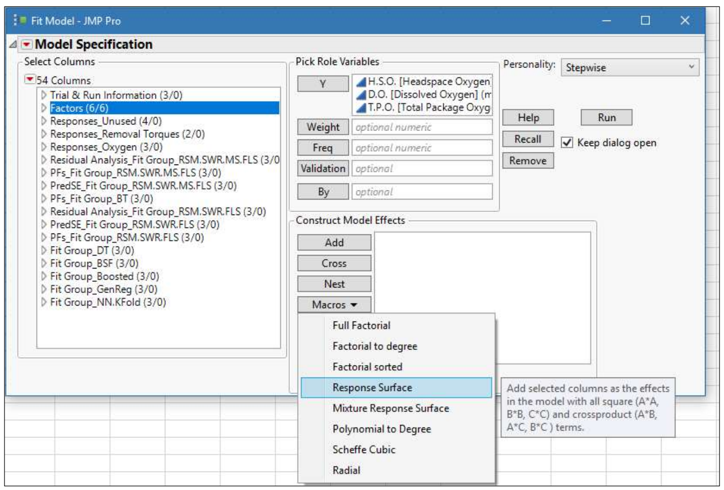
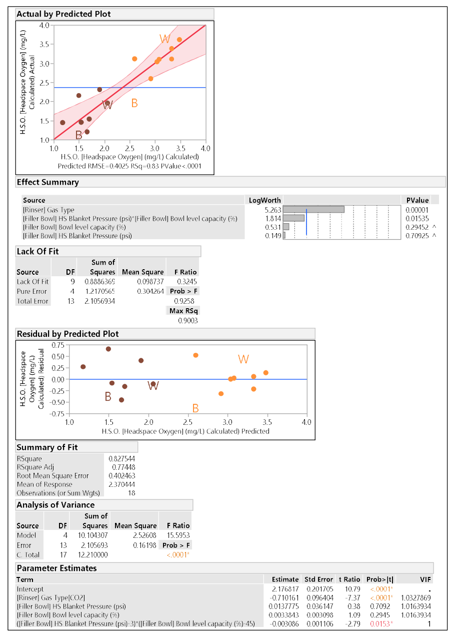
Creating Prediction Models and Evaluating Model Fit Performance

Fit Model → RSM Macro → Fit Least Square → Stepwise Regression (Minimum AICc)

Shown below is just one of the many prediction modeling capability in JMP. Note: We evaluate how well a model fits the data by reviewing the RSquared, RSquared Adj., VIFs, Residual Plot, etc.





Utilize JMP® Pro's Advanced Modeling Platform to Create Numerous Prediction Models and Then Compare Each Model's Performance

We then proceeded to use JMP Pro's other modeling platform to create several predictive. Models:

- *Decision Tree*
- *Bootstrap Forest*
- *Boosted Tree*
- *Generalized Regression*
- *Neural Network (KFold)*

Once these different models were created, we used the Model Comparison feature to compare side by side how each of the prediction model "types" compare against one another. Blue arrows shown below was the final model we selected to create the confirmation run array.

Model Comparison

Measures of Fit for H.S.O. [Headspace Oxygen] (mg/L) Calculated)

Predictor	Creator	.2 .4 .6 .8	RSquare	RASE	AAE	Freq
Pred Formula H.S.O. [Headspace Oxygen] (mg/L) Calculated) 2	Fit Least Squares		0.8275	0.3420	0.2771	18
H.S.O. [Headspace Oxygen] (mg/L) Calculated) Predictor 2	Partition		0.7068	0.4460	0.3569	18
H.S.O. [Headspace Oxygen] (mg/L) Calculated) Predictor 3	Bootstrap Forest		0.3565	0.6607	0.5733	18
H.S.O. [Headspace Oxygen] (mg/L) Calculated) Predictor 4	Boosted Tree		0.8915	0.2713	0.2088	18
H.S.O. [Headspace Oxygen] (mg/L) Calculated) Prediction Formula	Fit Generalized Adaptive Elastic Net		0.7017	0.4498	0.3469	18
Predicted H.S.O. [Headspace Oxygen] (mg/L) Calculated)	Neural		0.8944	0.2676	0.1856	18

Measures of Fit for D.O. [Dissolved Oxygen] (mg/L)

Predictor	Creator	.2 .4 .6 .8	RSquare	RASE	AAE	Freq
Pred Formula D.O. [Dissolved Oxygen] (mg/L) 2	Fit Least Squares		0.7604	0.2076	0.1721	18
D.O. [Dissolved Oxygen] (mg/L) Predictor 2	Partition		0.0000	0.4242	0.3580	18
D.O. [Dissolved Oxygen] (mg/L) Predictor 3	Bootstrap Forest		0.1653	0.3876	0.3276	18
D.O. [Dissolved Oxygen] (mg/L) Predictor 4	Boosted Tree		0.5855	0.2731	0.2222	18
D.O. [Dissolved Oxygen] (mg/L) Prediction Formula	Fit Generalized Adaptive Elastic Net		-0.091	0.4431	0.3453	18
Predicted D.O. [Dissolved Oxygen] (mg/L)	Neural		0.6044	0.2668	0.1851	18

Measures of Fit for T.P.O. [Total Package Oxygen] (mg/L)

Predictor	Creator	.2 .4 .6 .8	RSquare	RASE	AAE	Freq
Pred Formula T.P.O. [Total Package Oxygen] (mg/L) 2	Fit Least Squares		0.7900	0.5173	0.4030	18
T.P.O. [Total Package Oxygen] (mg/L) Predictor 2	Partition		0.6504	0.6674	0.6048	18
T.P.O. [Total Package Oxygen] (mg/L) Predictor 3	Bootstrap Forest		0.5795	0.7320	0.6760	18
T.P.O. [Total Package Oxygen] (mg/L) Predictor 4	Boosted Tree		0.8677	0.4106	0.2984	18
T.P.O. [Total Package Oxygen] (mg/L) Prediction Formula	Fit Generalized Adaptive Elastic Net		0.4054	0.8705	0.6389	18
Predicted T.P.O. [Total Package Oxygen] (mg/L)	Neural		1.0000	0.0005	0.0001	18

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Next Steps…Confirmation Run (CO_2 & N_2) Based on Winemaker's Preferences

Verifying Prediction Models with Confirmation Runs

We had hoped to be able to verify our Confirmation DOE work before we submitted this poster to JMP® for the 2017 JMP® Discovery Summit.
Unfortunately, due to our Production Schedule, we did not have any open line time to conduct our Confirmation DOE.

Our goal is to run the confirmation DOE trials using the predicted settings shown on the right hand side as soon as possible. After our confirmation run testing is completed, we will be able to confirm if the prediction model is correctly predicting positive results. Our next steps will then be to run our "optimal settings" on a full scale production run and also run a "baseline" settings so that we can measure, and quantify the % improvement. Remember, to determine % improvement, we must measure our current process and then make the improvements and then remeasure it again.

"Proof is in the Pudding"….Proving how we use JMP® to Extend Wine Shelf Life

In order to prove that we can extend shelf life of the 187mL PET products, we plan on sending both Optimal Settings and Baseline settings products to two different parties for Sensory Evaluation. (1) will be an outside lab that will conduct Sensory and Consumer Acceptance Testing over a 24 month period. (2) will be sent to our internal Sensory panelists for testing for the same 24 month period.

The goal for us is to be able to prove that the Optimal Settings products will out perform the Baseline Settings products for Sensory Testing, thereby proving that by lowering TPO values (via the DOE work) and optimizing the line, we can extend wine shelf life.