stat teaser

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Workshop Schedule

Experiment Design Made Easy
September 14-15, 2010: Minneapolis, MN
November 3-4, 2010: Minneapolis, MN
December 7-8, 2010: Minneapolis, MN
$1295 ($1095 each, 3 or more)

Response Surface Methods for Process Optimization
December 9-10, 2010: Minneapolis, MN
$1295 ($1095 each, 3 or more)

Mixture Design for Optimal Formulations
August 17-18, 2010: Minneapolis, MN
October 26-27, 2010: Minneapolis, MN
$1295 ($1095 each, 3 or more)

Advanced Formulations: Combining Mixture & Process
October 28-29, 2010: Minneapolis, MN
$1495 ($1195 each, 3 or more)

Designed Experiments for Life Sciences
September 29-30, 2010: Minneapolis, MN
$1495 ($1195 each, 3 or more)

Basic Statistics for DOE
August 16, 2010: Minneapolis, MN
September 28, 2010: Minneapolis, MN
November 2, 2010: Minneapolis, MN
$595 ($495 each, 3 or more)

PreDOE: Basic Statistics for Experimenters (Web-Based)
Go back to the basics of statistics. See *www.statease.com/clas_pre.html* for more information. FREE (a $95 value)

Free Webinar: DOE Made Easy & Powerful via DX8 Part II—RSM
Thursday, August 19 at 10:30 AM CT
See http://www.statease.com/webinar.html.

Workshops limited to 16. Contact Elicia Bechard at 612.746.2038 or workshops@statease.com.

Stat-Ease® statistics made easy®

Whirley Pop DOE—Part II

In the last Stat-Teaser newsletter, I wrote about the Whirley Pop™ popcorn popper and its vital role in the enjoyment of our weekly "movie night". We explored the effect of stirring, pre-heat time, and brand of popcorn on the key characteristics of the popcorn in a 2^3 factorial with center points. For details on the factors and design results, please see the April 2010 Stat-Teaser newsletter. From that first Design of Experiment (DOE), we came up with some interesting conclusions and, as to be expected from any good experiment, many more intriguing questions. In this follow up, we'll try to answer some of those questions as we augment the first DOE to learn more about making the best popcorn possible to ensure "movie night" will be thoroughly enjoyed for years to come.

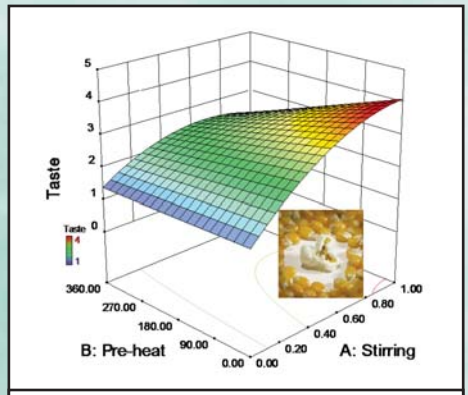

Figure 1: 3D surface plot of the Taste Response

In the first DOE, we achieved the best taste, texture, and volume of popcorn with constant stirring (a level of 1.0) and no pre-heating (a similar conclusion can be drawn from the graph of this design in Figure 1). The last factor, brand of popcorn wasn't statistically significant. A key finding in the first DOE was the detection of significant curvature which we made possible by running center points. The curvature hinted that we may achieve better taste by only stirring a fraction of the time. This question begged more study: Who wouldn't want better tasting popcorn while doing less work? To answer this question, we augmented the original factorial design to fit the curvature by adding points to fit a quadratic model.

Augmenting the Design

Augmenting the design in Design-Expert® software was easy. From the Design Tools menu, we chose Augment Design. The default augment was an RSM Optimal design, which is a response surface method (RSM). RSM designs find the optimum process settings by fitting higher order models (in this case quadratic) and looking for peaks or valleys. Normally, one would augment from a factorial design to a standard central composite design (CCD), but in this case we had a categoric factor (popcorn type) which precluded that option. Therefore, using the computer-generated optimal algorithm (via RSM optimal design) was the only way to go. The default augment for a quadratic model was four model points. That means, by adding just

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four more points to the existing data, we should be able to resolve which quadratic terms will properly model the curvature through the center points. However, after evaluating our design using the Fraction of Design Space* (FDS) plot, we chose to add 6 points to give us higher precision. Evaluation is always an important step after building a design, especially with an augment like this.

The Results

With the new data in hand, it was apparent that the significant curvature detected in the first DOE was due to a significant A^2 term in the model for both taste and unpopped kernels (UPKs). In Figure 1, you can see the curvature in the new model, which wasn't present after the first DOE (see Figure 1, Part 1 of the series). This is a key difference between the factorial and RSM designs.

In the RSM design, we are fitting curves, so a maximum can be found in the middle of the multilevel space. This isn't possible with the two-level factorial design, which fits straight lines. For instance, look at the curve in Figure 2 for high preheat (B+). It shows that a level of about 0.6 stirring will give the best taste, with taste degrading with more or less stirring. Also, notice that the LSD bars (I-beams) are now shorter. The shorter bars indicate higher confidence, which is a consequence of having more runs in the DOE. In the first DOE, we had said there was not a statistical difference between B- and B+ at constant stirring, because the LSD bars overlapped. However, now that we have more data and smaller LSD bars, it's clear that there is a statistically significant difference. No pre-heat (B-) is the better choice. From the no pre-heat (B-) curve in the figure, it looks like we will need constant stirring (1.0) to get the best taste.

Optimization usually comes down to a series of trade-offs. In our case, we started by looking at the model graphs and then setting goals on each individual response in numerical optimization. This analysis showed that a stirring fraction of 0.76 would minimize UPKs, but a better taste, texture, and volume of popcorn were still found at constant stirring (1.0 fraction). Using the prediction node in Design-Expert, we compared the predictions for these two possible solutions. The comparison showed that the solution with shorter stirring would decrease the number of UPKs by only two kernels, but it degraded the taste and texture by almost 1 full unit on the 1 to 5 rating scale. Therefore, when we used the numerical optimization to simultaneously search for the optimum with goals set for all four responses, we found that the solution of constant stirring was best (with no pre-heat). In other words, to get the best taste, we must accept a few more UPKs as a trade-off.

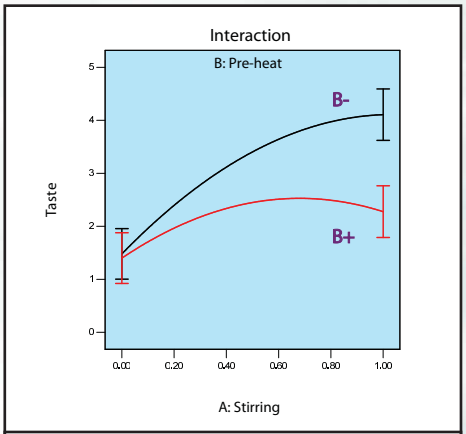

Fig. 2: Effect of stirring and pre-heat on the taste response for DOE II

Since it was confirmed that the brand of popcorn doesn't matter, we'll go with the cheap popcorn to save some money. And now, for the crown jewel of RSM designs…look back at the 3D surface plot in Figure 1. This curvy graph clearly supports the solution we found in optimization namely, the best tasting popcorn is achieved with a high level of stirring and no pre-heat.

Augmenting to a response surface design allowed us to model the curvature and get a better picture of what was going on in the center of the design space. We found that the A^2 term was needed to fit the center points. In other words, the stirring factor was causing the curvature, not the pre-heat. We also found that we could minimize UPKs by stirring about three-fourths of the time, but this would degrade the taste and texture too much to be worth it. With RSM, we were able to better characterize the system and increase our process knowledge. In this case, we confirmed our original conclusion. Constant stirring and no pre-heat seems to be the best way to go. After these experiments, I'm sure my wife and I will never look upon our Whirley Pop popper quite the same way again. More importantly, we can be confident that we're getting the most out of our favorite night of the week, "movie night."

—Brooks Henderson, DOE Consultant
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Brooks is a consultant with Stat-Ease, Inc. Outside of work, Brooks has many interests. When he and his wife Kristen (who is also an engineer) are not hiking, golfing, playing tennis, taking in a Twins game at the new Target Field, or performing popcorn DOE's; he enjoys advancing his career as a minor league baseball (AA level) player for the Springfield Cardinals…on his video game console. In addition to his love of sports and the outdoors, Brooks likes to stay on the cutting edge of health and nutrition, continues to enhance his knowledge of investing, and enjoys managing his family's portfolio of stocks. Also see http://www.statease.com/brooksh.html for more information on Brooks.

*More details on Fraction of Design Space can be found in a previous Stat-Teaser newsletter at: http://www.statease.com/news/news0809.pdf.

Sidebar: Graphical Optimization by *Brooks Henderson*

One useful method for finding optimum process settings is to use graphical optimization. This is shown in Figure 1 below. The "operating window" where all the goals are met is highlighted yellow. For Figure 1, the goals are: greater than 90 volume, less than 2 UPK, and taste and texture greater than 4. Here, you can get an idea for which constraints are restricting the operating window the most. For the criteria in Figure 1, UPKs and Taste are narrowing down the window, while the volume goal is easily achieved. The best way to use this graph is to click and drag on the contours to narrow down the window. I originally set the goal for UPKs at 10, but this was not restricting the window at all, so I dragged this contour down to find that I could achieve less than 2 UPKs before the window narrowed much.

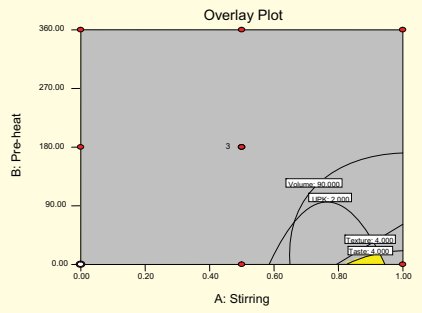

Fig. 1: Graphical Optimization – the yellow area is the sweet spot where our criteria is met

The Icing on the Cake—Adding Intervals to Graphs

Version 8 of Design-Expert software (DX8) offers many wonderful new features. One of my favorites is its ability to add confidence, prediction, or tolerance intervals to the graphical optimization. This is just the ticket for the FDA's QbD (quality by design) requirements. These three statistical intervals differ in subtle, but important ways:

- Confidence Interval (CI): *an interval that covers a population parameter (like a mean) with a pre-determined confidence level (such as 95%.)*
- Prediction Interval (PI): *an interval that covers a future outcome from the same population with a pre-determined confidence level.*
- New in v8—Tolerance Interval (TI): *an interval that covers a fixed proportion of outcomes from the population with a pre-determined confidence level. (For example, 99% of the product will be in specification with 95% confidence.)*

Note that a confidence interval contains a parameter (standard deviation, mean, etc.), while a tolerance interval encompasses a fixed proportion of a population.

Previous versions of Stat-Ease software provided a listing of the confidence and prediction intervals under Point Prediction as shown in Figure 1 below (the TI became available in v8). Now, as seen in Figure 2, these intervals can be added as bands in Graphical Optimization. (Data is taken from our popular case on microwave popcorn, available upon request.) The new pictorial representation suits QbD purposes because it focuses on the region where you are most likely to get consistent production results. The confidence levels (alpha value) can be changed under the Edit Preferences option.

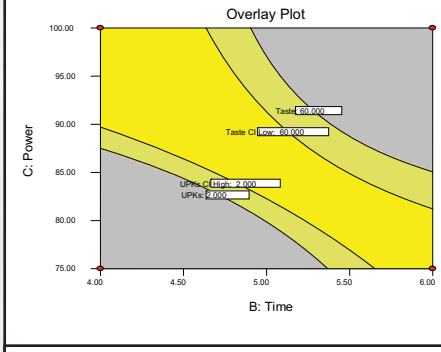

Fig. 2: Design space shown in Graphical Optimization with confidence interval bands

Our latest workshop "Basic Statistics for DOE (SDOE)" highlights the usage of these intervals, along with other "must-know" topics such as hypothesis testing and one-way ANOVA. For more information on SDOE, please see http://www.statease.com/clas_sdoe.html.

Check out class schedules and details on a full range of workshops for everyone from beginners to advanced users at http://www.statease.com/clas_pub.html. We hope to see you in class soon!

—Shari Kraber, Stat-Ease Consultant
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									99% of Population	
Response	Prediction	Std Dev	SE Mean	95% CI low	95% CI high	SE Pred	95% PI low	95% PI high	95% TI low	95% TI high
Taste	66.5	4.97494	1.75891	61.6165	71.3835	5.27672	51.8495	81.1505	32.3495	100.65

Fig. 1: Point Prediction results

Make Use of 10 Free Stat-Ease DOE Resources

08/10

Stat-Ease, Inc. offers an extensive collection of design of experiments (DOE) resources to help you in your work. These resources are free online and available at the click of your mouse. Here's a quick rundown on 10 places you can go to for software and DOE help:

1. **Free 45-day Software Trials**—The latest versions of both the Design-Expert and Design-Ease trials are downloadable online. See the Design-Expert v8 trial at http://www.statease.com/dx8trial.html.

2. **Software *Getting Started* Manual and Software Tutorials**—Work through the tutorials to become familiar with the software. For links to the latest downloads, go to http://www.statease.com/soft_ftp.html.

3. **Design-Expert Online Tour**—See the download address in number 2 above for a link to this tour. It is an excellent interactive introduction to the software for those who are new to DOE.

4. **PreDOE: Basic Statistics for Experimenters Web-Based Course**—This free 3-6 hour course (a $95 value) will give you a jump start on the basic statistics needed to do DOE. Sign-up at http://www.statease.net/class_signon.asp. There is also a statistics self-assessment at this site which you can take to determine whether or not you need the PreDOE course.

5. **Articles and Case Studies**—Stat-Ease offers a wealth of DOE articles and case studies from a variety of industries on our web site. Make use of this valuable resource by going to http://www.statease.com/articles.html.

6. **Free Webinars**—Offered on a regular basis Stat-Ease webinars range from beginning to advanced levels. View past presentations or sign up for the next one at http://www.statease.com/webinar.html.

7. **Stat-Ease Support Forum**—If you have a DOE question, log onto the forum for help. View FAQ's or post a question. You'll find the forum at http://statease.biz/forum/.

8. **Stats Made Easy Blog**—By Mark Anderson, this is a wry look at all things statistical and/or scientific from an engineering perspective. View it at http://www.statsmadeeasy.net/.

9. **DOE FAQ Alert**—This fun monthly e-mail newsletter by Mark Anderson includes frequently asked questions, software updates, software tips, upcoming talks, conferences, workshops, etc. Sign up at http://www.statease.com/doealertreg.html.

10. **Stat-Teaser Newsletter**—View the latest and greatest issue online at http://www.statease.com/newsltr.html and sign up for the paper copy at http://www.statease.com/maillist.html.

Stat-Ease offers our customers free technical support, free updates, and a limited amount of free statistical help. Feel free to contact us with any questions you may have. We appreciate your interest!

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