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Workshop Schedule

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Whirley Pop DOE

Ah, movie night! My wife and I agree that movie night, which we have in our house every Sunday, is our favorite night of the week. Now, it's not necessarily the movie that we enjoy so much. If we happen to watch a dud of a movie, it's still a good night. I guess it's just the time spent together that we enjoy and of course, the popcorn! We cannot have a movie night without those tender white morsels drizzled in butter and salted to perfection. A movie just wouldn't be the same without it.

Brooks making Whirley Pop Popcorn

To enhance our favorite night of the week, we decided to experiment with our popcorn popping technique to try to maximize the delight of our taste buds and minimize the wasted unpopped kernels at the bottom of our bowl. There's nothing worse than getting shorted on the pure enjoyment of eating popcorn.

Being experimenters, my wife and I have tried many popping methods, including the easiest—microwave popcorn—but we've found that nothing beats the taste and enjoyment we get from cooking it on the stove with the Whirley-Pop™ popcorn popper. It's pictured above.

The Setup: Factor and Design Selection
There are numerous variables to play with when using this stovetop popper. One question we wanted to answer was, "Do we really need to stand at the stove and stir the whole time it's popping?" A second question arose from my parents' recommendation that we pre-heat the pot by placing one kernel in the pan until it pops, and then adding in the rest of the kernels. We had never done it this way, so we wondered if it would make a difference. Lastly, we wanted to address whether spending the extra money for a premium popping corn was worth the price. So, we had three factors to investigate: Stirring, Pre-heat time, and Popcorn type.

We chose to do a full 2^3 factorial, testing all possible combinations. We also added three center points. The full factorial with center points is a good choice because it allows us to test for curvature. If curvature is detected, we can augment to a central composite design (CCD) to model the quadratic terms by adding a few extra runs to the original data. In all, we tested three factors at 2 levels:

A. Stirring, in fraction of time stirred from 0.0 to 1.0
B. Pre-Heat Time, in seconds from 0 to 360
C. Popcorn Type (categoric), from Cheap to Costly.

Because Factor C is categoric, the three

center points we specified became six, three for each level of this categoric factor.

To facilitate using center points, we wanted to make as many factors numeric as possible. Factor A, stirring, was a little tricky. We didn't want to just test stirring vs. not stirring, because that wouldn't allow us to make a center point and test an intermediate amount of stirring. To make it numeric, we defined it as the fraction of time stirred. The low and high levels are self-evident, 0.0 is not stirring and 1.0 is constant stirring. At the center points, which required 0.5 fraction of time stirred, we stirred for 15 seconds, stopped stirring for 15 seconds, stirred 15 seconds…and so on.

The Results

We measured four responses for this experiment. Taste was rated on a 1 to 5 scale with 5 being the best. Texture was also rated on a 1 to 5 scale with 1 being hard and 5 being soft. We prefer tender popcorn, so a value of 5 was desirable here. We counted the number of unpopped kernels (UPKs) after popping and this was our third response. The final response was an estimate of the volume of popcorn in the pot after popping. Unfortunately, we didn't have a graduated cylinder for measuring volume. That's probably the only piece of superfluous kitchenware that we didn't receive as a wedding gift. So, we just estimated the volume in the pot after popping. Given the wide range of our responses, it seems we had enough discrimination to draw some conclusions here.

Stirring and Pre-Heat both had a significant effect on taste and texture. In each case, it was best to go with constant stirring and no pre-heating; so much for our dreams of not having to stir at all. I guess Whirley-Pop knew what they were doing when they added that stirring mechanism to the pot. On the other hand, not having to pre-heat is a
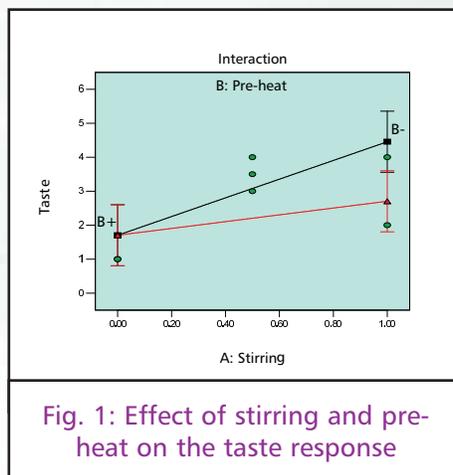

Fig. 1: Effect of stirring and pre-heat on the taste response

win for us. There is one caveat, though. Take a look at the stirring/pre-heat interaction graph for taste (Figure 1). At a stirring rate of 1.0 (right side of graph), it appears that no pre-heat (B-) will give the best taste. However, the error bars overlap slightly, so it can't be deemed statistically significant. We do have enough information to go without pre-heating in the future, though. Even if we had just equivalent taste with and without the pre-heating, we can save time by cutting out this step. When things are statistically equivalent, go with the easier or cheaper option.

Another thing to note is the significant lack of fit detected by our center points. Look at the green dots in Figure 1. These are the results at our center point treatments using the expensive popcorn. The true data points lie above the lines predicted by our model. It appears we may be able to get better tasting popcorn if we only stir half of the time or some intermediate proportion. I like the sound of that: less work and better taste! The ANOVA summary table also showed that there is significant curvature with a p-value of 0.0058 for the adjusted model.

The significant curvature suggests that we can better fit the data by adding a quadratic term, either A^2 or B^2, but because we only did a factorial design, we don't have enough data to determine which term is needed. We will have to augment the current design with more points to get a CCD

for response surface methods (RSM), which will tell us which term is correct.

For UPKs, the only factor found to be significant in the design space was factor A, stirring. More stirring reduced the number of unpopped kernels significantly (from a mean of 73.9 UPKs to only 2.8 UPKs). The volume of popcorn in the pot after popping varied mostly due to the stirring and pre-heat factors. Just like with taste, more stirring and no pre-heating was the best combination, giving us the highest volume of popcorn.

What did we learn?

Constant stirring (a level of 1.0) with no pre-heating gave the most desirable responses for taste, texture, and volume of popcorn. The brand of popcorn didn't make a statistically significant difference over the range tested, but it did appear to have some effect. We should include it in further studies. The analysis also detected significant curvature for the taste response that would suggest that we can get a better taste rating if we stir for an intermediate proportion of time. However, constant stirring reduced the number of UPKs. To decide whether we should use constant stirring to reduce UPKs or an intermediate level to possibly increase taste and texture, we'll have to upgrade to a response surface design so that we can model that intermediate proportion of stirring. If we want to keep the same factors and levels, we can simply augment the current design with a few more runs to get a CCD. However, we may want to throw the other known factors (time and temperature) that we didn't test into the final characterization and optimization study. *Stay tuned for Part II.*

—Brooks Henderson, DOE Consultant
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Brooks is the newest trainer/consultant at Stat-Ease, Inc. Take a look at his biography at http://www.statease.com/brooksh.html.

New Advanced Mixture Design Workshop

Stat-Ease, Inc. is proud to present its newest workshop, *Advanced Formulations: Combining Mixture & Process Variables*. This 2-day class is Part II on mixture design, building on the basics taught in the *Mixture Design for Optimal Formulations* workshop.

In this advanced workshop, you'll learn state-of-the-art tools for design and analysis of experiments on mixtures, including how to incorporate process variables. By the end of the class you will know how to mix your cake, bake it, and ice it too using optimal designs.

During the *Advanced Formulations* workshop you will:
♦ Set up optimal designs that combine mixture components and process factors
♦ Learn how to deal with both mixture composition and the amount applied
♦ Contend with categoric variables, such as material type

♦ Combine one mixture with another (frosting on the cake)
♦ Map mixtures to process space via ratios, thus enabling the application of factorials and response surface methods (RSM)
♦ Become an expert on innovative mixture models such as the partial quadratic
♦ Understand when it is advantageous to invert the mixture space via re-coding of components to upper-bounding
♦ Learn why the metrics for mixtures, for example by weight vs. volume, make a difference in the properties of the design.

To view the course outline, go to *http://www.statease.com/out_mix2.html*. Knowledge of the fundamentals of mixture design, covered in the *Mixture Design for Optimal Formulations* workshop, is a prerequisite.
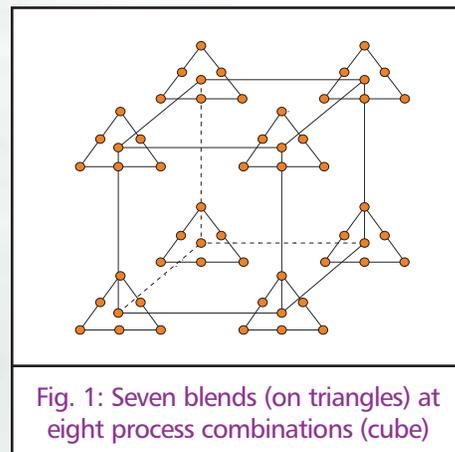
For those of you who work with formu-

Fig. 1: Seven blends (on triangles) at eight process combinations (cube)

lations and want to learn how DOE can help you make improvements, we are offering the two mixture design workshops in succession May 18-21, 2010. Attend either class separately, or attend both in the same week and save $395 on tuition. For more information on this and all the workshops Stat-Ease offers see *http://www.statease.com/clas_pub.html*. We hope to see you in class soon!

Third European DOE User Meeting

We are pleased to invite you to the *Third European DOE User Meeting*, co-sponsored by Stat-Ease, Inc., CQ Consultancy, and Statcon. It will be held May 31st–June 3, 2010 in Lucerne, Switzerland at the first-class Astoria Hotel.

The meeting will focus on design of experiments (DOE), with a special emphasis on Design-Expert® v8 software. Both the theoretical and practical aspects of DOE will be addressed, including the latest developments in the field. During the two meeting days there will by lectures by keynote speakers and other DOE experts, case study presentations by DOE practitioners, and an opportunity to consult with experts about your own DOE applications. Optional pre- and post-meeting workshops are available to give you the

Photo courtesy of freefoto.com

skills to apply what you have learned. Optional workshops offered include:
1. *DOE and RSM Simplified*
2. *Formulations Simplified*
3. *Multivariate Data Analysis in a DOE Context.*

We encourage you to come to the *Third European DOE User Meeting*. This is your opportunity to:
♦ learn how DOE makes companies successful

♦ get an overview of new developments in DOE
♦ listen to illustrative and inspiring case study presentations
♦ consult with experts about your own DOE applications and problems
♦ be introduced to the new features in Design-Expert 8
♦ network with other DOE users—share your knowledge and ideas and make new contacts
♦ receive a 20% discount coupon for any new Design-Expert or Design-Ease software package
♦ spend time in beautiful Lucerne, Switzerland.

For more information and to register see http://www.statease.com/european-meeting.html. See you in Switzerland!

Last Chance for Upgrade Savings on DX8!

Improve your product or process with Design-Expert (DX), Version 8 software. Special discount upgrade pricing extended through April 30th, 2010. For product details on DX8 and more, visit the Stat-Ease web site at *http://www.statease.com.* Download a free 45-day trial at *http://www.statease.com/dx8trial.html*.

To place your order, call 612.378.9449, fax this form to 612.746.2069, or mail it to the address below. Thank you for your business!

Qty	Item	Other Required Information	Unit Cost	Ext. Cost
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	Upgrade to DX8 from DX7.0, Old Serial # required:		$295 (reg. $395)	
	Upgrade to DX8 from DX6 or earlier, Old Serial # required:		$395 (reg. $595)	
	Upgrade to DX8 from any version of Design-Ease, Old Serial # required:		$595	
	Design-Expert 8 Annual Network [**3-seat** annual license (includes free upgrades and updates)]		$1050/year	
	Design-Expert 8 Annual Network [**5-seat** annual license (includes free upgrades and updates)]		$1625/year	
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