

stat teaser

Workshop Schedule

Experiment Design Made Easy

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*Includes a \$95 student materials charge which is subject to state and local taxes.

Attendance is limited to 16. Contact Elicia at 612.746.2038 or workshops@stateease.com.



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Popcorn Experiment Remains Fresh for Featuring Factorial Screening

(Over the last 20 years or so that we've been publishing the Stat-Teaser I have detailed many fun experiments that make use of statistical design and analysis of experiments. I really enjoy practicing what Stat-Ease preaches. I'd been thinking that it would be good to resurrect some of my early write-ups that never got posted to our internet site because the World Wide Web had not been invented yet!

First on my list was the experiment on microwave popcorn done by my son Hank for his 5th grade science project. Amazingly enough, the same day that we decided to re-publish this, I received an e-mail from DOE guru Doug Montgomery, author of the popular textbook, Design and Analysis of Experiments. A fellow professor, Bill Woodall of the Department of Statistics at Virginia Tech, had a DOE student who wanted to assign an experiment to an introductory engineering statistics class—he was thinking of assigning the popcorn experiment, where yield is to be maximized. Doug remembered my detailing of Hank's experiment and so he asked me to pass this along to Bill for referral by his student.

What follows is not my original Stat-Teaser article on microwave popcorn in the Winter of 1993, but rather a revised excerpt of a contemporaneous article published by PI Quality magazine. This article inspired a reviewer at a UK magazine, Quality News, to say that "the use of a popular and essentially highly control-*



In Search of Perfect Popcorn

lable piece of kitchenware, a microwave oven, for use in an experiment that will provide an enjoyable by-product—popcorn, a local delicacy—shows sheer genius." Enjoy.

—Mark Anderson, mark@stateease.com

**The complete article, essentially unadulterated from what was originally published, is now posted on the Stat-Ease web site at <http://www.stateease.com/pubs/popcorn.pdf>.*

Cook it hot enough, not too long, and a little bit above the floor of the oven. And preheating the oven by heating a glass of water for 1 minute has no effect. Don't even bother.

Those were the conclusions we made from applying the design of experiments (DOE) technique to the problem

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of preparing microwave popcorn. In particular, cooking microwave popcorn demonstrated how DOE helps apply the Pareto principle. In other words, it helps to identify what Juran calls the vital few factors from among the trivial many.

To begin, a brainstorming session was held to identify all possible factors that could be studied as independent variables. For this study, five major factors were selected from a broader range of ideas.

- A. Price, Generic vs. Brand
- B. Time, 4 vs. 6 min.
- C. Power, Medium vs. High
- D. Preheat, No vs. Yes
- E. Elevate, No vs. Yes

The idea for the study grew out of the last two factors. A quick study of microwave popcorn instructions at the local supermarket showed that all packages pretty much say the same thing. The instructions advise that the consumer perform a range-finding operation, cooking the popcorn pouch for 2-5 min. on a high setting until the rate of popping subsides to an interval of about one pop every three seconds.

Two unusual instructions caught our attention. One involved having the microwave bag resting on a microwave-safe rack at about the center of the chamber, as opposed to resting on the floor of the oven. The second involved the preheating step. One of these unusual factors did influence the results, the other didn't.

Our study was designed around a two-level factorial model. Some of the factors were by their nature discrete and binary; others were continuous. All variables had only two values. To limit the continuous variables, range-finding trials were conducted to set low and

high levels for each of the experiments. During some of the range-finding runs, the popcorn was seriously overcooked. A kitchen filled with smoke, we found, was a small price to pay for the education gained.

The brand factor was selected based on the central intent of the study, to determine if there is a strong correlation between the quality of the finished product and the price of the package on the grocery store shelf. The brands tested were selected to contrast a nationally distributed big-name brand against a local grocery store (generic) brand of microwave popcorn.

Most of these factors should be familiar to the reader. The preheating variable may be unusual to some, so let us explain it in more detail. It was in fact a part of what initially raised our curiosity.

The instructions on one package of popcorn that we had tried suggested that using a preheating step could increase the yield of the cooking process. If the occurrence of corn that remains unpopped (we call these bullets) is high, the instructions suggested, the yield can be increased by operating the oven with a glass of water inside for a period of one minute.

Our question was, does this preheating step—which also would raise the humidity inside the oven—really help? We shall see.

A statistically desirable array of combinations of the low and high levels was built, for a total of 16 runs, half the total number (32) of combinations possible. Such a fractional factorial design is sufficient to learn all we needed to know about popping popcorn. In fact, making more runs would not add to our knowledge. It is not necessary to run all 32 combinations to study the interactions

between factors. The runs were randomized to protect the study against lurking variables—such as changes in the environment—that could otherwise confound the study. To simplify the administration of such a study, we used Design-Ease® software for design of experiments. It handled randomizing the samples and the statistical analysis.

To measure the effects of the variable factors in each run, three response factors were considered. First the unpopped kernels (bullets) were weighed and the weight recorded. Likewise, burnt popcorn was collected from each sample run and weighed. However, this response turned out to be unreliable.

The third response—taste—was subjective, but finding people willing to serve on a judging panel was not difficult in this case. Taste evaluations were recorded using a scale from 1-10, with 10 being high or good. Observed values ranged from 1.0 to 9.0.

Observations from the runs were then entered into the Design-Ease package. The software calculated the effect each independent variable and combination of variables had on the responses. The software automatically produced a plot of effects, which helped isolate the factors that were key to determining the yield—the percentage of unpopped bullets.

One of these factors was the preheating step (D). Preheating had no impact on the responses. This is an important outcome because it means we don't have to wait an extra minute for the popcorn. The four remaining factors (brand, time, temperature, and elevation) significantly affected the bullets.

The normal plot of effects for the taste response reveals a highly significant interaction between time (B) and power

Popcorn Experiment Continued...

(C) (see Figure 1). The biggest effect comes from the time alone, but its impact depends on the level of power. As the interaction plot shows, when the time was limited to its low (-) level of 4 minutes, the predicted taste responses were roughly equal, around 7.5. (The points fall within the 95% confidence Least Significant Difference (LSD) bars displayed by the software.) With time set at its high (+) level of 6 minutes, however, the taste response varies significantly depending on other factors—in this case, the temperature or setting of the microwave oven. When set on high, enough of the popcorn burned to pull the taste response value down to under 2. Set on medium-high, the taste response dropped somewhat less, to around 6.

With this information, we feel that preheating the microwave oven is a waste of time. On the other hand, elevating the pouch in the oven is a good idea. No matter how powerful your home oven is, cooking microwave popcorn at a high setting and for a shorter rather than a longer time probably produces a

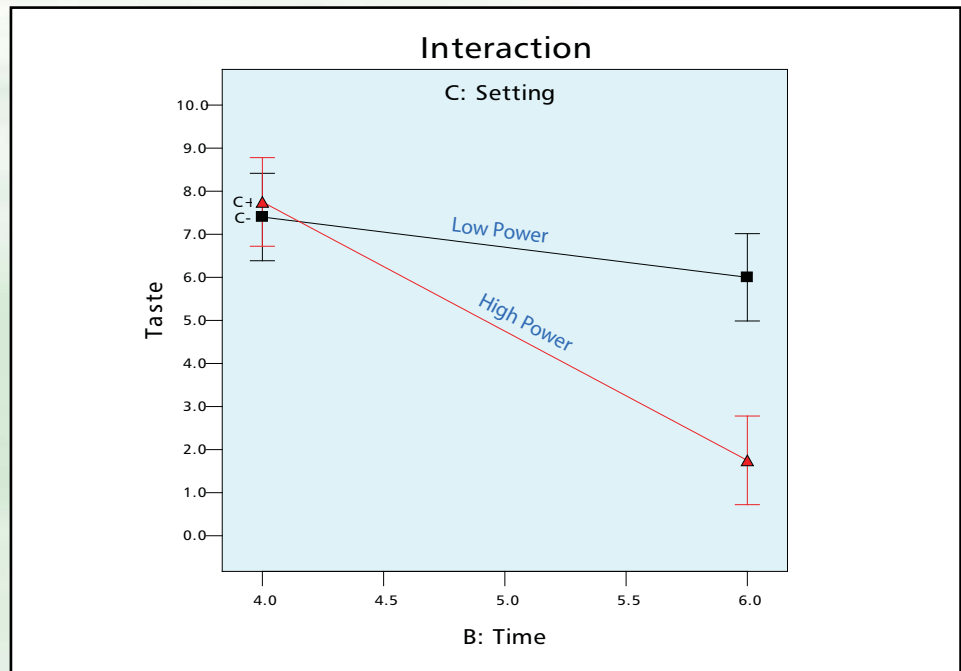


Fig. 1: The normal plot of effects for the taste response reveals a highly significant interaction between time (B) and power setting (C)

tastier result.

The results also suggest that a name brand performs better than a generic one, although our tests covered only the two brands. Clearly, more investigation

is called for before one changes one's brand preference. As a result of this study, however, we were able to reduce the presence of bullets or unpopped kernels by 80 percent, a significant gain in yield.

Follow-Up Study Reveals More Secrets for Making Popcorn

Our DOE on microwave popcorn unintentionally turned out to be a destructive test. The heat and smoke generated at the upper limits of time and power degraded the chamber to a point where we decided it might be best to get a new machine.

We purchased a more powerful and sophisticated microwave that included a pre-programmed setting for popcorn. Not content to leave things be, we did a follow-up factorial at plus and minus times around the factory setting, and two additional factors: prechilling the bag, and putting it on a wind-up

carousel. We did all the combinations plus 4 centerpoints on time for a total of 12 runs.

We thought the carousel would distribute the microwaves more evenly, but it caused a significant increase in bullets, perhaps because it absorbs energy.

Increasing the time caused a small but significant reduction in bullets. However, this was counteracted by a reduction in taste.

Prechilling did not significantly

impact either the bullets or the taste, so it's unnecessary. As a result of this study, we decided to use the factory setting for popcorn and no carousel.

PS. If you have not yet had your fill of Mark's experiments on microwave popcorn, see his December 2001 Stat-Teaser article on the "Popcorn Shootout" posted at www.statease.com/news/news0112.pdf. It reports on a simple comparative experiment on which brand to stock for the Stat-Ease company kitchen.

Take Advantage of Free DOE Webinars

03/08

Stat-Ease is proud to offer webinars on design of experiments (DOE). Presented on a regular basis, topics range in level from beginner to advanced. This is your opportunity to learn more about subjects that interest you. Take advantage of this DOE resource and increase your effectiveness as an experimenter. Stat-Ease webinars are informational, easy, and FREE! Please join us for our upcoming webinar on multiple response optimization (see below).

Multiple Response Optimization with Design-Expert® Software (Intermediate Level)

Tuesday, April 1 at 8 AM Central USA Time or Wednesday, April 2 at 12 PM Central USA Time

The optimization module in Design-Expert searches for combinations of factor levels that simultaneously satisfy the requirements placed on each of the responses and factors. Discover how to get the most out of the optimization module in order to find the "sweet spot" for your product or an operating window for your process. Learn how to fine-tune your search by adding weights and importance settings to your basic criteria. A case study will be used to illustrate all of the features of Design-Expert's optimization module.

Note: Attendance is limited for these two one-hour webinar sessions. Contact our Communications Specialist, Karen Dulski, to sign up (karen@statease.com or 612.746.2030). If space is available, she will send you the WebConnect link and telephone dial-in information for ConferenceNow. Toll-free access extends worldwide, but not to all countries. View instructions online at http://www.statease.com/webinars/webinar_attendee_instruct.pdf.

"This was a very good webinar and I look forward to future ones! I picked up several pointers as well as reinforcing the concepts I already knew. It is a good feeling knowing you are doing something the right way (mostly)! You did a good job with the material and kept us on track. Thanks again for putting these on."

—Paul Rhude, Intertape Polymer Group

Don't worry if you have missed previous webinars. All presentations are posted on our web site at <http://www.statease.com/webinar.html>. Past presentations include: "10 Ways to Mess Up an Experiment & 8 Ways to Clean It Up" (Basic Level), "Sizing Mixture (RSM) Designs for Adequate Precision via Fraction of Design Space (FDS)" (Advanced Level), and "A Factorial Design Planning Process" (Intermediate Level). If you have suggestions for future webinars, please e-mail mark@statease.com. We hope you take advantage of this new resource!

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