Efficient Experiments

User-Friendly Software
for Statistical Design of Experiments

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High price pressure and accordingly small margins force the producers of the food industry to constantly optimize their production processes. At the same time, the sensory quality of the products must be secured and improved. These two objectives can be brought in harmony by an efficient experimentation with statistical experimental design techniques. This methodology is for instance used for the production of Tilsiter cheese.

In the concrete case, the material consumption necessary for the cheese production should be lowered. For this purpose, salting was examined, next to other processing phases. One had to determine the influence of salt bath parameters – such as NaCl content, pH value, temperature and salting duration – on the mass loss as well as on the increase of the oven-dry mass. Thereby, quality standards had to be satisfied according to the cheese regulations. The results of the sensory tests were indicated by a total score (see Table 1). The goal of the analysis was to determine the combination of the factors of influence for which the mass decrease is minimal while the sensory evaluation of the cheese is as high as possible.

Factor	Unit	Variation from	to
NaCl content	%	16	22
pH value	–	4.8	5.4
Temperature	°C	15	18
Salting duration	h	20	44
Variable	**Unit**		
Mass loss	kg		
Oven-dry mass increase	%		
Sensory score	–		

Table 1. Response variables and factors considered.

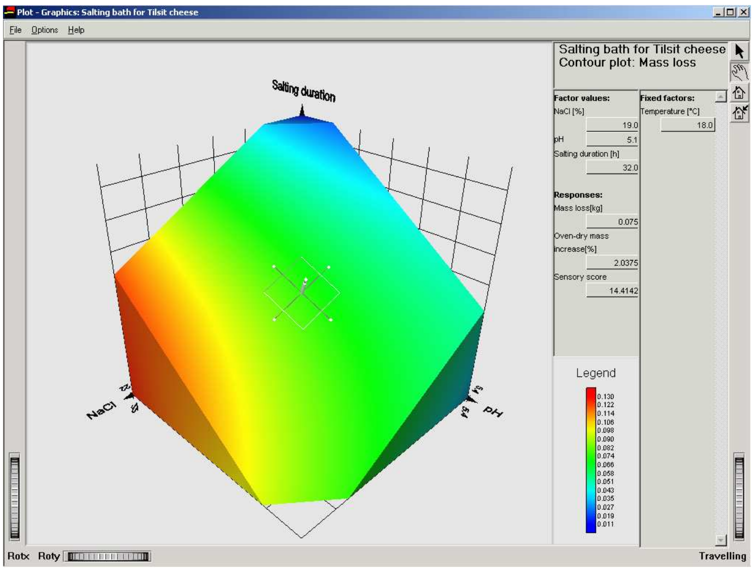

Figure 1. Mass loss as a function of NaCl content, pH value and salting duration. The "joystick" enables to read the predicted response values for various factor setting combinations.

For experimental design and analysis, the software Stavex from AICOS Technologies was used. This statistical program has been specifically developed for experimental design in the laboratory and in production. Stavex proposes experimental designs according to the user inputs and subsequently analyses the results.

Suitable experimental designs

For dealing with the problem, the user must first enter response variables and influence factors, the latter with their respective range of variation (or factor levels). Qualitative and quantitative influence factors and response variables are permitted. In the present case, all of them are quantitative. Furthermore, an optimization direction (maximization, minimization, target value optimization) can be specified for each response variable. Here, a minimum mass decrease and obviously a maximal sensory score are desired. For more complex experiments, further options are available, e.g. the specification of mixture factors, multiple-factor restrictions as well as blocked experiments.

On the basis of these inputs, the software determines suitable experimental designs. An important criterion is thereby the number of factors specified: for a given number of experiments, the individual factor influence can be examined more precisely if fewer factors are present. The software therefore suggests in case of many factors a so-called screening, and in case of few factors an optimization. The screening enables a rough estimation of the factor effect; on the other hand, the optimization makes it possible to determine an optimal setting of the factor values. A third possibility is called modeling and constitutes a middle course that is used above all for the analysis of interactions between the factors.

In the concrete case four factors are present, and the examination of the interactions is of particular interest. Therefore the software suggestion, modeling, is accepted. From the list of the suggested experimental designs, a so-called full factorial design with 16 runs was selected. The users decided to perform this plan altogether three times, so that a total of 48 results was obtained for 16 combinations of the factor levels.

Analysis and interpretation

The analysis of the results is provided as a clear and understandable report in HTML format and is illustrated by numerous graphics. The user obtains the significant effects of the influence factors on the response variables, the regression functions and those experimental conditions for which the response variables reach their optimum. The software offers many additional tools for the evaluation of the analysis: measures of the model quality, outlier investigation and the examination of model hypotheses. In case of modeling, the software carries out an automatic factor selection: factors that prove non-significant are removed from the regression model.

The analysis performed here shows that all factors are of importance for the mass loss. Furthermore, there are interactions between the following pairs of factors: NaCl content / pH value, NaCl content / temperature, pH value / salting duration, temperature / salting duration. A limited mass loss is to be obtained with a low NaCl content, a low pH value, a high temperature and a long salting duration. The model diagnoses indicate an altogether adequate statistical model.

For the interpretation of the results, graphics are very useful. Figure 1 shows the mass loss as a function of three of the four factors, the fourth factor (temperature) being set to a fixed value (here: 18.0°C). The

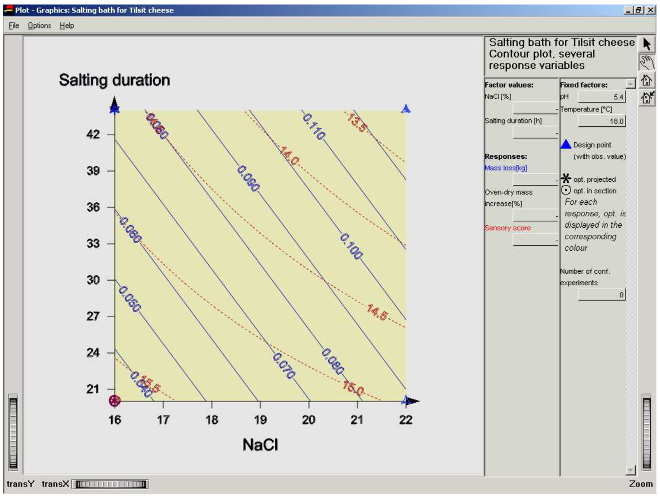

Figure 2. Mass loss (blue lines) and sensory score (red lines) depending on NaCl content and salting duration. The representation with overlaid contour lines enables to evaluate simultaneously several response variables.

analysis of the sensory score also shows a significant influence of all factors. Regarding the interactions, only that between temperature and salting duration is not significant. Luckily, one achieves under similar conditions good results for both sensory examination and mass loss, as shown by Figure 2: salting duration and NaCl content should be set low. The temperature has a relatively small influence on the mass loss. Only the pH value behaves antagonistically regarding the two response variables. The results of the oven-dry mass increase are similar to those of the mass loss.