2021-2022
Second semester

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Optimization of Industrial Production of Popcorn in Local Food Company

Abstract

The design of experiment approach is a systematic methodology that examines all of the relationships and interactions between process factors on the desired responses. This project aims to apply this advanced technique instead of the conventional trial-and-error approach to optimize the popcorn quality at FOOSCO Food Supply Co. The factors investigated in this study are temperature, socking time, drum speed, and air velocity. The popping yield, volume expansion ratio, and bulk density were the response variables investigated as quality measures of popcorn. It was revealed that the multi-optimization approach delivered the best results with less residual error than single optimization. The optimized process responses of popping yield, expansion ratio, and bulk density using a multi-optimization approach were found to be at a temperature of 201°C, socking time of 3.232min, drum speed of 8rpm, and air velocity of 31m/s with 1 composite desirability resulting in a maximum popping yield of 90%, minimum bulk density of 24.17g/L, and maximum expansion ratio of 30 with a deviation of 5.2%,3.7, and 5g/L from the predicted values respectively.

Objective and Motivation

The production optimization of popcorn project aims to optimize the quality of popcorn produced by FOOSCO Food Supply Co, by implementing the design of experiment concept and statistically analyzing experimental results to identify the most significant factors affecting popcorn quality. Also, it aims in proposing a model that describes the popcorn popping process, as well as obtaining the optimum conditions for the popcorn production process to produce popcorns that meets the standards, and costumer's satisfaction. The greatest motivation was to help the company optimize its production in an effective and time efficient way and to improve the popcorn quality produced in FOOSCO Food Supply Co ensuring that the consumer enjoys a high-quality local product that is capable to competes in the international market. For such porpoise, the team was motivated to use the design of experiment approach as it holds high efficiency and accuracy and in analyzing the results compared to other classic approaches such as the conventional trial and error approach that is commonly used in the local food industries.

Design and Implementation

The main chosen factors in this project were the heating temperature, soaking time, air blower velocity, and rotary drum speed, in which the effect of each factor on the measured responses which are the volume expansion ratio, bulk density, popping yield, and moisture content of popcorn, was studied. The basis of choosing these factors and their levels along with the responses, was the consideration of the method of popping utilized by the company, which is air popping, beside the published studies concerning the effect of distinct factors on the popping process. Response Surface Methodology (RSM) was utilized in modeling and optimizing the current study since it is one of the most effective methods used in modeling and optimizing food processing operations where the central composite design (CCD) is implemented since it considers the study of the extreme points in the process and factors with more than three levels. The CCD design was carried out using Minitab 2020 statistical software, with the four factors considered, each having five levels, with alpha equal to 2, and three center points in cube, resulting in 27 experimental runs. For optimizing the responses, the target was maximizing the expansion volume, as well as minimizing the bulk density to match the factory standards for the packaging, beside maximizing the popping yield to minimize the waste and increase the productivity of the process.

The Design was implemented in the following order:

- Measuring of popcorn quantity per experiment to minimize the amount of waste in materials.
- Conducting CCD constructed experiments.
- Statistically analyzing the results using the statistical tools in Minitab, ANOVA, and indicating the model performance in terms of coefficient of determination ($R2$), mean absolute error (MAE), mean absolute percentage error (MAPE), mean square error (MSE), and root mean squared error (RMSE).
- Performing the multiple-optimization, and the single optimization for each of the responses to obtain the optimum conditions.
- Evaluating both optimization approaches based on their ability to predict responses and residual errors, to find the best approach.

Results

After measuring the moisture content, it was found that there is no significant variation between the samples as the calculated moisture content ranged between 12-12.5%. Based on these results it has been confirmed the applicability of the pre-treatment stage so that no source of variation will occur in advanced stages. A proportional relationship obtained between socking time and moisture content, indicating that increasing the socking time leads to higher moisture absorbed by the kernel. The temperature and drum speed was found to be significant factors in the popping yield. The temperature was also found as a significant factor in the volume expansion ratio. In terms of the bulk density, it was revealed that both, temperature and socking time-drum speed interaction were significant factors. To evaluate the fitness of model to the data, the coefficient of determination of the models was estimated for popping yield, expansion ratio, and bulk density were found to be 84%, 73%, and 80%, respectively, and the proposed regression models were found to be moderately adequate in fitting the data.

The optimization verification experiment was carried out at a temperature of 201°C, 3.232 min socking time, 8 rpm drum speed, and 31m/s air velocity, giving a maximum yield of 90%, 30-time expansion of initial size, and bulk density of 24.17 g/L. A comparison was performed between the single, and multi-objective optimization in terms of the ability to attain the targeted quality measures of popcorn, in addition to the accuracy of the prediction system of each of the optimization approaches.

Comparison	Multi-optimization		Single Optimization	
	Residuals	|RelativeError|%	Residuals	|RelativeError|%
Popping Yield	5.281	5.85	12.18	13
Volume Expansion Ratio	3.746	12.44	5.9	25.65
Bulk Density	5.045	20.87	3.748	17.50

Conclusion

The popcorn quality in FOOSCO Co was successfully optimized using the response surface methodology, for the hot air popping method. Based on deviations between the predicted and the resulted values in both optimization approaches it can be clearly stated that the multi-objective optimization gives a better prediction, and a desired outcome from all the aspects compared to the single-objective optimization.

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