STATISTICAL METHODS IN OPTIMIZATION OF FOOD MATERIALS

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Abstract
Statistical methods play a vital role in science and in various fields of industry. An experimental design is an application of treatments applied to experimental units and is then part of a scientific method based on the measurement of one or more responses. The process and the operation of the system should be well observed. For this reason, in order to obtain a final result, an experimenter should plan and design experiments and well analyze the results. Response Surface Methodology (RSM) is one of the most widely used experimental designs for optimization.

RSM is a useful method because it allows researchers to evaluate the effects of multiple factors and their interactions in one or more response variables. Recent studies widely aim high yield and quality in extraction of food materials and determining optimum conditions for this extraction process. In this study, Box-Behnken design (BBD), central composite design (CCD), cube style-central composite design (SCCD), face central composite design (FCCD) and face central design (FCD) which are main designs applied in food science in recent years has been reviewed

Keywords: Statistical methods, experimental designs, food, optimization

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Introduction

The food industry wants to improve process performance and increase the efficiency without increasing cost and time. Optimization is commonly used to determine the conditions for a best output [1]. The manufacturers search for alternative processes to improve the yield with decreasing the cost and power required for production. Therefore, all new techniques including ultrasound (US), microwave (MW) and pulsed electric field (PEF) aim to improve the quality and physicochemical properties of foods and reduce the processing time and energy consumed during extraction compared to traditional methods [2].

The response surface mythology is a mathematical and statistical method, widely used in optimization of foods. The response surface method is also used not only for optimization but also for determining the effects of individual process variables and interactions on responses [3]. The appropriate selection of design, determining the independent variables and level of factors are most important steps of a RSM application [1] There are some general mistakes which the researchers make when applying the response surface method are to give the optimum point on the maximum or minimum values, to use model inappropriately even if the model does not fit and the lack of fit test is statistically significant[3].

Experimental Designs Used in Optimization

Utilization of response surface methods in the optimization studies are interest to many researchers in the last few decade [1, 4, 5]. The steps to follow in order to carry out this method properly are identification of the problem, determination the dependent variables (responses), determination the independent extraction variables (factors), decision of factor levels, selection the proper design, running experiment, evaluation the model, optimization of model and finally the validation of model (Figure 1) [4].

Full factorial design (FFD), Box-Behnken design (BBD), central composite design (CCD), cube style-central composite design (SCCD), face central composite design (FCCD) and face central design (FCD) are main designs used commonly in food science. Recent response surface method studies used in optimization of food materials are summarized in Table 1.

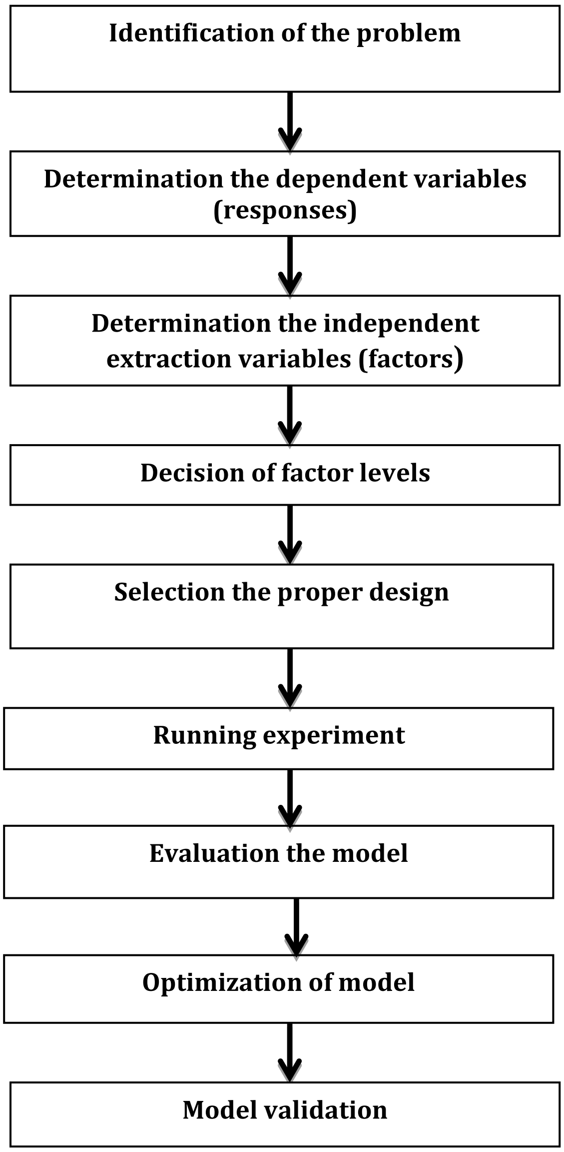

Figure 1. Steps for response surface methodology[4]

Table 1. Summary of some optimization studies in food materials used RSM

Extraction	Extraction method	Process parameters	Design method	Dependent variables	Model	Ref
Olive leaf	Ultrasound assisted extraction	Solvent concentration, the ratio of solid to solvent, extraction time	BBD	Extract yield, total polyphenol content, antioxidant activity	Quadratic polynomial	[6]
Olive waste	Nonconventional aqueous extraction method	NaOH, temperature, time, mass of the waste	BBD	Total phenolic content, relative color strength	Quadratic polynomial	[7]
Olive leaf	Solvent-Free Microwave-Assisted Extraction	Amount of sample, irradiation power, the extraction time.	FCCD	Oleurope in yield and total phenolic content	Quadratic polynomial	[8]
Olive oil	Ultrasound assisted extraction	Ultrasound time, ultrasound temperature, malaxation time	BBD	Oilyield, acidity	Quadratic polynomial	[9]
Olive oil	High power ultrasound assisted extraction	Olive paste flow, ultrasound intensity, fruit temperature before crushing, olive moisture, olive fat content	BBD	Olive paste temperature	2FI	[10]
Olive oil	Conventional extraction	Malaxation time and temperature	CCD	Acidity, peroxidevalue, K232, K270, Total phenolic content	Quadratic polynomial	[11]
Black Carrot	Ultrasound assisted extraction	Ultrasound energy density, temperature	CCD	Anthocyonin compounds	Quadratic polynomial	[12]
Curry leaf	Ultrasoundassistedextraction	Temperature, ultrasonic power, methanol concentration	CCD	Catechinyield, myricetin yield, quercetin yield, antioxidant activity	Quadratic polynomial	[5]
Rapeseed meal	Ultrasound assistedsolvent extraction	Temperature, liquid to material ratio, duration and ultrasonic power	BBD	Carotenoid yield	Second-order (Quadratic) polynomial	[13]

Table 1 (Continued)

Extraction	**Extractionmethod**	**Processparameters**	**Design method**	**Dependentvariables**	**Model**	**Ref**
Coffee silver skin	Ultrasound assisted extraction / Microwave assisted extraction	Extraction time, extraction temperature	CCD	Total phenolic content, radical scavenging capacity, total caffeoylquinic acids, caffeine content	Quadratic polynomial	[14]
Brown seaweed	Ultrasound assisted extraction	Extraction time, acidconcentration, ultrasoundamplitude	BBD	Total phenolic, Fucose , Uronicacids	Second-order (Quadratic) polynomial	[15]
*Trapa quadrispinosa*s tems	Ultrasound assisted extraction	Ultrasonic time, liquid to material ratio, ultrasonic temperature	BBD	Polysaccharide yield, Ferric-Reducing Antioxidant Capacity (FRAC)	Quadratic polynomial	[16]
Sphallerocarpus gracilis roots	Hot water extraction, Ultrasound assisted extraction	Extraction temperature, Extraction time, Liquid-solidratio, Ultrasound power	BBD	*S. gracilis* yield	Quadratic polynomial	[17]
Papaya seedoil	Ultrasound assisted extraction	Time, temperature, ultrasound power, Solvent to sample ratio	SCCD	Yield , antioxidant activity , p-anisidin value, peroxide value, totox value	Quadratic polynomial	[18]
Pomegranate seedoil	Ultrasound assisted extraction	Ultrasonic power, extraction temperature, extraction time, the ratio of solvent volume and seed weight	BBD	Oil yield	Quadratic polynomial	[19]
Spriluna powder	Ultrasound	Temperature, Sonicationenergy, sonication time	BBD	Oil holding capacity	Quadratic polynomial	[20]
Spriluna powder	Ultrasound	pH, Sonicationenergy, sonication time	BBD	Water holding capacity	Quadratic polynomial	[20]
Olive pomace	Microwave	Microwavepower, irradiation time, solvent-to-sample ratio	FCD	Oilyield, physicochemical oil properties	Quadratic polynomial	[21]
Gac fruit peel	Solvent extraction	Extraction time, extraction temperature, solvent ratio	BBD	Total carotenoid, Antioxidantcapacity	Quadratic polynomial	[22]

Extraction methods, process parameters, design method, dependent variables and the model found in studies are also shown in the same table. BBD is one of the most commonly design method used by several researchers recently[23]. The BBD design generally consists of 17 combinations including three replicates of the center point to evaluate the pure error when 3 factors were evaluated.
In some studies, BBD in the experimental design may consist of more treatments including five replicates of the central point when factors are higher than 3[19].
CCD is the other widely used design developed by Box and Wilson in 1951. It consists of factorial points, a central point and axial point. Thus, more experiments are required in CCD when compared to BBD, FFD and other designs.[1].

Conclusion

In food processes, the response surface method has been successfully used to optimize parameters to obtain a better product. It determines the effect of independent variables on dependent variables. In addition, empirical model is also produced by the RSM approach. RSM is derived from the graphical view that follows after the fitting of the mathematical model. The main aim to apply RSM is to optimize process for a higher quality or less energy, and evaluate the relationship between the independent and dependent variables. In optimization studies, selection of the appropriate design, finding the dependent parameter and its levels are most crucial steps.

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