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Section 1

MANE 6313

Subsection 1

Week 13, Module C

Student Learning Outcome

- Select an appropriate experimental design with one or more factors,
- Select an appropriate model with one or more factors,
- Evaluate statistical analyses of experimental designs,
- Assess the model adequacy of any experimental design, and
- Interpret model results.

Module Learning Outcome

Analyze a CCD experiment.

Central Composite Design Case Study

RSM Example

4.6 Numerical Example

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4.6 A NUMERICAL EXAMPLE: THE EFFECT OF HEAT AND OTHER FACTORS UPON FOAMING PROPERTIES OF WHEY PROTEIN CONCENTRATES

Richert et al. (1974) investigated the effects of heating temperature (X_1), pH level (X_2), Redox potential (X_3), sodium oxalate (X_4), and sodium lauryl sulfate (X_5) on foaming properties of whey protein concentrates. Several response variables were studied, one of which was the percent of undenatured protein, Y . A central composite design with six center points was employed in order to fit a second-order model. The design in coded form and the observed data values are listed in Table 4.6. The original and coded levels of the input variables are listed in Table 4.7.

Table 4.7 Original and Coded Levels of Independent Variables

Variable	Original	Coded				
		-2	-1	0	1	2
Heating temperature	X_1 ($^{\circ}\text{C}/30 \text{ min}$)	65.0	70.0	75.0	80.0	85.0
pH	X_2	4.0	5.0	6.0	7.0	8.0
Redox potential	X_3 (volt)	-0.025	0.075	0.175	0.275	0.375
Sodium oxalate	X_4 (Molar)	0.0	0.0125	0.025	0.0375	0.05
Sodium lauryl sulfate	X_5 (% of solids)	0.0	0.05	0.10	0.15	0.20

Source: S. H. Richert, C. V. Morr, and C. M. Cooney (1974). Reprinted from *Journal of Food Science*. Copyright © by Institute of Food Technologies.

Source: Khuri and Cornell (87).

Response Surfaces: Designs and Analyses.

CCD Data

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Second-Order Models and Designs

Table 4.6 Experimental Design (Coded) and Response Values

x_1	x_2	x_3	x_4	x_5	Y (%)
-1	-1	-1	-1	1	80.6
1	-1	-1	-1	-1	67.9
-1	1	-1	-1	-1	83.1
1	1	-1	-1	1	38.1
-1	-1	1	-1	-1	79.7
1	-1	1	-1	1	74.7
-1	1	1	-1	1	71.2
1	1	1	-1	-1	36.8
-1	-1	-1	1	-1	81.7
1	-1	-1	1	1	66.8
-1	1	-1	1	1	73.0
1	1	-1	1	-1	40.5
-1	-1	1	1	1	74.9
1	-1	1	1	-1	74.2
-1	1	1	1	-1	63.5
1	1	1	1	1	42.8
-2	0	0	0	0	80.9
2	0	0	0	0	42.4
0	-2	0	0	0	73.4
0	2	0	0	0	45.0
0	0	-2	0	0	66.0
0	0	2	0	0	71.7
0	0	0	-2	0	77.5
0	0	0	2	0	76.3
0	0	0	0	-2	67.4
0	0	0	0	2	86.1
0	0	0	0	0	77.4
0	0	0	0	0	74.6
0	0	0	0	0	79.8
0	0	0	0	0	78.3
0	0	0	0	0	74.8
0	0	0	0	0	80.6

factorial

$$2^{5-1} = 16$$

axial

6 CP

Source: S. H. Richert, C. V. Morr, and C. M. Cooney (1974). Reprinted from Journal of Food Science. Copyright © by Institute of

Full Model

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Coded Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	77.21	8.16	9.46	0.000	
x1	-10.15	4.18	-2.43	0.033	1.00
x2	-0.53	4.18	-0.13	0.901	1.00
x3	1.17	4.18	0.28	0.784	1.00
x4	-0.13	4.18	-0.03	0.976	1.00
x5	-0.96	4.18	-0.23	0.822	1.00
x1*x1	-2.60	3.78	-0.69	0.505	1.02
x2*x2	-8.29	3.78	-2.19	0.051	1.02
x3*x3	-4.09	3.78	-1.08	0.302	1.02
x4*x4	0.69	3.78	0.18	0.859	1.02
x5*x5	-0.00	3.78	-0.00	1.000	1.02
x1*x2	-6.21	5.12	-1.21	0.251	1.00
x1*x3	2.77	5.12	0.54	0.599	1.00
x1*x4	1.77	5.12	0.35	0.736	1.00
x1*x5	0.71	5.12	0.14	0.893	1.00
x2*x3	-1.68	5.12	-0.33	0.749	1.00
x2*x4	-0.26	5.12	-0.05	0.961	1.00
x2*x5	0.48	5.12	0.09	0.927	1.00
x3*x4	0.04	5.12	0.01	0.993	1.00
x3*x5	1.51	5.12	0.29	0.774	1.00
x4*x5	0.03	5.12	0.01	0.995	1.00

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x_1, x_2, x_2^2

18 terms
not statistically
sig w. 1000

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	20	5977.2	298.86	0.71	0.754

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Error	11	4607.7	418.88		
Lack-of-Fit	6	4507.6	751.27	37.54	0.001
Pure Error	5	100.1	20.01		
Total	31	10584.9			

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$$\text{Full}$$

$$df_R = 20 \quad SS_R = 5977.2$$

$$df_E = 11 \quad MS_E = 418.88$$

$$\text{Reduced}$$

$$df_R = 3 \quad SS_R = 4348.5$$

$$F_0 = \frac{(5977.2 - 4348.5) / (20 - 3)}{418.88}$$

$$= 0.2287$$

$$F_{17,11}$$

Not statistically significant