M.C. Gacula, Jr.

DESIGN AND ANALYSIS OF SENSORY OPTIMIZATION



CONTENTS

2

CHAPTER	PAGE
PREFACE	vii
1. INTRODUCTION	1
1.1 Statistical Inference	1
1.2 Experimental Design	2
1.3 Sample Size	2
1.4 Randomization	4
1.5 Analysis of Variance	6
1.6 Multiple Comparison Tests	7
Duncan's Multiple Range Test	8
Rank Sum Multiple Comparison Test	8
1.7 Some Useful Tools for Data Analysis	9
Deviation from the Mean	10
Rejection of Outlying Observations	11
Test Procedures	15
2. DESIGNS FOR COMPARING TWO POPULATIONS	23
2.1 Paired Comparison Design	23
2.2 Group Comparison Design	25
3. COMPLETELY RANDOM AND RANDOMIZED	
COMPLETE BLOCK DESIGN	29
3.1 Completely Randomized Design	29
3.2 Randomized Complete Block Design	32
4. INCOMPLETE BLOCK DESIGNS	35
4.1 Balanced Incomplete Block Design	35
4.2 Incomplete Blocks Augmented with Control	39
5. CROSSOVER DESIGN	45
5.1 Crossover Design in Home-Use Consumer Tests	45
5.2 Rating Scale Response	48
5.3 Binary Response	52
5.4 Analysis of Data with Carry-Over Effects	55

ix

CONTENTS

6.	FRACTIONAL FACTORIAL DESIGN FOR FACTORS	
	AT TWO LEVELS	57
	6.1 The 2 ^k Factorial Designs	57
	The 2 ² Factorial Design	57
	Estimate of Average Factor Effects	59
	The 2 ³ Factorial Design	66
	Addition of Center Point in 2 ^k Factorial Design	74
	6.2 One-Half Fraction of 2 ⁴	74
	6.3 One-Half and One-Fourth Fraction of 2^k	80
7.	SCALING METHODS	83
	7.1 Sensory Measurements	83
	Nominal Scale	83
	Ordinal Scale	85
	Interval Scale	85
	Ratio Scale	86
	7.2 The Thurstone-Mosteller Model	87
	7.3 Ranking Method	91
	Rank Scaling in Balanced Incomplete Block Designs	94
	7.4 Transitivity Property of Paired Comparison	98
	7.5 Scaling Consumer Acceptance	99
	In-House Consumer Test	99
	Home-Use Test	100
	Central Location Test	100
	Questionnaire Design	100
8.	PRODUCT OPTIMIZATION	105
	8.1 Preliminaries	105
	Test for Adequacy of Statistical Model	106
	Least Squares Estimation of Regression Parameters	108
	8.2 Why Use Optimization Technique?	118
	8.3 Types of Optimization Experiments	120
	Nonmixture Experiments	122
	Mixture Experiments	122
	Space Configuration of Nonmixture and Mixture Designs	123
	8.4 Plackett and Burman Design	133
	8.5 Box and Behnken Design	137
	8.6 Box and Wilson Design	141
	8.7 Mixture Designs	153
	Mixture Models	156
	Scheffé Simplex-Lattice Design	157
	Schette Simplex-Centroid Design	163
	Designs with Constraints on Proportion	169

Х

CONTENTS

8

8.8 Search for Optimum Areas in Response Surfaces	174
8.9 Use of Contour Maps in Product Reformulation	182
8.10 Augmentation of Fractional Factorial Design	186
The Augmented 1/2 Fraction of 2 ⁴	187
The Augmented 1/2 and 1/4 Fractions of 25	188
The Augmented 1/4 Fraction of 26	189
8.11 Precaution of Fraction Factorial Designs	194-
8.12 Optimization of Discrete Variables	199
Discrete Variable Optimization	203
Optimization of Discrete and Continuous Variables	207
8.13 Optimization for Robustness	211
The Taguchi Method	214
Types of Quality Characteristics	215
Problems with Perceived Quality Characteristics	215
The Measurement of Quality	217
Scales for Perceived Quality	220
The Use of Signal-to-Noise Ratio in Formula Selection	229
9. CLAIM SUBSTANTIATION	237
9.1 Claim Substantiation Guidelines	237
9.2 Testing of Claims Hypothesis	240
9.3 Experimental Design and Claims Support	241
9.4 Test for Equivalence and Superiority	242
Calculation of Power of the Test	245
Sensory Equivalence	247
Sample Size and Power of the Test	252
9.5 Null Hypothesis with Specified Difference	254
APPENDIX: STATISTICAL TABLES	257
REFERENCES	291
INDEX	299

xi