ANALYSES OF TASTE PANEL SCORES FOR GRAPE JUICE SAMPLES, 1964

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Abstract

Seventeen experiments were each designed as a balanced incomplete block design with v=5 treatments, r=6 replicates, k=3 treatments per incomplete block, and b=10 incomplete blocks; and each experiment was repeated (i.e., a second replicate) to produce 34 experiments. Five different sets of five treatments were used. One set of treatments was used on five different harvest dates. The analyses were obtained for each of the 34 experiments, for the sums of the two replicates from the 17 experiments, and for the differences between the two replicates from the 17 experiments. Suggestions are given for combining the analyses. Some discussion of the results is presented.

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A series of experiments in a balanced incomplete block design were conducted using the Geneva Experiment Station taste panel (1A, 2A, 3A, 4A, and 5A experiments) and using a commercial taste panel (experiments 1B, 2B, 3B, and 5B). The balanced incomplete block design used consisted of using b=10 tasters as the blocks each tasting k=3 grape juice samples at one sitting. There were v=5 treatments in the design with each treatment being replicated r=6 times. Two complete sets of each balanced incomplete block design were run with the treatment block arrangment being the same for the A group but different for the two sets of the B group. In addition, there were five harvests for each set of treatments in the 1A and 1B series, and there were five sets of treatments.

In the 1A and 1B experiments the five treatments were hand-harvest and mechanical harvest held for 2 hours, for 4 hours, for 8 hours, and for 20 hours.

The ten separate balanced incomplete block design experiments conducted in each of the A and B series were:

Harvest	1	, Replicate	1
"	1	"	2
"	2	"	1
"	2	"	2
"	3	"	1
"	3	"	2
"	4	"	1
"	4	"	2
"	5	"	1
"	5	"	2

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Thus, there were 20 such experiments in the 1A plus the 1B series.

In the 2A and 2B series of experiments only one of the harvests was considered, resulting in two experiments in the 2A group and two experiments in the 2B group. The five treatments were mechanical harvest held for 5 hours and four treatments of hand-harvested grapes with the juice held for zero, 2, 12, and 21 hours, respectively.

In the 3A and 3B series of experiments only one of the harvests was considered resulting in four experiments, two each in the A and in the B series. The five treatments in this set of experiments were with the whole berry harvested by hand and held zero hours and by mechanical harvesting and held $2\frac{1}{2}$ hours and $9\frac{1}{2}$ hours, and with the berry pulp harvested mechanically and held for one hour and for 8 hours.

In the 4A set of experiments the five treatments were combinations of time of holding pulp and time of aerating pulp for the following periods:

Pulp held for	$3\frac{3}{4}$ hrs.	4 hrs.	4 hrs.	$7\frac{3}{4}$ hrs.	$9\frac{1}{4}$ hrs.
Pulp aerated for	0 hrs.	1 hr.	$2\frac{1}{2}$ hrs.	$\frac{1}{4}$ hr.	0 hr.

There were two sets of this experiment. There were no 4B experiments.

In the 5A and 5B experiments, each with two sets, the five treatments were hand-harvested with no aeration and mechanical harvested samples with zero, 10, 20, and 60 minutes of aeration.

Statistical Analysis

The general analysis for an incomplete block design or for sets of incomplete block designs may be obtained from several places in the literature (e.g.

Federer [1955], Experimental Design, Chapter XIII). The design and analysis for replicate 1 of the 2A series is described below. The design and data are:

Treatment		Panelist or incomplete block and score										
Type	Held for	1	2	3	4	5	6	7	8	9	10	Sum
Mechanical	5 hrs.	5			1	8		8	7		4	33
Hand	0 hr.		2		4		3	3		5	7	24
Hand	2 hrs.	9	6	9	9	9	8					50
Hand	12 hrs.			3		6	1		3	4	8	25
Hand	21 hrs.	8	9	8				10	10	10		55
Sum		22	17	20	14	23	12	21	20	19	19	187

Since r=6 and $\lambda = 3$ = number of times each treatment is compared with every other treatment in an incomplete block, the normal equations for the treatments may be put in the form

$$(rI - N'N/k)\tau = (6I - \frac{6-3}{3} I - \frac{3}{3} J)\tau = (5I - J)\tau = Q$$

where I is the identity matrix, J is the matrix of ones, and τ and Q are column vectors. Using the fact that $\Sigma\hat{\tau}_i=0$ we note that the solution for the i^{th} treatment effect is:

$$\hat{\tau}_i = \frac{1}{5} Q_{i.} = \frac{1}{5} \left\{ Y_{i.} - \sum_{j=1}^{10} n_{ij} \bar{y}_{.j} \right\}$$

where $Y_{i.}$ and $Y_{.j}$ are the treatment and block totals, respectively, and $n_{ij}=1$ if the i^{th} treatment occurs in the j^{th} block and zero otherwise. The $Q_{i.}$ are computed as:

$$Q_{1.} = Y_{1.} - (Y_{.1}+Y_{.4}+Y_{.5}+Y_{.7}+Y_{.8}+Y_{.10})/3 = 33 - 119/3 = -20/3$$

$$Q_{2.} = Y_{2.} - (Y_{.2}+Y_{.4}+Y_{.6}+Y_{.7}+Y_{.9}+Y_{.10})/3 = 24 - 102/3 = -30/3$$

$$Q_{3.} = Y_{3.} - (Y_{.1}+Y_{.2}+Y_{.3}+Y_{.4}+Y_{.5}+Y_{.6})/3 = 50 - 108/3 = 42/3$$

$$Q_{4.} = Y_{4.} - (Y_{.3}+Y_{.5}+Y_{.6}+Y_{.8}+Y_{.9}+Y_{.10})/3 = 25 - 113/3 = -38/3$$

$$Q_{5.} = Y_{5.} - (Y_{.1}+Y_{.2}+Y_{.3}+Y_{.7}+Y_{.8}+Y_{.9})/3 = 55 - 119/3 = 46/3$$

The corresponding $Q_{.j}$ for blocks and the solutions for the block effects are:

$$Q_{.1} = 22 - (33+50+55)/6 = -6/6$$

$$Q_{.2} = 17 - 129/6 = -27/6$$

$$Q_{.3} = 20 - 130/6 = -10/6$$

$$Q_{.4} = 14 - 107/6 = -23/6$$

$$Q_{.5} = 23 - 108/6 = 30/6$$

$$Q_{.6} = 12 - 99/6 = -27/6$$

$$Q_{.7} = 21 - 112/6 = 14/6$$

$$Q_{.8} = 20 - 113/6 = 7/6$$

$$Q_{.9} = 19 - 104/6 = 10/6$$

$$Q_{.10} = 19 - 82/6 = 32/6$$

$$\hat{\beta}_1 = 22/3 - 187/30 - (-20+42+46)/45 = -37/90$$

$$\hat{\beta}_2 = 17/3 - 187/30 - (-30+42+46)/45 = -167/90$$

$$\hat{\beta}_3 = 20/3 - 187/30 - (42-38+46)/45 = -61/90$$

$$\hat{\beta}_4 = 14/3 - 187/30 - (-20-30+42)/45 = -125/90$$

$$\hat{\beta}_5 = 23/3 - 187/30 - (-20+42-38)/45 = 161/90$$

$$\hat{\beta}_6 = 12/3 - 187/30 - (-30+42-38)/45 = -149/90$$

$$\hat{\beta}_7 = 21/3 - 187/30 - (-20-30+46)/45 = 77/90$$

$$\hat{\beta}_8 = 20/3 - 187/30 - (-20-38+46)/45 = 63/90$$

$$\hat{\beta}_9 = 19/3 - 187/30 - (-30-38+46)/45 = 53/90$$

$$\hat{\beta}_{10} = 19/3 - 187/30 - (-20-30-38)/45 = 185/90$$

With these results we are now in a position to compute an analysis of variance table as given below:

Source of variation	d.f.	Sum of squares	
Total	30	$\sum_i \sum_j n_{ij} Y_{ij}^2$	= 1399
Correction for mean	1	$Y_{..}^2/n_{..} = 187^2/30$	= 1165.63
Blocks (ignoring treatments)	9	$\sum_{j=1}^{10} Y_{.j}^2 - Y_{..}^2/n_{..}$	= 36.03
Treatments (eliminating blocks)	4	$\sum \hat{\tau}_i Q_{i.} = \sum Q_{i.}^2/5$	= 147.20
Intrablock error	16	subtraction	50.14
Blocks (eliminating treatments)	9	$\sum \hat{\beta}_j Q_{.j}$	= 46.37
Treatments (ignoring blocks)	4	$\sum Y_{i.}^2/r - Y_{..}^2/n_{..}$	= 136.87

An F statistic testing the hypothesis of equality of treatment means may be computed as follows:

$$F(4,16 \text{ df}) = \frac{\text{Treatments (elim.block)m.s.}}{\text{Intrablock error m.s.}} = \frac{147.20/4}{50.14/16} = 11.7 \quad .$$

The above F value is greater than $F_{.01}(4,16) = 4.77$. Likewise, the F statistic using the blocks (elim. tr.) m.s. is

$$F = \frac{46.37/9}{50.14/16} = \frac{5.15}{3.13} = 1.65 < F_{.05}(9,16) = 2.54 \; ..$$

The analyses for the 34 individual experiments are presented in Table 1. From these data we notice considerable variation in the results. For example, the variation between treatments is relatively large for the first two harvests and not for the remaining three harvests in the A group. In the B group, only the second harvest has relatively large mean squares as compared to the remaining four harvests. Also, in series 5 of the A group, the F ratio for treatments/error changes from less than one to more than 11 in going from the first to the second replicate.

In order to obtain a measure of the replicate by other effects interaction, and since the block-treatment arrangement in the two replicates was identical, analyses of variance were run on the sums and differences of scores. From these results one may combine the analyses for the two replicates in the following analysis of variance:

Source of variation	d.f.	
Total	60	
Correction for mean	1	} { Sum of correction terms in individual analyses
Replicate	1	
Block (ign.treat.) within replicate	18	{Sum of two sums of squares in individual analyses
Treatment (elim.block) within replicate	8	{Sum of two sums of squares in individual analyses
Treatment (elim.block)	4	(from sums)
Treatment (elim.block) × replicate	4	(from differences)
Intrablock error within replicate	32	{Sum of intrablock error sums of squares
Block (elim.treat.) within replicate	18	{Sum of individual analyses sums of squares
Block (elim.treat.)	9	(from sums)
Block (elim.treat.) × replicate	9	(from differences)

Although other partitionings are possible the above should suffice. These data were not summarized, but may be obtained directly from the IBM analyses sheet.

Other interactions are apparent in the data, especially those involving the two groups A and B. For example, the average intrablock error mean square for the B group is only 1/3 that for the A group. The F ratio of treatments/error in the A group is about 4 while that in the B group is about 3 despite the fact that the error mean square is only 1/3 that in the A group. The F ratio of blocks/error in the A group is 1.5, whereas this ratio in the B group is 2.6 despite the fact that the block mean square for the A group is 1.8 times larger than for the B group.

If one wished the 1A group with 5 harvests could be analyzed as per the following analysis of variance:

Source of variation	d.f.	
Total	300	
Correction for mean	1	
Harvest	4	
Replicates within harvests	5	
Block (ign. treat.) within replicates and within harvests	90	
Treatment (elim. blocks) within replicates and within harvests	40	
Treatment (elim. blocks) = T		4
T × harvests		16
T × replicates within harvests		20
Intrablock	160	
Blocks (elim. treat.) within replicates and harvests	90	
Blocks (elim. treat.) = B		9
B × harvests		36
B × replicate within harvest		45

Also, the two groups 1A and 1B over the five harvests could be combined into a single analysis of variance table as follows:

Source of variation	d.f.
Total	600
Correction for mean	1
Harvests = H	4
Group A vs. B = G	1
G × H	4
Replicates within groups and harvests	10
Block (ign.treat.) within replicate, harvest, and group	180
Treatment (elim. block) within replicate, harvest, and group	80
Treatment (elim. block) = T	4
T × H	16
T × G	4
T × G × H	16
T × replicates within groups and harvests	40
Intrablock	320
Block (elim. treat.) within replicate, group and harvest	180
Blocks (elim. treat.) within group A = B_1	9
B_1 × H within group A	36
Blocks (elim. treat.) within group B = B_2	9
B_2 × H within group B	36
Blocks × replicates within group A	45
Blocks × replicates within group B	45

However, due to heterogeneity of intrablock error variances such a combined analysis of variance is of questionable utility. A more fruitful investigation would appear to be an examination of the treatment effects adjusted for blocks from replicate to replicate, from harvest to harvest, and from group A to group B. Such a study may throw light upon the nature of treatment and taster differences. (A transformation of the scores was considered but rejected. If the treatments had been ranked in each incomplete block then some such transformation as rankits could have been used.)

Table 1. Mean squares for analyses of 34 individual experiments arranged in a balanced incomplete block design.

Series	Harvest	Replicate	Mean squares: A (Geneva panel) Intra-block (16 df)	A (Geneva panel) Treat. (elim. block) (4 df)	A (Geneva panel) Block (elim. treatment) (9 df)	B (Commercial panel) Intra-block (16 df)	B (Commercial panel) Treat. (elim. block (4 df)	B (Commercial panel) Block (elim. treatment) (9 df)
1	1	1	5.99	16.39	4.67	1.36	0.40	4.23
		2	2.05	23.63	10.37	2.49	1.52	4.73
	2	1	3.14	46.61	8.44	0.71	7.16	7.62
		2	4.11	25.41	7.42	2.34	9.14	5.40
	3	1	2.78	5.07	6.34	0.81	0.76	0.48
		2	2.81	4.93	8.41	0.58	1.68	2.39
	4	1	4.48	2.73	9.64	1.24	2.53	2.00
		2	2.89	3.92	6.56	0.72	5.30	3.67
	5	1	4.89	4.59	7.74	1.03	3.37	3.29
		2	3.58	10.02	8.62	1.31	2.27	3.43
2	-	1	3.13	36.80	5.15	1.51	4.47	3.30
		2	4.56	32.43	2.16	1.83	3.36	2.34
3	-	1	6.38	29.48	6.42	2.89	7.76	2.06
		2	6.34	25.81	9.56	1.11	10.72	5.73
4	-	1	4.86	27.74	3.61	-	-	-
		2	4.04	30.01	5.47	-	-	-
5	-	1	9.74	7.69	1.99	1.13	5.47	4.32
		2	3.24	35.06	4.90	1.75	7.99	4.92
Average (Series 4 omitted)			4.38	19.41	6.77	1.43	4.62	3.74