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The Effect of Fixed and Random Models in the Interpretation of Biological Data

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Abstract: Problem statement: Data on variation of sugar content in maize Ogi, fermented maize flour, obtained from 4 maize hybrids subjected to 5 different days of fermentation were used to test the effects of fixed and random statistical models on the interpretation of biological results. **Approach:** The data were subjected to analysis of variance using both fixed and random models. **Results:** Highly significant difference ($p = 0.1$) was present among hybrids, days of fermentation and interaction of hybrids and days, where the fixed model was used. On the other hand, where the random model was assumed, the interaction component of variance was found not to be significantly different from zero contrary to the findings with the fixed model. **Conclusion/Recommendations:** The results indicate that the statistical model used may influence interpretation of biological results.

Key words: Random model, fixed model, analysis of variance, fermented maize flour, statistical model

INTRODUCTION

This study was designed to investigate the effect of fixed and random models on the interpretation of biological data with particular interest in the variation of sugar content in maize Ogi.

The data used in this study were obtained from an experiment with 4 maize hybrids subjected to 5 different days of fermentation. The aim of the experiment was to determine the effects of the maize hybrids and the period of fermentation on the yield and quality of Ogi (Alika and Omekara, 1991).

Ogi, Nigerian fermented cereal porridge, is a popular food in Nigeria. It is made from either corn or sorghum. It is mostly consumed by adults, infants and children and also frequently used as a weaning diet (Ashaye *et al*., 2000). Ogi porridge is commonly smoothed creamy and free flowing. It is eaten by people of different ages and economic status (Bamingo and Muller, 1972).

A quantity being random means that it fluctuates over units in some population: and which particular unit is being observed, depends on chance. When some effect in statistical model is modelled as being random, we mean that we wish to draw, conclusions about the population from which the observed units were drawn, rather than about these particular units themselves (Snijdes and Tom, 2005). Fixed and random models differ primarily in the inclusion or deletion of specific interaction components along with components of main effects.

The data used in this study were subjected to two-way analysis of variance with two replications. In this study we restricted ourselves to the fixed and random models. When the levels of an independent variable are not randomly selected from a population of levels, but are fixed (say by the researcher) the analysis of variance model is referred to as a fixed-effect model. On the other hand, if the levels of an independent variable included in a study are randomly selected from a population of levels, the resulting analysis of variance model is referred to as a random-effect model.

MATERIALS AND METHODS

The analysis of variance for the fixed and random models is presented in Table 1 and 2. In Table 2, note that for both factor A and factor B effects, Expected Mean Square (EMS) contains two components of variation in addition to σ_E^2 One of these components is due to either of the two main effects and the other components is due to interaction.

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Table 1: Fixed model for the analysis of variance

Sources of variation	Degree of freedom	Sum of square	Mean sum of square	F-ratio	Expected mean square
Factor A	(a-1) = S_1	SS_A	$MS_A = \frac{SS_A}{(a-1)}$	$F_A = \frac{MS_A}{MS_E}$	$\sigma_E^2 + bn\sigma_a^2$
Factor B	(b-1) = S_2	SS_B	$MS_B = \frac{SS_B}{(b-1)}$	$F_B = \frac{MS_B}{MS_E}$	$\sigma_E^2 + an\sigma_\beta^2$
Interaction	(a-1)(b-1) = S_3	SS_{AB}	$MS_{AB} = \frac{SS_{AB}}{(a-1)(b-1)}$	$F_{AB} = \frac{MS_{AB}}{MS_E}$	$\sigma_E^2 + n\sigma_{a\beta}^2$
Error	ab (n-1)	SS_E	$MS_E = \frac{SS_E}{ab(n-1)}$	-	σ_E^2
Total	abn-1	SS_T	-	-	-

Table 2: Random model for the analysis of variance

Sources of variation	Degree of freedom	Sum of square	Mean sum of square	F-ratio	Expected mean square
Factor A	(a-1) = S_1	SS_A	$MS_A = \frac{SS_A}{S_1}$	$F_A = \frac{MS_A}{MS_{AB}}$	$\sigma_E^2 + n\sigma_{a\beta}^2 + nb\sigma_a^2$
Factor B	(b-1) = S_2	SS_B	$MS_B = \frac{SS_B}{S_2}$	$F_B = \frac{MS_B}{MS_{AB}}$	$\sigma_E^2 + n\sigma_{a\beta}^2 + an\sigma_\beta^2$
Interaction	(a-1)(b-1) = S_3	SS_{AB}	$MS_{AB} = \frac{SS_{AB}}{S_3}$	$F_{AB} = \frac{MS_{AB}}{MS_E}$	$\sigma_E^2 + n\sigma_{a\beta}^2$
Error	ab(n-1) = S_4	SS_E	$MSE = \frac{SS_E}{S_4}$	-	σ_E^2
Total	abn-1	SS_T	-	-	-

Table 3: Data from the experiment

	Period of fermentation				
Hybrids	1	2	3	4	5
8505-4	0.20[1]	0.38	0.12	0.37	0.28
	0.30	0.47	0.56	0.60	0.55
8644-32	0.15	0.15	0.19	0.25	0.52
	0.34	0.36	0.41	0.25	0.35
8644-31	0.13	0.13	0.16	0.39	0.27
	0.47	0.14	0.11	0.24	0.21
8321-18	0.29	0.29	0.12	1.10	1.50
	0.56	0.14	0.32	1.10	1.10

[1]Values in the first row represent replicates 1 and values in the second row represent replicate

Thus, to test either of the main effects in random-effect model, the mean sum of square of the interaction between factor A and factor B (MS_{AB}) is the appropriate error term. Since EMS for the interaction effect contains σ_E^2 plus only one additional source of variation, the appropriate error term to test the interaction effect is the Mean Square Error (MSE) (Hinkel *et al*., 1979). The data used for the study are shown in Table 3.

We presented the different types of maize hybrids as factor A and period of fermentation as factor B, a 2-factor arrangement with replication was found adequate for the data.

Three subscripts j, k and i were used to represent each individual observation with i = 1-4 for factor A; j = 1-5 for factor B and k = 1-2 for replications.

Table 4: Analysis of variance table

Source of variation	Degree of freedom	Sum of Square (SS)	Mean Square (MS)	F
Factor A	3	1.0457	0.3486	14.00
Factor B	4	0.8763	0.2191	9.36
Interaction	12	1.4004	0.1167	4.99
Error	20	0.4673	0.0234	-
Total	39	3.7897	-	-

The model is:

$$X_{ijk} = \mu + \alpha_i + \beta_j + \gamma_{ij} + e_{ijk}$$

Three hypotheses were tested in the model:

$$HO_A : \alpha_1 = \alpha_2 = \sigma_3 = \sigma_4 = 0$$

$$HO_B : \beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = 0$$

$$HO_{AB} : \gamma_{ij} = 0, \text{for all i, j; i} = 1,2,3,4 \text{ j} = 1,2,3,4,5$$

Details of the calculation of ANOVA derived from Table 4 are presented as:

$$\sum_{i=1}^{4}\sum_{j=1}^{5} T_{ij}^2 = 18.7659,\ \sum_{j=1}^{5} T_{.j.}^2 = 55.4957,$$

$$\sum_{i=1}^{4} T_{i..}^2 = 71.0627,\ \sum_{i=1}^{4}\sum_{j=1}^{5}\sum_{k=1}^{2} X_{ijk}^2 = 9.8503$$

$$SS_A = \frac{\sum_{i=1}^{4} T_{i..}^2}{nb} - \frac{T^2}{nab} = \frac{71.0627}{10} - \frac{242.4249}{40} = 1.0457$$

$$SS_B = \frac{\sum_{j=1}^{5} T_{.j.}^2}{na} - \frac{T^2}{nab} = \frac{55.4957}{8} - \frac{242.4249}{40} = 0.8763$$

$$SS_E = \sum_{j=1}^{4}\sum_{j=1}^{5}\sum_{k=1}^{2} X_{ijk}^2 - \sum_{i=1}^{4}\sum_{j=1}^{5}\frac{T_{ij}^2}{n} = 9.8503 - 9.3830 = 0.4673$$

$$SS_{AB} = SS_T - SS_A - SS_B - SS_E$$
$$= 3.7897 - 1.0457 - 0.8763 - 0.4673 = 1.4004$$

Test for significance were determined as:
Fixed model:

Hypotheses	Test statistic	Rejection region
HO_A vs HA_A	$F_A = \frac{MS_A}{MSE}$	$F_A \geq F_{S_1,S_4}(\alpha)$
HO_B vs HA_B	$F_B = \frac{MS_B}{MSE}$	$F_B \geq F_{S_2,S_4}(\alpha)$
HO_{AB} vs HA_{AB}	$F_{AB} = \frac{MS_{AB}}{MSE}$	$F_{AB} \geq F_{S_3,S_5}(\alpha)$

Random model:

Hypotheses	Test statistic	Rejection region
HO_A vs HA_A	$F_A = \frac{MS_A}{MS_{AB}}$	$F_A \geq F_{S_1,S_3}(\alpha)$
HO_B vs HA_B	$F_B = \frac{MS_{AB}}{MSE}$	$F_B \geq F_{S_2,S_3}(\alpha)$
HO_{AB} vs HA_{AB}	$F_{AB} = \frac{MS_{AB}}{MSE}$	$F_{AB} \geq F_{S_3,S_4}(\alpha)$

RESULTS AND DISCUSSION

When the fixed model was considered, we found that in all the cases, $F_{calculated}$ is greater than $F_{tabulated}$ (that is, $F_{cal}>F_{taab}$). We therefore concluded that the main effects and the interaction effects are significant. That is we will have to reject the null hypotheses HO_A, HO_B and HO_{AB} at level $\alpha = 0.01$.

On the other hand, when the random model was considered, the F ratio resulted that $F_{calculated}$ is less than $F_{tabulated}$ and concluded that we cannot reject the null hypotheses HO_A and HO_B at $\alpha = 0.01$.

On the other hand when the random model was considered, the F-ratios resulted that $F_{tabulated}$ is less than $F_{tabulated}$ and concluded that we cannot reject the null hypotheses HO_A and HO_B at $\alpha = 0.01$. So we concluded that the main effects are not significant. In the case of interaction effect $F_{AB}>F_{tab}$ signifying that HO_{AB} is rejected at $\alpha = 0.01$.

CONCLUSION

The data in Table 3 were subjected to two-way analysis of variance using both fixed and random models. When the model used was regarded fixed, we concluded that the main effects and interaction effects were significant. That is, we will have to reject the null hypotheses of no difference among the main effect and interaction effect. In other words, we are saying that the types of maize used, the period of fermentation affects the quality of Ogi produced.

On the other hand, we observed that when the random model was used, the main effects were not significantly different from zero but that the interaction effects were significant. That is to say that the interaction between the type of maize used and the fermentation period affects the quality of Ogi produced.

Our interpretations based on the random model means that the 4 hybrids used were a sample from a population of hybrids and that the hybrids used were selected randomly. Again, the period of fermentation can be regarded as a sample from a population of days of the year.

It is pertinent to mention that the model used in any experiment has a lot to do as regard the conclusion of the researcher (Owoloko, 1991). Generally, the decision on which model to use in any particular experiment depends solely on the researcher and in some cases on the nature of the experiment or the experimental unit.

Our results statistically indicate that the statistical model used may influence interpretation of biological data such as ours.

We therefore recommend that appropriate steps are taken in insuring that the right statistical model is used when carrying out biological experiments

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