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SECTION D 2

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Some Aspects about Using Statistical Methods in the Evaluation of Sausages

The methods used in the evaluation of foods are either subjective or objective. Subjective evaluation is accomplished by a human being with his limitations. The evaluation performed by him is influenced especially by environmental conditions, state of physical and mental health of the individual and his tendency for comparative rather than absolute evaluations. The results of objective evaluation are obtained by chemical- physical or other measurements and because they are derived experimentally, human being has no possibilities to influence them.

The modern quality control always includes both subjective and objective methods. The reliability of the results of the subjective evaluation depends on the size and degree of training of the panel. The evaluation accomplished by a trained panel gives often a distinct picture of the consumer acceptance. The objective methods, on the other hand, are very suitable for the measurement of quality standards and they can be used when investigating e.g. the nutritive value, quantity of additives or characteristics of physical quality. The correlations existing between the subjective and objective methods support the quality control (Kramer and Twigg, 1962).

A necessary qualification for a successful quality control is the realization of two factors, namely its accuracy and dependability. In the evaluation of the sausages these factors are mostly settled with the help of organoleptic evaluation and chemical approximate analysis. The organoleptic evaluation gives an account of quality characteristics like the appearance, structure, color, odor and flavor. The chemical approximate analysis, on the other hand, is a criterion of the quality of the ingredients used in the manufacture of the sausages. The chemical approximate analysis includes usually the determination of water, fat, protein, salt and residue.

A statistical investigation was made of 1556 sausages manufactured in Finland and analyzed chemically and evaluated organoleptically at the Institute of Meat Technology at the University of Helsinki. The main purpose of the investigation was to examine the effect of the water, fat, protein, salt and residue content on the flavor and total organoleptic score of the sausages. Importance was also attached to the factors which affect the quality of the sausages regarding the type, the region of manufacture and the changes appearing during different seasons.

Material and methods

The material investigated consisted of 1556 sausages which had been prepared in 25 plants in different parts of Finland and corresponded to 8 different types of sausages. From these, three belonged to the sausage class A where no addition of starch is allowed according to the food legislation. Five from these belonged to the class B where the addition of starch up to 6 per cent is allowed.

In the approximate analysis the content of water, fat, protein and salt was determined and the residue was calculated. In the organoleptic evaluation the following scores were given: appearance 0-4, structure 0-4, color 0-4, odor 0-4 and flavor 0-6. The taste panel consisted of

at least five qualified tasters.

The statistical calculations and tests were made by using an IBM 1640 computer which was accessible at the Computation Center of the University.

In the statistical investigation the following methods were used:

1) When the interrelationship between the water, fat, protein, salt and residue content and the flavor and the total score obtained in the organoleptic evaluation of sausage was tested, first a linear regression analysis was performed by using four explanatory variables. At the first occasion these variables were water, fat, protein and residue content and at the second occasion fat, protein, salt and residue content. The significance of the regression lines was then tested by using the F-test. The significance of the single regression coefficients was tested with the T-test.

2) When testing the quality of the sausages* manufactured in South and North Finland, the comparison of the mean values was made by using the t-test in which $s = \sqrt{\frac{s_1^2}{n_1} + \frac{s_1^2}{n_2}}$ independently on the differences between the intraclass variation. Because n_1 and n_2 were always > 200 the degree of freedom was $= \infty$

3) When testing the seasonal differences appearing in the quality of the sausages the year was divided in six parts. The differences between the sixths of the year were then tested by using the analysis of variance. The significance of the deviations was then calculated by applying the t-test. The changes appearing in the fat and residue content of the sausages were used as a criterion when the seasonal variations were calculated.

Results

When the effect of the water, fat, protein, salt and residue content on the flavor and total organoleptic score of the eight types of sausages investigated was tested separately, the results presented in Table 1 were obtained.

Table 1. The chemical composition of the sausages and the corresponding flavor and total scores obtained in the organoleptic evaluation.

Sausage class and number of samples	% Water	% Fat	% Protein	% Salt	% Residue	Flavor score	Total score
B_1 218	62,1	20,3	10,5	2,2	4,9	3,6	16,1
B_2 156	60,9	21,9	10,5	2,2	4,8	3,4	15,6
A_1 293	64,4	17,0	14,1	2,4	2,1	3,9	16,0
B_3 139	60,6	21,0	10,4	2,2	5,8	3,3	15,3
A_2 182	63,0	19,7	12,1	2,2	3,0	3,3	15,5
B_4 291	62,5	18,8	10,6	2,3	5,8	3,2	15,6
A_3 116	50,5	28,7	15,7	3,0	2,1	3,8	16,9
B_5 161	62,2	14,0	11,3	2,4	10,1	3,0	15,1

The significance of the regression coefficients and regression lines obtained in the linear regression analysis are presented in Table 2.

When comparing the effect of fat, protein, salt and residue content on the flavor and total score of sausages in a linear regression analysis, a comparison was made, on one hand, between all sausages of the A class and, on the other hand, between all sausages of the B class. The results of these tests are combined in Table 3.

Table 3. The effect of fat, protein, salt and residue content on the flavor and total score of the sausages in the linear regression analysis.

The effect of different factors	Sausage class	Fat a	Fat b	Protein a	Protein b	Salt a	Salt b	Residue a	Residue b
on flavor	A	+		+	0,1	-	5	-	5
	B	-		+		+		-	0,1
on total score	A	+	5	+	5	+	0,1	-	
	B	-		-	2	+		-	1

a = sign of coefficient
b = significance of coefficient (t %)

The sausages manufactured in South and North Finland were compared in regard to the quality. The results are presented in Table 4.

Table 7.

Sausage class and number of samples		The statistical effect of different factors									
		on flavor					on total score				
		F %	t %				F %	t %			
			Water	Fat	Protein	Residue		Water	Fat	Protein	Residue
B_1	218						1	(-) 1	(-) 1	(+) 1	
B_2	156	1	(-) 0,1			(-) 1	0,1	(-) 1			(-) 1
A_1	293						2,5			(+) 5	
B_3	139	2,5	(-) 5	(-) 5		(-) 5	0,5	(-) 0,1	(-) 1		
A_2	182	0,5	(-) 1		(+) 5		2,5	(-) 5	(-)	(+) 5	
B_4	291	1	(-) 1	(-) 5			0,5	(-) 1	(-) 5		
A_3	116						5	(-) 5	(-) 5		
B_5	161	5				(-) 0,1					

The statistically tested effect of the chemical composition on the flavor and total score of sausage in the linear regression analysis

F % = risk per cent for the significance of regression line

t % = risk per cent for the significance of the regression coefficients.

Table 4. The variations of sausages between South and North Finland

Sausage class	Water		Fat		Residue		Flavor		Total score	
	a	b	a	b	a	b	a	b	a	b
B_1	-	1	+	0,1	-	0,1	+		+	
B_2	+	-			-		+		+	5
A_1	-	-			-		+		+	
B_3	-	5	+	1	-	5	-		+	
A_2	-		+		-	1	+		+	
B_4	-		+	1	-	1	+		+	
A_3	-		+		-	1	+	5	+	
B_5	+		-		+		+		+	

a. + value greater in South Finland
   - value greater in North Finland

b. t %

When the differences appearing in the fat and residue content of the entire sausage population were used as a criterion, the seasonal variations between the sixths of the year were investigated by using the analysis of variance. In the fat contents no differences were found between the different sixths of the year. The differences were distinct, instead, regarding the residue contents and the results have been presented in Table 5.

Table 5. The differences in the residue contents between the different sixths of the year

Compared with a sixth of the year	Sixth of the year 1	2	3	4	5
2	X				
3	X				
4	XXX	XX	XXX		
5	XX		X		
6	XX		XX	XX	

APPENDIX

The linear regression analysis: four explanatory variables

The observation values of the explanatory variable are indicated by y_k (k=1,..,n), whereat the corresponding values of the explanatory variables are x_{ik} (i=1,..,4 , k = 1,..,n). The coefficients b_i of the regression line $y = a + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4$ are determined with the help of the following aquation group:

$$(1)\quad \begin{cases} b_1SSD_{x_1} + b_2SPD_{x_1x_2} + b_3SPD_{x_1x_3} + b_4SPD_{x_1x_4} = SPD_{x_1y} \\ b_2SPD_{x_1x_2} + b_2SSD_{x_2} + b_3SPD_{x_2x_3} + b_4SPD_{x_2x_4} = SPD_{x_2y} \\ b_1SPD_{x_3x_1} + b_2SPD_{x_3x_2} + b_3SSD_{x_3} + b_4SPD_{x_3x_4} = SPD_{x_3y} \\ b_1SPD_{x_4x_1} + b_2SPD_{x_4x_2} + b_3SPD_{x_4x_3} + b_4SSD_{x_4} = SPD_{x_4y} \end{cases}$$

and the constant $a = \bar{y} - b_1\bar{x}_1 - b_2\bar{x}_2 - b_3\bar{x}_3 - b_4\bar{x}_4$

The annotations used above:

$$SSD_{x_i} = \sum_{k=1}^{n} (x_{ik}-\bar{x}_i)^2, \quad SPD_{x_ix_j} = \sum_{k=1}^{n} (x_{ik}-\bar{x}_i)\,(x_{jk}-\bar{x}_j),$$

$$\bar{x}_i = \frac{1}{n} \sum_{k=1}^{n} x_{ik}$$

t-value is obtained from the equation $t = \frac{b_i - \ _i}{s_{b_i}}$

in which

$s^2_{b_i} = s^2 c_{ii}$, $s^2 = \sum_{k=1}^{n} (y_k - \bar{y})^2/(n-1)$, b_i is one of the regression coefficients calculated above and $_i$ is its hypothetical value (in the cases in question = 0). The degree of freedom is n-2. For example, the value of c_{ii} is obtained by determining the equation group (1) after the b_i:s have first been replaced with the corresponding c_{ii}:s (i = 1,..,4) and

$$SPD_{x_i y} = \begin{cases} 1 & \text{if } i = 1 \\ 0 & \text{if } i = 2,3,4 \end{cases}$$

By using the equation groups obtained by corresponding substitutions also c_{22}, c_{33} and c_{44} can be determined.

The analysis of variance, one way classification

It is presumed that number of classes in which the observations have been divided = k and the number of observations in the class i is n_i. The observations are marked with x_{ij}. The F-value of the analysis of variance is obtained by using the equation

$$F = \frac{s_2^2}{s_1^2}$$

in which

$$s_{1_i}^2 = \sum_{i=1}^{k} \sum_{j=1}^{n_i} (x_{ij} - \bar{x}_i)^2 / \left(\sum_{i=1}^{k} n_i - k \right)$$

$$s_2^2 = \sum_{i=1}^{k} n_i \, (\bar{x}_i - \bar{\bar{x}})^2 / (k - 1),$$

$$\bar{\bar{x}} = \sum_{i=1}^{k} \sum_{j=1}^{n_i} x_{ij} / \sum_{i=1}^{k} n_i$$

The t-value is obtained by using the equation

$$t = \frac{\bar{x}_i - \bar{x}_j}{s_1 \sqrt{(1/n_i) + (1/n_j)}}$$

in which the degree of freedom is $\sum_{i=1}^{k} n_i - k$.

The t-test in the comparison of the mean values

In the comparison of the mean values of the classes x_{1i} $(i = 1,..,n_1)$ and x_{2j} $(j = 1,..,n_2)$ the t-value was determined with the help of the following equation:

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{(s_1^2 / n_1) + (s_2^2 / n_2)}}$$

in which

$$s_i^2 = \sum_{j=1}^{n_i} (x_{ij} - \bar{x}_i)^2 / (n_i - 1) \quad (i = 1,2)$$

Literature:

Hald, A. 1962. Statistical Theory with Engineering Applications 5th ed., John Wiley & Son, New York and London

Kramer, A. and Twigg, B.A. 1962. Fundamentals of Quality Control for the Food Industry. The Avi Publ. Co., Inc, Westport, Connecticut