The mobile flatbed expert system of food quality sensory assessment

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Abstract. This article is represented network computer system for collection and evaluation of organoleptic indicators of food quality based on the methods of rank correlation and multifactorial dispersive analysis in real time. The article is describing information technology of expert evaluation of food quality by individual tasters and tasting commissions by indicators, that not measured by technical means of control, based on client-server network architecture. The software implementation of system for collecting and statistical processing of data, based on the principles of multifactorial dispersive analysis in real-time mode, makes possible to evaluate influence of the human factor on objectiveness and reliability of tasting results, as well as to visualize the data of expert assessments by various expert groups.

1. Introduction

Sensory analysis and evaluation of food quality is the basis for commodity examination of the state of food products and forecasting consumer demand. The usage of modern methods of sensory analysis requires from tasters not only specialized knowledge of methodology and application of, procedures for generating lexical dictionaries or scaling, but also the provision of consolidated, consistent assessments that confirm the objectiveness of the results [1].

Regardless of the experience and degree of training of tasters, individual differences always arise in their assessments of the state and quality of food products, associated with sensory sensitivity, the knowledge base, and the subjectivity of the scales of organoleptic measurements [2, 3]. In connections with it, the adequate interpretation and objectification of individual assessors of tasters requires the development of IT technologies for factor analysis of food tasting results based on mathematical statistics methods [4] and computer programs for processing and visualizing data from sensory quality control of a product.

An objective assessment of food quality, taking into account a variety of state parameters, alternatives and criteria, can be implement by using intelligent computer technologies for processing and formalizing knowledge with the adoption of optimal decisions based on statistical methods of multivariate data analysis with an objective assessment of adequacy and confirmation of hypotheses.

The complexity of problem solution is determined by the probabilistic spread of characteristics and properties of an initial biological raw material, as well as subjectivity of individual expert tasters opinions. The samples for testing cannot be completely identical in nutritional and biological value of the elements (protein, fat, connective tissue, etc.). If the expert does not

have enough knowledge and competencies, then even the most sophisticated software product will not conduct a qualitative analysis of the data [5].
Therefore, the adequacy of the assessment in each case essentially depends on the influence of the human factor with the individual psycho-physiological capabilities of sensory perception and needs correction, checking the objectivity of expert assessments, considering the coherence of certain group of experts opinions and experience.
Information technology is proposed based on the methods of ranking correlation and multivariate dispersive analysis, for expert sensory evaluation of food quality by individual tasters and tasting commissions by indicators, that not measured by any technical means of control in a client-server network architecture.

2. Rank correlation in organoleptic sensory evaluation of food quality

Organoleptic assessment quality of end product, obtained result of expert survey of experts, achieves by method of rank correlation, according to which a group of quantitatively non-measurable ranks by each expert independently of each other in order of decreasing or increasing their influence on the assessment of product quality. The ranking results are recorded in a matrix of ranks x_{ij}, $i = 1, m, j = 1, \overline{n,}$ pointing place j-th parameter among n another i-th expert.
Since, expert opinions of tasters do not always matches each other, total ranks are determined to obtain an objective assessment.

$$R_j = \sum_{i=1}^{m} x_{i,j}; \quad j = \overline{1,n}$$

and the coefficient of concordance W is calculated, which characterizes the objective relationship between the estimates of m independent tasters using the formula:

$$W = \frac{12 \cdot S(d^2)}{m^2 \cdot (n^3 - n)},$$

$$S(d^2) = \sum_{j=1}^{n} \left[\sum_{i=1}^{m} x_{i,j} - \frac{1}{2} m(n+1) \right]^2$$

ranging from 0, in the absence of a link between rankings of experts, to 1 with their full consent in ordering the impact on the product quality functional Q.
After assessing the significance of showing, that the indicator W of consistency of opinions of tasters is not accidental, to each organoleptic indicator are assign weighting factor g_j:

$$g_j = \frac{M}{\sum_{i=1}^{m} x_{ij}}; \quad j = \overline{1,n}$$

where M – scale factor.
Weighting factor g_j reflect the practical experience of qualified experts and characterize comparative impact j-th factor on total quality assessment of the product in regression:

$$Q = Q_0 + \sum_{j=1}^{n} g_j x_j$$

where Q_0 – assessment of the standard quality of the product, and allows you to objectively identify the most significant factors deviations from the specified quality of the product.The vector of weight coefficients for clarity are presents in the form of a bar chart in accordance with the index number of the indicator or in descending order of the absolute values of the coefficients. If the distribution of weights is uniform or close to it, then the level of a priori knowledge is low and further accumulation and processing of statistical data is necessary. In turn, the uneven distribution with an exponential decrease in the weights corresponds to a high degree of a priori knowledge about the quality of the product.

3. Multifactorial dispersive analysis of organoleptic evaluations

The data with a multi-level structure is analyzed by multifactorial statistical procedures [6], which allow to determine differences between two or more data sets for all dependent variables simultaneously. This helps to reduce the level of general mistake of the first kind and to assess the degree of interrelation between dependent variables, and makes it possible to establish combinations of sensory variables, which allow to distinguish patterns in the case of non-manifestation of differences in each of them separately [7].

The general algorithm for processing the results of sensory evaluation, includes the determination of the sample size from the general population and formulation of a zero (H_0) and alternative (H_1) hypotheses, choice of significance level ($\alpha = 0.01$; or $\alpha = 0.05$; or $\alpha = 0.1$) and conducting an assessment, data collection and calculation of total statistical criteria; acceptance or denial zero (H_0) hypothesis and result interpretation.

In case of two-factor analysis of variance, grouping are using according to two factors, and in addition to the experimental error, the variance of estimates due to individual differences between tasters in the group is takes into account [8]. In this case, the order of submission of samples A, B and C should be individual for each taster, and their combinations ABC, ACB, BAC, BCA, CAB, CBA are distributed in equal proportions to ensure complete randomization. The total sample variance for all experiments, is equal to sum of the intergroup and intragroup variances and value of Fisher criterion calculates not only as the ratio of the intergroup and intragroup variances of assessors of tasters, but as ratio of the variance of estimates between individual experts to the intragroup variance.

The dispersive analysis methodology was put to the basis for software development with a client-server architecture for collection and statistical processing of sensory data. Fisher's precision criterion goes through all possible options of a contingency table with the same total frequencies in rows and columns, i.e. carries out all kinds of construction of zero-models which built on the assumption of influence absence on the factor which is under study [9, 10].

4. Software implementation of an expert system with a client-server network architecture of sensory evaluation of food quality

The software system of the client server expert system consists of two subsystems: the server software and the user, the client. The "client" software subsystem installs on the user's computer and transmits requests to the "server" subsystem to a shared computer to process data and requests from clients and return them back to the user's computer.

The functional structure of the system includes six modules that enter parameters for estimating and evaluating product descriptors; creating a data set for analysis; touch profile; comparison with the standard; help (user and administrator).

The list of parameters (figure 1), determined by the purpose of the tasting, includes:

- the number of samples tasted and evaluated descriptors;
- type of scale (structured or unstructured); structured five- and nine-point scales are used, according to which each indicator has respectively 5 or 9 degrees of quality. According to a five-point scale: 5 – points mean excellent quality; 4 – good; 3 – satisfactory; 2 – unsatisfactory, but acceptable; 1 – unsatisfactory.

Nine-ball scale recommended in the Federal Scientific Center V.M. Gorbatov, expands the range of organoleptic quality assessment with the introduction of a scale of quantitative

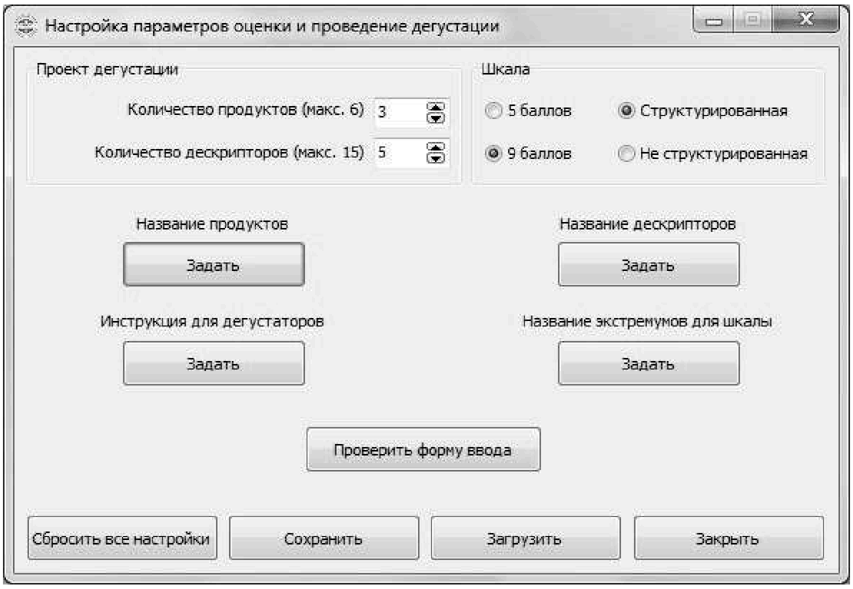

Figure 1. Module of setting parameters.

characteristics: 9 – for optimum quality; 8 – very good; 7 – good; 6 – above average; 5 – medium; acceptable, but undesirable – 4 or 3; unacceptable – 2 or 1.

- name of the evaluated descriptors;
- folder for saving files with tasting results (text format – * .txt);
- instruction for the tasting commission.

After setting the evaluation parameters, the taster connects to the server program and enters his identification data (for example, full name) and further, using the intensity scale of the descriptors in the product samples, evaluates individually the intensity of the product descriptors, recording the results from the beginning of the scale. After evaluating all the descriptors in the first product, the taster proceeds to assess the next product or finishes the tasting.

In figure 2, as an example, a table presents results of two-factor analysis of variance by descriptor - “smoking smell”.

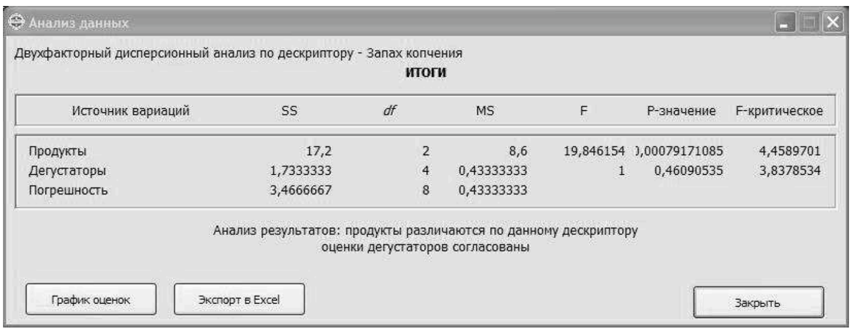

Figure 2. Result of the taster’s consistency check by the descriptor “Smoking odor”: *SS* – dispersion; *df* – degree of freedom; *MS* – unbiased estimates; *F* – calculated Fisher criterion; *P-value* – function of *F* distribution; *F critical value* – table value of Fisher criterion.

As a null hypothesis (H_0), the system advances: – the products do not affect the "smell of smoking" taste descriptor, and the alternative hypothesis (H_1) – the products affect the "smell of smoking" taste descriptor. To verify them, we used Fisher's exact test at a significance level of $\alpha = 0.05$.
From the data in figure 3, the calculated value of *F-criterion* of factor x_1 (products) $F \approx 19.85$, and the critical region is formed by the right-hand interval (4.46; $+\infty$). Since F falls into the critical region, the null hypothesis (H_0) is rejected and the alternative (H_1) hypothesis is accepted, i.e. factor x_1 (foods) affects the taste "smoked smell".
Similarly, held assessment on the second factor – "tasters". With a zero (H_0) hypothesis –tasters do not affect the "smell of smoking" taste descriptor and alternative (H_1) – tasters affect the "smell of smoking" taste descriptor. The values in figure 3 shows, that calculated indicator of the F-criterion factor x_2 (tasters) $F = 1$, and the critical region is formed by the right-hand interval (3.84; $+\infty$). Since F does not fall in the critical region, the null (H_0) hypothesis is accepted, i.e. influence of factor x_2 (tasters) on the taste "smoked smell" was not confirmed.
Selective coefficient of determination:

$$\overline{\rho}_{x_1^2} = \frac{SS_{x_1}}{SS_{x_1} + SS_{x_2} + SS_{x_\epsilon}} = \frac{17.2}{17.2 + 17.3 + 3.47} \approx 0.77$$

shows that 77% of the total selective variation in the quality of a descriptor (the smell of smoking) is related to the influence of the product type on it.
In the column, *P-value* determines P-value, which corresponds to the calculated value of criterion F.
In our example, the *P-value* for factor x_1 (products) depends on the values of F; *df* and *MS* of this factor, located in the first row of the table, and has a value of 0.00079.
The *P-value* for the x_2 factor (tasters) depends on the values of F; *df* and *MS* of this factor, located in the second line of the table, and equal to 0.46.
According to the Fisher-Snedecor criterion, if the *P-value* is less than 0.05 ($P < 0.05$), then the data do not agree. Based on the calculation, analysis and comparison, the system makes conclusion "Products differ in this descriptor, the assessors of the tasters are consistent".
In the case of a consistent and reliable assessment, the program allows you to build a sensory profile (profilogram) of the product characteristic being evaluated (figure 4) with a number of intensity assessment axes equal to the number of specific descriptors.
Figure 3 shows an example of the sensory profile of three samples of boiled sausage in the form of a polygon with vertices combining the obtained product characteristics.

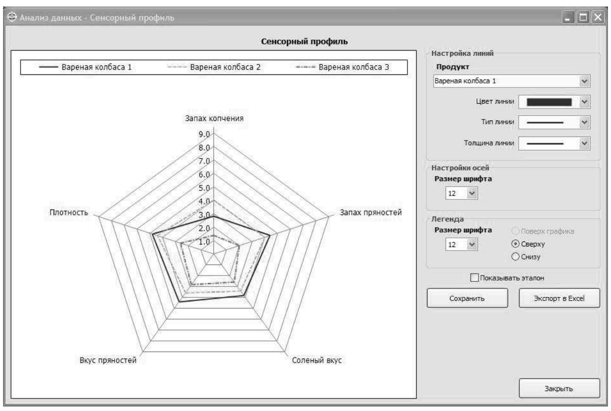

Figure 3. Sensory profile of three cooked sausage samples.

Using similar procedures, the program allows you to determine the position of a product produced at an enterprise among competitors based on a comparison of its profile with competitors' product profiles.

For comparison product profile and the "reference" are preliminarily produced a reference product which is the basis for comparing all the products involved in the assessment. The characteristics of the reference sample determine the "reference" sensory profile, which compares with the profile of a similar sample from another batch (figure 4).

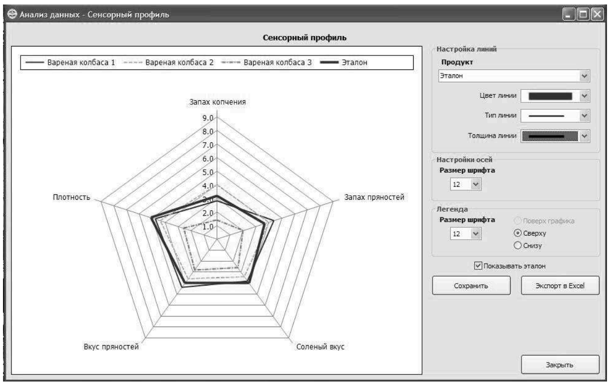

Figure 4. Sensory profile of the reference and three cooked sausage samples.

The computer program also allows you to identify changes in the sensory characteristics of the product when replacing food ingredients, additives or spices in the composition of the formulation, the use of new types of packaging, etc.

5. Experimental investigations of the program product

The given example of the program realization of the network centralized expert system with the dialog interface along with the individual numerical (score and statistic) assessments by expert tasters presents the objectivized conclusion and recommendations in assessment of product quality by the results of processing of the subjective data from expert groups that included up to 20 tasters by 15 descriptors and 6 product types with construction of illustrative profilograms with the dimension of up to 15 descriptors and possible data export to MS Excel. With that, accuracy and reliability of the objectivized assessments is determined by the numerical values of the criteria presented in figure 2 for the specific case, as well as by the degree of agreement and competence of the opinions of the qualified expert tasters assessing technically uncontrollable organoleptic properties of food products and their influence on the total quality assessment.

6. Conclusion

Therefore, the computer program with the client-server architecture based on the principles of the multivariate analysis of variance realizes the information technology for support of decision making in sensory food quality assessment contrary to the traditional expert systems and packages of applied programs. It performs real-time collection, accumulation and statistical processing of sensory data from a taste panel and visual presentation of the objectivization results in different graphic forms.

7. References

[1] Lawless, H.T. Sensory evaluation of food: principles and practices / H.T. Lawless, H. Heymann. – New York: Springer Science & Business Media, 2010. – 596 p.
[2] Piggott, J.R. Review: Evaluation of assessor performance in sensory analysis / J.R. Piggott, E.A. Hunter // Italian Journal of Food Science. – 1999. – Vol. 4(11). – P. 289-303.
[3] Tomic, O. Performance indices in descriptive sensory analysis A complimentary screening tool for assessor and panel performance / O. Tomic, C. Forde, C. Delahunty, T. Naes // Food Quality and Preference. – 2013. – Vol. 28(1). – P. 122-133.
[4] Johnson, R.A. Applied Multivariate Statistical Analysis / R.A. Johnson, D.W. Wichern. – New York: Prentice-Hall, 2007. – 800 p.
[5] Mitchell, M.N. Strategically using General Purpose Statistics Packages: A Look at Stata, SAS and SPS // Technical Report Series. – 2005. – Vol. 1.
[6] Statistical Consulting Group: UCLA Academic Technology Services [Electronic resource]. – Access mode: http://www.ats.ucla.edu/stat/technical-reports/umber1editedFeb 2 2007/uclaATSstat trl 1.1 0207.pdf (08.09.2018).
[7] Stahle, L. Multivariate analysis of variance (MANOVA) / L. Stahle, S. Wold // Chemometrics and Intelligent Laboratory Systems. – 1990. – Vol. 9. – P. 127-141.
[8] Lee, S.M. Development of sample preparation, presentation procedure and sensory descriptive analysis of green tea / S.M. Lee, S.-J. Chung, O.-H. Lee, H.-S. Lee, Y.-K. Kim, K.-O. Kim // Journal of Sensory Studies. – 2008. – Vol. 23. – P. 450-467.
[9] O'Mahony, M. Sensory Evaluation of Food. Statistical Methods and Procedures. – New York: Marcel Dekker, 1986. – 488 p.
[10] Patefield, W.M. Algorithm AS 159. An efficient method of generating r x c tables with given row and column totals // Applied Statistics. – 1981. – Vol. 30(1). – P. 91-97.
[11] Gotelli, N.J. Swap algorithms in null model analysis / N.J. Gotelli, N.J. Entsminger // Ecology. – 2003. – Vol. 84. – P. 532–535.