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Calculation and Experimental Check of Uncertainty of Results When Measuring Humidity and Other Physical and Chemical Values of Food Products

Masharipov SH.M[1]., Nazarbaeva B.A[1]., Miraliyeva A.Q[1]., Mahmudjonov M.M[1]

[1]Tashkent state technical university, 100095, 2 str. University, Tashkent, Uzbekistan
E-mail: masharipovshodlik2@gmail.com

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Abstract

The article deals with the assessment of accuracy and uncertainty in humidity measurement and other physical and chemical parameters of food products. It is known that Production of industrial products is directly related to the receipt and use of measurement information both when assessing the quality of raw materials and finished products, and when monitoring and managing technological parameters at all stages of production processes. Ensuring high quality of products by obtaining high-quality measurement information requires the development and implementation of a set of measures to improve the method of processing experimental data when evaluating accuracy characteristics, first of all it is related to uncertainty of measurement results. Estimation of measurement uncertainty (quantitative values) is one of the important tasks facing each laboratory. The requirement to estimate measurement uncertainty is laid down in the international standard ISO/IEC 17025-2017, as well as the ILAC-G17:2002 policy.

Keywords: Physical and chemical index, material humidity, measurement uncertainty, food products, measurement accuracy, measurement uncertainty sources

1. Introduction

The international metrological community has long developed and adopted the basic principles of the concept of uncertainty, establishing them in the JCGM (Joint Committee for Guides in Metrology) series of international documents, as well as ISO/IEC Guide 98. Many additional guidelines have been developed on different measurement uncertainty assessment approaches in specific test/measurement areas (EA, EURACHEM, Nordtest, EUROLAB, etc.).

Figure 1 shows a flow chart of the analytical measurement process in relation to the field discussed herein. It takes into account the features of technology analytics outlined above. From this position we will analyze the role and value of each unit of this system.

In general, the task of analytics is to obtain information about real systems. Composition analysis can have several objectives:

1. Identify the content of one or more components.
2. Find the total quantity (mass or volume) of a particular substance directly in the measurement object, for example, to account for material values, to determine the cost of the measurement object, or to assess the nature and intensity of the technological impact on the object.

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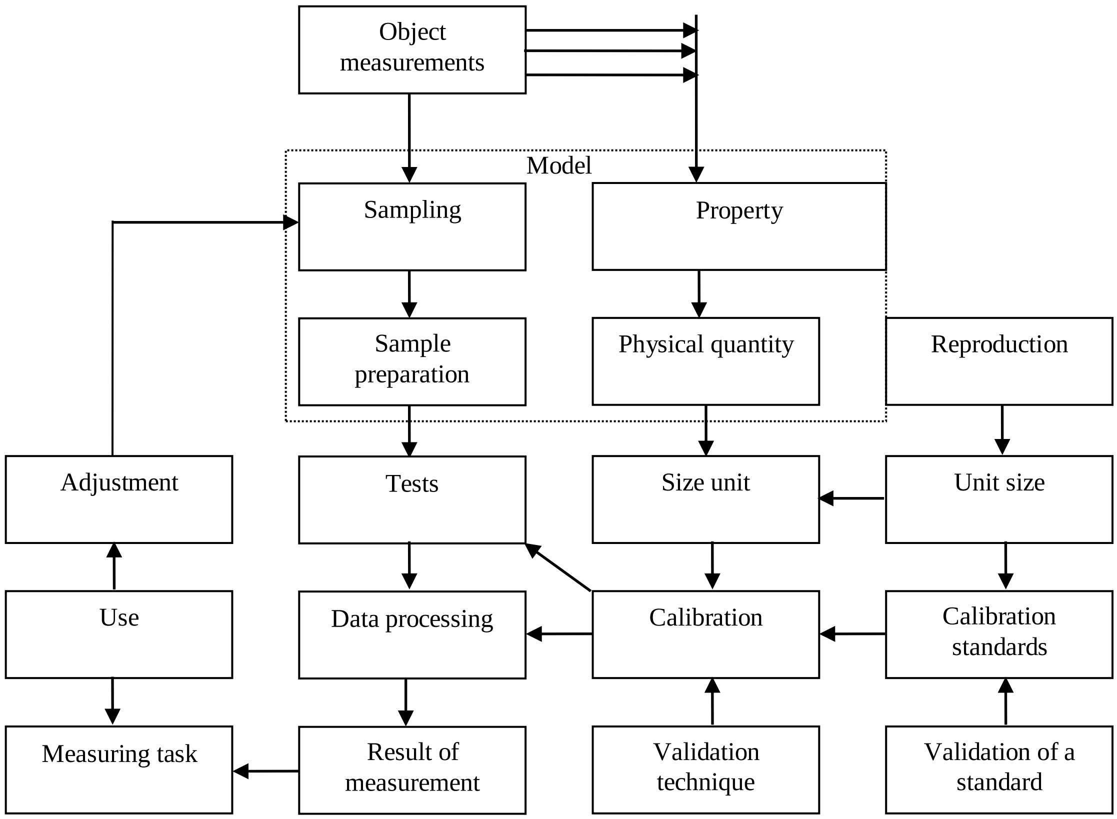

FIGURE 1: Block Diagram of the Analytical Measurement Process

2. Theoretical and experimental research

Measuring equipment, accessories, utensils, tools, materials and reagents:
Scales of non-automatic action as per GOST OIML R 76-1 with limits of permissible absolute error ± 0.5 mg.
Liquid thermometer with measurement range from 100 ° C to 200 ° C and division price of 1 ° C as per GOST 28498.
Clock as per GOST 27752.
Electric drying cabinet with temperature regulator, which provides maintenance of the set temperature mode from 100 ° C to 140 ° C with error ± 2 ° C.
Water bath providing temperature maintenance up to 100 ° C with error ± 2 ° C.
Desiccator 1-100 as per GOST 25336.
Measuring cylinder 1-500-1 as per GOST 1770.
Bulb 2-1000-2 as per GOST 1770.
A bux with a glass stick and a sand-free or sand-free lid was placed in an oven heated to a temperature of 130 ° C to 135 ° C, kept at that temperature for about 20 minutes, then placed in a desiccator 1/3 calcium chloride filled, allowed to cool and weighed.
Open busses with analysed samples, covers, glass sticks are placed in an drying cabinet heated to a temperature of (130 ± 2) ° C. When the bux is inserted into the cabinet, the temperature in it decreases slightly, so the drying time is counted from the moment when the thermometer again shows 130 ° C.

- for the first sample - $m_1(1)$=31,0044 g,
- for the second sample $m_1(2)$= 31,0035 g.

The weight of the weighing cup is determined by weighing on laboratory scales. When measuring the humidity of the two samples, the following input values were obtained:

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- for the first sample - $m_{ST}(1)$=11,0033 g,
- for the second sample $m_{ST}(2)$= 11,0022 g.

Weight of weighing cup with suspension after drying, m_2

- for the first sample - $m_2(1)$=28,9978 g,
- for the second sample $m_2(2)$= 28,9967 g.

The measured value of size

$$X_1 = \frac{m_1(1) - m_2(1)}{m_1(1) - m_{st}(1)} \cdot 100 = \frac{31{,}0044 - 28{,}9978}{31{,}0044 - 11{,}0033} \cdot 100 = 10{,}0324\ \% \tag{1}$$

$$X_2 = \frac{m_1(2) - m_2(2)}{m_1(2) - m_{st}(2)} \cdot 100 = \frac{31{,}0035 - 28{,}9967}{31{,}0035 - 11{,}0022} \cdot 100 = 10{,}0334\ \% \tag{2}$$

$$X = \frac{10{,}0324 + 10{,}0334}{2} = 10{,}0329 \tag{3}$$

$$u(m_1) = \frac{\Delta}{\sqrt{3}} = \frac{0{,}001 g}{1{,}732} = 0{,}00058 g \tag{4}$$

$$u_{sum} = \sqrt{u_1^2(m) + u_2^2(m) + u_{st}^2(m)} = \sqrt{3 \cdot (58 \cdot 10^{-4})^2 + (56 \cdot 10^{-6})^2} = 0{,}01\ \% \tag{5}$$

$$u(F) = \frac{r}{100\% \cdot 2{,}8 \cdot \sqrt{2}} = \frac{0{,}3}{100\% \cdot 2{,}8 \cdot \sqrt{2}} = 59 \cdot 10^{-6} \tag{6}$$

Sensitivity coefficients are calculated as partial derived functions of measurements by input values:

$$c_1 = \frac{(m_2 - m_{st})}{(m_1 - m_{st})^2} \cdot 100 = 4{,}7481 \tag{7}$$

$$c_2 = \frac{-100}{m_1 - m_{st}} = -4{,}9997 \tag{8}$$

$$c_3 = \frac{(m_1 - m_2)}{(m_1 - m_{st})^2} \cdot 100 = 10{,}0324 \tag{9}$$

$$c_4 = X = 10{,}0329 \tag{10}$$

3. Methodology

Based on the results of the study, a number of validated measurement uncertainty estimation techniques have been developed and implemented. In the course of development, a priori initial data have been implemented, including:

1. Procedure for estimation of uncertainty of results when determining massaged portion of tea moisture according to GOST 1936-85;

The principle of measurement: the essence of the method consists in drying the tea overhang at a certain temperature and calculating the weight loss in relation to the weight of the overhang before drying.

Mathematical measurement model:

$$X = \frac{m_1 - m_2}{m} \cdot 100 \tag{11}$$

where - m_1 - weight of the busse with the overhang before drying, g;m_2 - weight of loaf with overhang after drying, g;m - weight of the hinge before drying, g.

Accuracy rate: The final result of the analysis is the arithmetic mean of the results of two parallel definitions, the difference between which does not exceed 0.2%. Theresultiscalculatedtothefirstdecimalplace.

2. Method of estimation of uncertainty of results when determining massaged moisture fraction of confectionary products according to GOST 5900-2014;

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Measurement principle: The essence of the method consists in drying the analysed sample of the product at a certain temperature and calculating the weight loss relative to the mass of the analyzed sample before drying.

Mathematical measurement model:

$$X_1 = \frac{m_1 - m_2}{m} \cdot 100 \qquad (12)$$

where - m_1 - weight of the busse with lid, glass stick and analyzed sample of the product before drying, g; m_2 - weight of the busse with lid, glass stick and analyzed sample of the product after drying, g; m - weight of analyzed product sample, g. Calculations are made to the second decimal place followed by rounding to the first decimal place.

Accuracy rate:

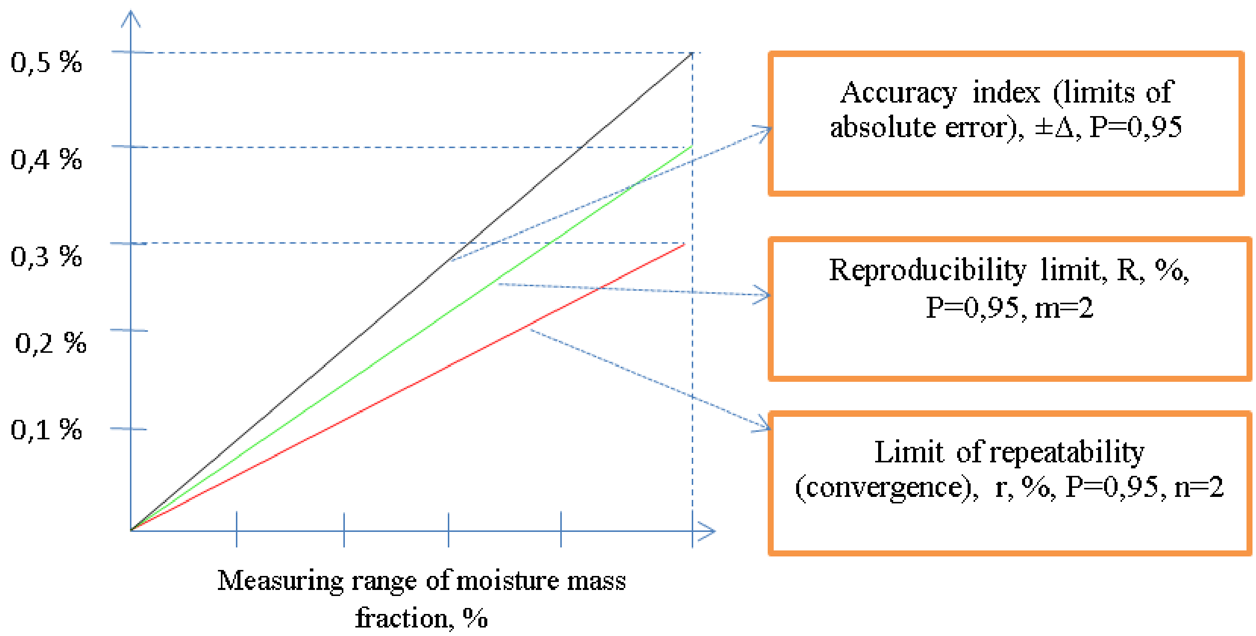

FIGURE 2: Accuracy Characteristics and Limits when Measuring Mass Fraction of Confectionary Products Moisture

4. Finding

Uncertainty budget is a report of measurement uncertainty, the components of that measurement uncertainty, their calculation, and their consolidation. Uncertainty budget may include measurement model, estimates and measurement uncertainties related to the values included in measurement model, covariances, types of probability density functions applied, number of degrees of freedom, measurement uncertainty estimation type and coverage factor.

The uncertainty budget is used to summarize and visualize all information previously received and analysed in quantitative form on input values to facilitate the direct calculation of the standard uncertainty value associated with the measured (output) value. The uncertainty budget can also be used to analyze the contributions of each uncertainty source to the total standard uncertainty to determine the accuracy of the measurement process, to adjust the measurement model, or to find ways to reduce uncertainty values from some of the contributions having the greatest impact on the final result.

It is assumed that the values of the input values are literally the best estimates of the input values, that they have been corrected for the effects and effects relevant to the model. If this is not the case, the necessary corrections should be entered into the model as separate inputs.

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Quantity, X_i	Measurement unit	Value of assessment	Interval in which the value is located	Uncertaintytype	Standard measurement uncertainty	Sensitivity index	Percentage contribution (contribution share), %
m_1	g	31,0044	±0,001 g	B	0,00058	4, 7481 g	5,8 %
		31,0035		B			
m_2	g	28,9978	±	B	0,00058	-4,9997 g	5,8 %
		28,9967		B			
m_{st}	g	11,0033	±	B	0,00058	10,0324 g	5,8 %
		11,0022		B			
F	-	1,0		B	0,000056	10,0329 %	0,6 %
X_i	%	10,0324	0,3	-	-	-	-
		10,0334			-		
X	%	10,0329		-	0,01	-	-

TABLE 1: Drawing up Виudget of Uncertainty

5. Conclusion

Based on the results of the study, it is possible to conclude:

- accredited testing laboratories require the development of uncertainty estimation techniques for each physical and chemical value measured (e.g. pH, density, massaging moisture fraction, temperature). For the sake of suitability, these methods require validation according to predetermined procedures;
- when developing measurement uncertainty estimation methodology for each physical and chemical indicators of food products, it is recommended to take into account the requirements of international standards JCGM (Joint Committee for Guides in Metrology (JCGM)). Laboratory and production conditions if experimental data are subject to normal distribution law as confidence level P = 0.95 and coverage factor k = 1.96;
- The most optimal method in our opinionfinding uncertainty of measurement results is a method of taking into account results of inter-laboratory intercalibration, as a simple but in the most complete way taking into account all possible factors of influence. Work on inter-laboratory matching of results is in itself a necessary and important component of the quality management system of the laboratory.

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