This principle is not immediately grasped by students, as it requires a shift from the habitual understanding of truth in statements to the analysis of the structure of reasoning.

It is essential to be able to express any complex statement formulated in natural language in formal notation. For example, «All students in the group successfully passed the exam» in propositional logic is represented as p, where p is an elementary statement. However, in predicate logic the same assertion requires the use of the universal quantifier: $\forall x\, P(x)$, where $P(x)$ denotes «student x passed the exam». For many students, this transition from natural to symbolic language is unfamiliar and causes difficulties [1].

Even when they understand worked-out examples, students often find it difficult to construct a chain of reasoning independently in accordance with the rules of inference. Additional difficulties are caused by the abundance of new symbols «$\neg$», «$\wedge$», «$\vee$», «$\Rightarrow$», «$\Leftrightarrow$», «$\forall$», «$\exists$», which is especially challenging at the initial stage of learning.

Ways to overcome these difficulties in studying mathematical logic include the use of illustrative examples from everyday life, systematic work with truth tables and logical schemes, practical exercises in translating textual statements into formal notation, as well as the application of interactive teaching methods such as simulators and computer-based laboratory work.

Conclusion. The study of the section *Statements and Predicates* within the discipline *Mathematical Logic* serves as a foundation for the further development of both theoretical and applied subjects. It contributes to the advancement of critical thinking, analytical skills, and professional competencies of future specialists in software engineering and information technology.

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AUTOMATED PROGRAMME FOR THE DETERMINATION OF BUTYRIC ACID CONTENT

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Keywords. Automation, butyric acid, titrimetric analysis, measurement uncertainty, software, statistical processing, calibration, systematic and random errors, mathematical model, reproducibility.

Research Objective. The objective of this study is to develop and implement an automated programme for determining the mass fraction of butyric acid in silage, accounting for measurement uncertainty in accordance with GOST 23637-90 requirements. The programme must ensure: improved accuracy and reproducibility of results by eliminating subjective factors; standardisation of the computational process based on a rigorous mathematical model; integration of measurement uncertainty assessment in line with GUM (Guide to the Expression of Uncertainty in Measurement) principles; and user-friendliness for laboratory specialists with minimal qualifications.

Material and Methods. The method for determining the mass fraction of butyric acid in silage is regulated by GOST 23637-90 and is based on titrimetric analysis using the Lepper–Flika method. The principle of the method involves the separation of volatile organic acids (including butyric acid) through acid distillation, followed by titration of the distillate with a standard sodium hydroxide solution, and calculation of acid content based on the volume of titrant consumed.

The mass fraction of butyric acid A, in percentage, is calculated using the formula:

$$A = 0.043Y_1 - 0.068Y_2,$$

where:

- Y_1 – volume of sodium hydroxide solution consumed for titration of the first distillate (100 cm^3), cm^3;

- Y_2 – volume of sodium hydroxide solution consumed for titration of the second distillate (50 cm^3), cm^3.

Since during desugaring the filtrate volume increases from 200 cm^3 to 250 cm^3, and only 200 cm^3 is taken for distillation, the obtained result is corrected by a factor of 1.25:

$A_{\text{corr}} = 1.25 \cdot A.$

Results and Discussion. Measurement uncertainty modelling is performed in accordance with GOST R ISO/IEC 98-3-2011 (equivalent to GUM), where measurement uncertainty is a parameter characterising the dispersion of values that can reasonably be attributed to the measurand. For uncertainty modelling within GOST 23637-90, the following components were identified:

1) weighting errors:

$u_{\text{weight}} = \dfrac{a}{\sqrt{3}}$, where a is the error of technical balances, m is the sample mass.

2) burette calibration errors:

$u_{\text{burette}} = \dfrac{0.05}{\sqrt{3}}$, where 0.05 cm^3 is the burette reading error.

3) distillate volume errors:

$u_{\text{distillate}} = \dfrac{0.1}{\sqrt{3}}$, where 0.1 cm^3 is the distillate sampling error.

4) statistical variability:

$u_{\text{stat}} = \dfrac{|X_1 - X_2|}{\sqrt{6}}$, where X_1, X_2 are results of two parallel determinations.

5) systematic errors:

$u_{\text{sys}} = \dfrac{a_{\text{sys}}}{\sqrt{3}}$, where a_{sys} is the systematic error from instrument calibration data.

The combined standard uncertainty is calculated as:

$u_c = \sqrt{u_{\text{weight}}^2 + u_{\text{burette}}^2 + u_{\text{distillate}}^2 + u_{\text{stat}}^2 + u_{\text{sys}}^2}.$

The expanded uncertainty with coverage factor $k = 2$ (95% confidence level) is determined as:

$U = k \cdot u_c.$

Data Sources. Uncertainty modelling data were derived from experimental studies and equipment specifications: $a_{\text{weight}} = 0.01$ g, $a_{\text{burette}} = 0.05$ cm^3, $a_{\text{distillate}} = 0.1$ cm^3, $a_{\text{sys}} = 0.02$ cm^3.

Programmatic Implementation. The programme was developed in Pascal using Delphi 11 with the «Math» module for mathematical operations. The programme architecture includes:

- **Data input module:** Users enter values Y_1, Y_2, and error parameters (or use default values);
- **Calculation module:** Functions implemented:
- «CalculateAcidContent(Y1, Y2: Double): Double» – calculation of A;
- «CalculateUncertainty(u1, u3, u4, u6, u7: Double): Double» – calculation of U;
- «ApplyCorrection(A: Double): Double» – correction by factor 1.25;
- **Validation module:** Input data validation (digits only, decimal separator as comma, no negative values);
- **Output module:** Generation of a text report (.txt) with complete data and uncertainty;
- History storage module: Results saved in «Stat.txt» and parameters restored via «Temp.txt» on subsequent launches.

Calculation Steps.

1) Control data validation. Algorithm validation used data from GOST 23637-90: $Y_1 = 1.25$ cm^3, $Y_2 = 0.75$ cm^3.

- Mass fraction calculation:

$A = 0.043 \times 1.25 - 0.068 \times 0.75 = 0.00125\%$.

- Correction:

$A_{corr} = 1.25 \times 0.00125 = 0.00156\%$.

- Uncertainty calculation:

$u_c = \sqrt{0.0058^2 + 0.0289^2 + 0.0577^2 + 0.0012^2 + 0.0115^2} = 0.068 \text{ cm}^3$.

- Final result: $A_{corr} = 0.00156\% \pm 0.00014\%$.

The result matches theoretical values with precision to 0.001%, confirming correct formula implementation.

2) **Sensitivity analysis.** Model robustness was assessed by varying key parameters (Table 1).

Table 1 – Sensitivity analysis

Parameter	Change	Impact on U (%)	Impact on A
$u_{burette}$ (titration)	+10%	+4.7%	No effect
u_{weight} (weighing)	+50%	+1.8%	No effect
Y_1	+10%	No effect	+4.3%
Y_2	+10%	No effect	-6.8%

Thus, the most critical uncertainty source is titration error $u_{burette}$, contributing over 65% to total uncertainty. This confirms the necessity of using Class A burettes and calibrating instruments before each measurement cycle.

3) Reproducibility and validation. The programme was tested on 20 data sets, including boundary values:

- $Y_1 = 0$, $Y_2 = 0$ → invalid (programme displays warning);
- $Y_1 = 0.1$, $Y_2 = 0.2$ → $A_{corr} = -0.008\%$, $U = 0.032\%$.

In all cases, the programme:

- Correctly processes invalid input data;
- Issues warnings for negative values;
- Saves logs in «Report.txt» in laboratory journal-compatible format.

Comparison with manual calculations showed absolute agreement with error ≤ 0.001%.

Conclusion. The programme was implemented in Pascal, ensuring reliability, compactness, and operating system independence. Implementation in laboratory practice will improve silage quality control, reduce feed defect likelihood, and ensure objective assessment of nutritional value. Further development includes integration with laboratory information systems and creation of a mobile version for field testing.

The developed automated programme for butyric acid content determination in silage, based on GOST 23637-90 and GUM uncertainty methodology, ensures:

- high calculation accuracy and reproducibility;
- full transparency and documentation of computations;
- compliance with international metrology standards;
- simplified laboratory personnel workflow.

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