TECHNICAL SPECIFICATION

ISO/TS 16634-2

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Food products — Determination of the total nitrogen content by combustion according to the Dumas principle and calculation of the crude protein content —

Part 2: Cereals, pulses and milled cereal products

Produits alimentaires — Détermination de la teneur en azote total par combustion selon le principe Dumas et calcul de la teneur en protéines brutes —

Partie 2: Céréales, légumineuses et produits céréaliers de mouture

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Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

In other circumstances, particularly when there is an urgent market requirement for such documents, a technical committee may decide to publish other types of document:

— an ISO Publicly Available Specification (ISO/PAS) represents an agreement between technical experts in an ISO working group and is accepted for publication if it is approved by more than 50 % of the members of the parent committee casting a vote;

— an ISO Technical Specification (ISO/TS) represents an agreement between the members of a technical committee and is accepted for publication if it is approved by 2/3 of the members of the committee casting a vote.

An ISO/PAS or ISO/TS is reviewed after three years in order to decide whether it will be confirmed for a further three years, revised to become an International Standard, or withdrawn. If the ISO/PAS or ISO/TS is confirmed, it is reviewed again after a further three years, at which time it must either be transformed into an International Standard or be withdrawn.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO/TS 16634-2 was prepared by the European Committee for Standardization (CEN) in collaboration with ISO Technical Committee TC 34, *Food products*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

ISO 16634 consists of the following parts, under the general title *Food products — Determination of the total nitrogen content by combustion according to the Dumas principle and calculation of the crude protein content*:

— *Part 1: Oilseeds and animal feeding stuffs*

— *Part 2: Cereals, pulses and milled cereal products* [Technical Specification]

Introduction

For a long time, the Kjeldahl method has been the most frequently used method for the determination of the protein content of food products. However, in recent years, the Kjeldahl method has increasingly been replaced by the Dumas method, which is faster and does not use dangerous chemicals. Although the principles of the two methods are different, both measure the nitrogen content of the product. Nitrogen content can be converted into protein content by using an appropriate factor. The value of this factor varies depending on the relative amounts of different proteins and their amino-acid composition in a given product.

Neither the Dumas nor the Kjeldahl method distinguishes between protein and non-protein nitrogen. In most cases, results obtained by the Dumas method are slightly higher than those of the Kjeldahl method. This is due to the fact that the Dumas method measures almost all of the non-protein nitrogen, whereas the Kjeldahl method measures only a part of it.

Taking into consideration the fact that the protein content of a product calculated by both methods only approximates to the true value, it is a matter of discretion which one is accepted. The most appropriate solution should be the use of a second factor for the elimination of the systematic error caused by the non-protein nitrogen content of the different products. However, this second factor has to be determined for each product, like the existing factors which indicate the ratio of the protein content to the nitrogen content.

Food products — Determination of the total nitrogen content by combustion according to the Dumas principle and calculation of the crude protein content —

Part 2:
Cereals, pulses and milled cereal products

1 Scope

This part of ISO 16634 specifies a method for the determination of the total nitrogen content and the calculation of the crude protein content of cereals, pulses and milled cereal products.

This method, like the Kjeldahl method (see References [1] and [6]), does not distinguish between protein nitrogen and non-protein nitrogen. For the calculation of the protein content, various conversion factors are used (see Annex D).

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 712, *Cereals and cereal products — Determination of moisture content — Reference method*

ISO 6540, *Maize — Determination of moisture content (on milled grains and on whole grains)*

ISO 24557, *Pulses — Determination of moisture content — Air-oven method*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
nitrogen content
mass fraction of the total nitrogen determined by the procedure specified in this part of ISO 16634

NOTE The mass fraction is expressed as a percentage.

3.2
crude protein content
nitrogen content (3.1) multiplied by a factor, usually 5,7 for wheat, rye and their milled products and 6,25 for others products falling within the scope of this part of ISO 16634

NOTE The factors for calculation of the crude protein content from the total nitrogen content are derived from the Kjeldahl method, which is the reference method for the determination of total nitrogen content. As the method specified in this part of ISO 16634 uses the same factors as the Kjeldahl method, the validity of these factors has to be verified due to the slight difference in the results obtained with the Kjeldahl and Dumas methods.

4 Principle

Samples are converted to gases by heating in a combustion tube. Interfering components are removed from the resulting gas mixture. The nitrogen compounds in the gas mixture, or a representative part of them, are converted to molecular nitrogen which is quantitatively determined by a thermal-conductivity detector. The nitrogen content is then calculated by a microprocessor.

5 Reagents

Use only reagents of recognized analytical grade or reagents of equivalent purity as specified by instrument manufacturers. Except for the reference materials (see 5.12), all reagents shall be free from nitrogen.

5.1 Carrier gas(es): use either 5.1.1 or 5.1.2.

5.1.1 Carbon dioxide, as pure as possible, but with a minimum CO_2 volume fraction of 99,99 %.

5.1.2 Helium, as pure as possible, but with a minimum He volume fraction of 99,99 %.

5.2 Oxygen, as pure as possible, but with a minimum O_2 volume fraction of 99,99 %.

5.3 Sulfur dioxide and halogen absorbent, to eliminate any sulfur from the sample [e.g. lead chromate ($PbCrO_4$) or steel wool].

5.4 Copper oxide/platinum catalyst, for the post-combustion tube.

Platinum catalyst [5 % of Pt on alumina (Al_2O_3)] is blended with CuO in the ratio 1 part:7 parts or 1 part:8 parts in accordance with the manufacturer's recommendations.

To prevent separation as a result of the different bulk densities of the two materials, it is recommended not to prepare the mixture before filling the tube but to pour the platinum catalyst and copper oxide simultaneously into the post-combustion tube using a suitable funnel.

5.5 Silver or copper wool.

This shall be disaggregated before being inserted into the post-combustion or reduction tube.

5.6 Silica (quartz) or **glass wool** or **cotton wool**, as recommended by the instrument manufacturer.

5.7 Copper or **tungsten (wire, cuttings, turnings** or **powder)**, for the reduction tube.

The use of copper or tungsten in one of these forms can improve the precision of analytical results for samples with low nitrogen contents (about 1 % mass fraction).

5.8 Diphosphorus pentoxide (P_2O_5) or **granulated magnesium perchlorate** [$Mg(ClO_4)_2$], or another suitable drying agent, to fill the drying tubes.

5.9 Hollow corundum spheres or **aluminium oxide pellets**, for the combustion tube.

5.10 Copper oxide (CuO), as filling material for the combustion tube.

5.11 Sodium hydroxide (NaOH), on a support material.

5.12 Aspartic acid ($C_4H_7NO_4$) or **ethylenediaminetetraacetic acid** ($C_{10}H_{16}N_2O_8$) or **glutamic acid** ($C_5H_9NO_4$) or **hippuric acid** ($C_9H_9NO_3$) **standard**, or other suitable reference materials with a known, constant, certified nitrogen content.

The minimum recovery should preferably be 99 % mass fraction.

5.13 Light petroleum, with a boiling range between 30 °C and 60 °C, or **acetone** or **ethanol**.

6 Apparatus

Usual laboratory equipment and, in particular, the following:

6.1 Analytical balance, capable of weighing to the nearest 0,000 1 g.

6.2 Grinding device, appropriate to the nature of the sample.

6.3 Sieve, of nominal opening size 800 µm or 1 mm, made of non-ferrous material.

6.4 Crucibles (e.g. made of stainless steel, quartz, ceramic material or platinum) or **tin capsules** or **nitrogen-free filter paper**, suitable for the Dumas apparatus used.

NOTE 1 Several instruments provided with an automatic sampler are commercially available.

NOTE 2 Some solid samples (e.g. powders) can be pressed to form pellets.

6.5 Dumas apparatus[1)], fitted with a furnace able to maintain a given temperature greater than or equal to 850 °C, with a thermal-conductivity detector and suitable device for signal integration.

Suitable Dumas apparatus operates according to the general flowchart given in Annex A, although different arrangements and components may be used.

NOTE Schematic diagrams of three commercially available instruments are shown as examples in Figures B.1, B.2 and B.3.

To avoid leaks, the sealing O-rings shall be slightly lubricated with high-vacuum grease prior to installation.

Experience has shown that it is important to clean all pieces of silicaware and glassware carefully and to remove fingerprints from tubes, using a suitable solvent (e.g. acetone), before inserting them in the furnace.

7 Sampling

A representative sample should have been sent to the laboratory. It should not have been damaged or changed during transport or storage.

Sampling is not part of the method specified in this part of ISO 16634. Recommended sampling methods are given in ISO 24333[7] for cereals and cereal products.

8 Preparation of test sample

The test sample shall be prepared from the laboratory sample in such a way that a homogeneous test sample is obtained.

Using a suitable grinding device (6.2), grind the laboratory sample. Generally, pass the ground material through a sieve (6.3) of nominal opening size 800 µm for small sample sizes (under 300 mg) or a sieve of nominal opening size 1 mm for larger sample sizes (300 mg or more). Mills that produce particle sizes meeting the specifications given in Table 1 will give acceptable results.

1) Elementar Analysensysteme, Sumika Chemical Analysis Service and LECO Instruments produce suitable equipment available commercially. This information is given for the convenience of users of this Technical Specification and does not constitute an endorsement by ISO of this equipment. Equivalent products may be used if they can be shown to lead to the same results.

Table 1 — Required particle size

Nominal size of sieve openings µm	Amount passing through sieve % mass fraction
710	100
500	95 to 100
200	85 or less

Grinding may result in moisture loss and therefore the moisture content of the ground sample should preferably also be determined when reporting nitrogen or protein contents on a dry-matter or constant-moisture basis. Determination of the moisture content shall be carried out in accordance with ISO 712 for cereals other than maize, ISO 6540 for maize and ISO 24557 for pulses.

The grinder efficiency can be checked by replicate preparation of ground samples of a 2+1 mixture of maize and soya seeds. The expected coefficient of variation should be less than 2 % mass fraction.

9 Procedure

9.1 General

Carefully follow the manufacturer's instructions for instrument set-up, optimization, calibration and operation. Switch the instrument on and allow it to stabilize as defined in local procedures.

An instrument performance test should be carried out daily, using the reference material (5.12). The recovery of nitrogen should be > 99,0 % mass fraction.

9.2 Test portion

Weigh, to the nearest 0,000 1 g, at least 0,1 g of the test sample into a crucible or tin capsule or nitrogen-free filter paper (6.4). For samples low in protein (< 1 % mass fraction), the amount of the test portion can be increased up to 3,5 g, depending on the type of Dumas equipment being used and on the nature of the sample.

Depending on the type of equipment used, if the sample contains over 17 % mass fraction of moisture, it may be necessary to dry it before analysis.

Lower masses may be necessary for very high protein content samples or when only very small amounts of sample are available. In the case of masses less than 0,1 g, a second (validation) determination shall be performed.

9.3 Control of oxygen supply

Control the oxygen supply, in particular the flow, in accordance with the instructions of the material supplier.

With each series of nitrogen content determinations, conduct as many blank runs as necessary to stabilize the equipment, using for each run an equivalent mass of sucrose in place of the test portion. The sucrose blank provides the amount of nitrogen that is introduced in the form of atmospheric air trapped within a powdered organic material. Use the mean value of the blank determinations as an error correction in the calculation of the nitrogen content of each test sample.

9.4 Calibration

For long-term instrument calibration, use pure compounds with a known, constant nitrogen content, e.g. aspartic acid (see 5.12), as standards. Analyse in duplicate three pure compounds, each in three different amounts chosen as a function of the measurement range for the actual samples.

To prepare a calibration curve, carry out at least five determinations with different amounts of the same compound, choosing the compound and the amounts used in such a way that the curve obtained will cover the range of nitrogen contents in the samples to be analysed.

If the test portion contains more than 200 mg of nitrogen, the calibration curve is likely to be non-linear. In the non-linear section, short segments can nevertheless be used for calibration purposes. To ensure the reliability of the curve in these segments, the amount of standard used shall be increased in steps corresponding to 1 mg to 5 mg of nitrogen over the segments.

Calibration can also be performed using standard aqueous solutions.

Check the calibration at least three times at the beginning of a series of analyses and then after every 15 to 25 samples, analysing either one of the standards (see 5.12) or a sample of known value. The value obtained for the nitrogen mass fraction shall differ by less than 0,05 % from the expected value. If it does not, repeat the calibration check after checking instrument performance.

9.5 Determination

With the instrument operating in the stable state, introduce the test portion in accordance with the manufacturer's instructions.

During the analysis, the following processes take place in the instrument (see Figure B.1, B.2 or B.3).

The test portion is quantitatively combusted under standard conditions at a temperature of at least 850 °C, depending on the instrument and the material being analysed.

Volatile decomposition products (mainly molecular nitrogen, nitrogen oxides, carbon dioxide and water vapour) are transported by the carrier gas (see 5.1) through the instrument.

Nitrogen oxides are reduced to molecular nitrogen, and the excess oxygen is bound to the copper or tungsten (5.7) in the reduction column.

Water is removed by drying tubes filled with magnesium perchlorate, diphosphorus pentoxide or another drying agent (see 5.8). If carbon dioxide is used as the carrier gas (see 5.1.1), it is removed by being passed over a suitable absorbent, e.g. sodium hydroxide (5.11) on a suitable support material.

Interfering compounds (e.g. volatile halogen and sulfur compounds) are removed by absorbents (5.3) or chemical reagents, e.g. silver wool (5.5) or sodium hydroxide (5.11) on a suitable support material.

The remaining gas mixture, consisting of nitrogen and carrier gas, is passed through a thermal-conductivity detector.

9.6 Detection and integration

For quantitative nitrogen determination, the instrument uses a sensitive thermal-conductivity cell that is optimized for the carrier gas employed and that may have automatic zero adjustment between measurements on successive test portions. After amplification and analogue/digital conversion of the detector signal, the data obtained are processed by peripheral microprocessor hardware.

10 Calculation and expression of results

10.1 Calculation

10.1.1 Nitrogen content

The results for the total nitrogen content, w_N, expressed as a percentage mass fraction, are usually available in the form of instrument printouts.

10.1.2 Crude protein content

The correction factor, F_c, is obtained from Equation (1):

$$F_c = \frac{100 - w_{H_2O,1}}{100 - w_{H_2O,2}} \quad (1)$$

where

$w_{H_2O,1}$ is the moisture mass fraction, expressed as a percentage, before grinding;

$w_{H_2O,2}$ is the moisture mass fraction, expressed as a percentage, after grinding.

The crude protein content, w_p, expressed as a percentage mass fraction, is obtained from Equation (2):

$$w_p = w_N F F_c \quad (2)$$

where

w_N is the nitrogen content, expressed as a percentage mass fraction, of the sample at its natural moisture content;

F is the generally agreed conversion factor for the product analysed, equal to 5,7 for wheat, rye and their milled products and 6,25 for other products falling within the scope of this part of ISO 16634 (see Annex D).

If requested, the crude protein content expressed as a percentage mass fraction of the dry matter, w_{pd}, can be calculated from Equation (3):

$$w_{pd} = \frac{100 w_p}{100 - w_{H_2O}} \quad (3)$$

where w_{H_2O} is the moisture content, expressed as a percentage mass fraction, determined in accordance with ISO 712, ISO 6540 or ISO 24557.

10.2 Expression of results

Express the result to three significant figures (e.g. 9,53 % or 20,5 % or 35,4 %).

11 Precision

11.1 Interlaboratory tests

Details of interlaboratory tests carried out to determine the precision of the method are given in Annex E.

The values derived from these interlaboratory tests may not be applicable to concentration ranges and matrices other than those given, i.e. to nitrogen contents between 0,05 % and 13,89 %.

11.2 Repeatability

The absolute difference between two independent single test results, obtained using the same method on identical test material in the same laboratory by the same operator using the same equipment within a short interval of time, will not be greater than the repeatability limit, r, given below in more than 5 % of cases:

$$r = 2{,}8 s_r = 2{,}8(0{,}001\,3 w_{\mathrm{N}} + 0{,}012)$$

where

s_r is the repeatability standard deviation;

w_{N} is the nitrogen content, expressed as a percentage mass fraction.

11.3 Reproducibility

The absolute difference between two single test results, obtained using the same method on identical test material in different laboratories with different operators using different equipment, will not be greater than the repeatability limit, R, given below in more than 5 % of cases:

$$R = 2{,}8 s_R = 2{,}8(0{,}012\,6 w_{\mathrm{N}} + 0{,}017)$$

where

s_R is the reproducibility standard deviation;

w_{N} is the nitrogen content, expressed as a percentage mass fraction.

11.4 Critical difference

11.4.1 Comparison of two groups of measurements in the same laboratory

The critical difference, CD, i.e. the difference between two averaged values obtained from two test results under repeatability conditions, is given by:

$$\mathrm{CD} = 2{,}8 s_r \sqrt{\frac{1}{2n_1} + \frac{1}{2n_2}} = 2{,}8 s_r \sqrt{\frac{1}{2}} = 1{,}98 s_r$$

where

s_r is the repeatability standard deviation;

n_1 and n_2 are the number of test results corresponding to each of the averaged values.

11.4.2 Comparison of two groups of measurements in two different laboratories

The critical difference between two averaged values obtained in two different laboratories from two test results under repeatability conditions is equal to:

$$CD = 2{,}8\sqrt{s_R^2 - s_r^2\left(1 - \frac{1}{2n_1} - \frac{1}{2n_2}\right)} = 2{,}8\sqrt{s_R^2 - 0{,}5s_r^2}$$

where

s_r is the repeatability standard deviation;

s_R is the reproducibility standard deviation;

n_1 and n_2 are the number of test results corresponding to each of the averaged values.

11.5 Uncertainty

The measurement uncertainty, U_e, is a parameter representing the distribution of the values that may reasonably be attributed to the result. This uncertainty is given by a statistical distribution of the results from the interlaboratory tests and is characterized by the experimental standard deviation.

The uncertainty, U_e, is equal to plus or minus twice the reproducibility standard deviation given in this part of ISO 16634:

$$U_e = \pm 2s_R$$

where s_R is the reproducibility standard deviation.

12 Test report

The test report shall contain at least the following information:

a) all information necessary for the complete identification of the sample;

b) the sampling method used, if known;

c) the test method used, with reference to this part of ISO 16634;

d) all operating details not specified in this part of ISO 16634, or regarded as optional, together with details of any incident which may have influenced the test result(s);

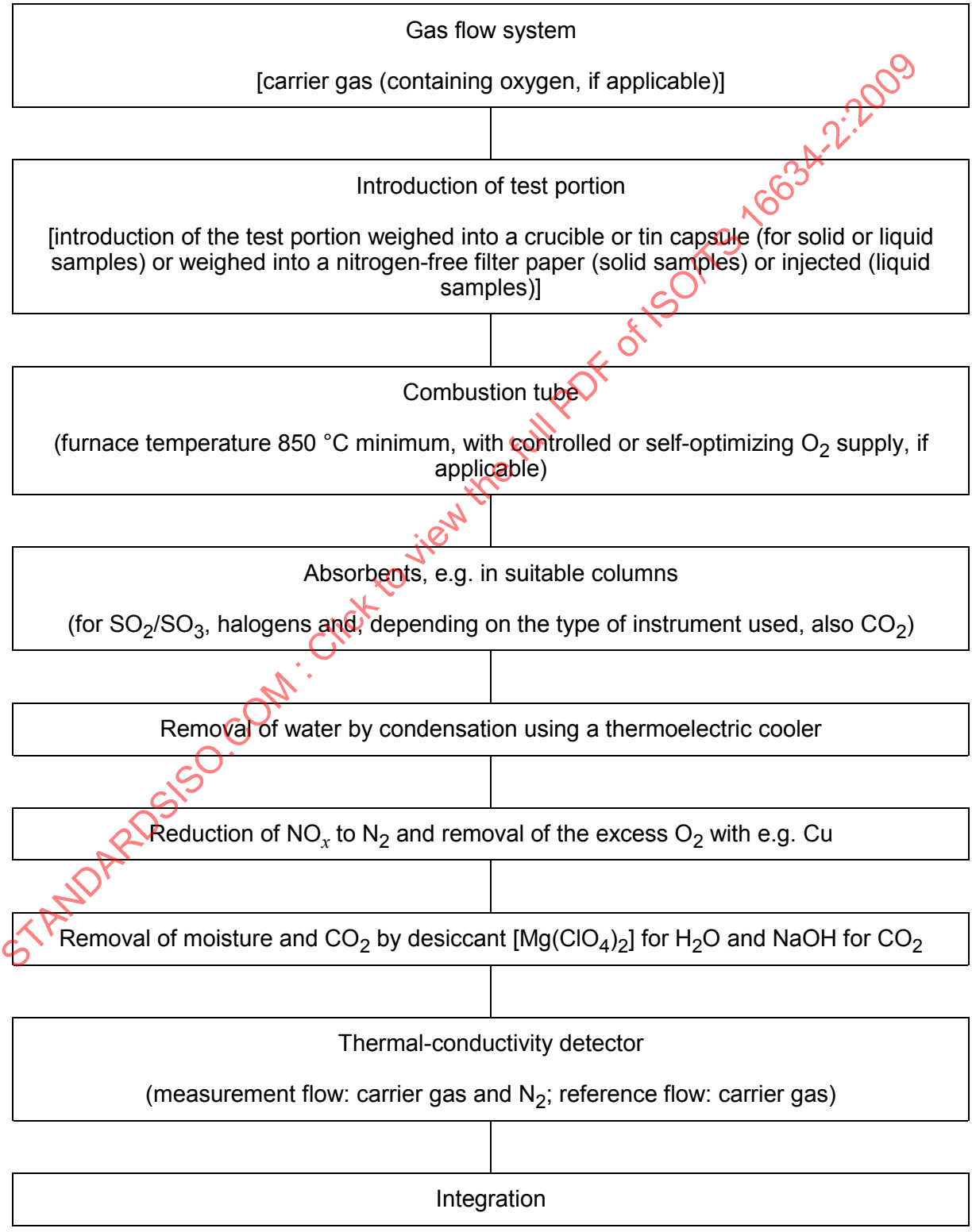
e) the test result(s) obtained, the conversion factor used and the moisture content of the test sample or the reference moisture content;

f) if the repeatability has been checked, the final quoted result obtained;

g) the date of the test.

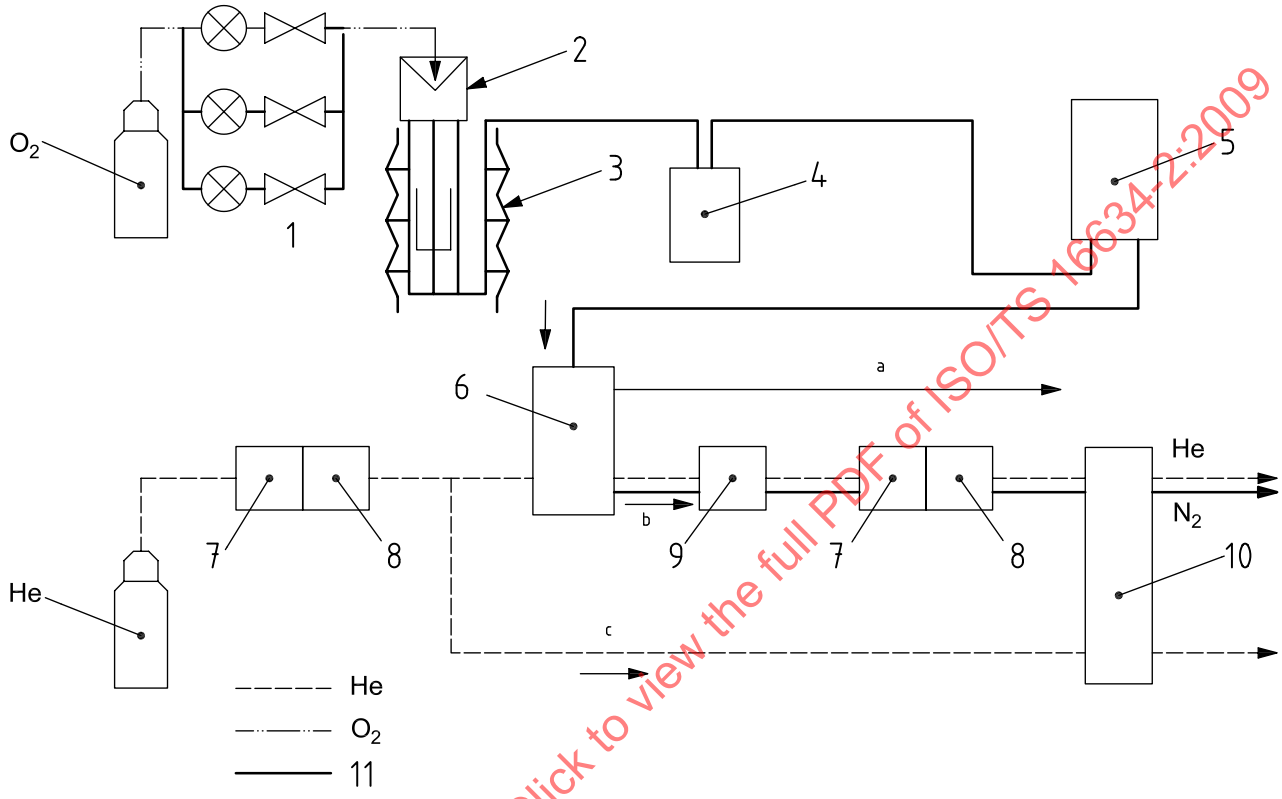
Annex A
(informative)

Flowchart for a basic Dumas apparatus



Annex B
(informative)

Schematic diagrams of suitable types of Dumas apparatus

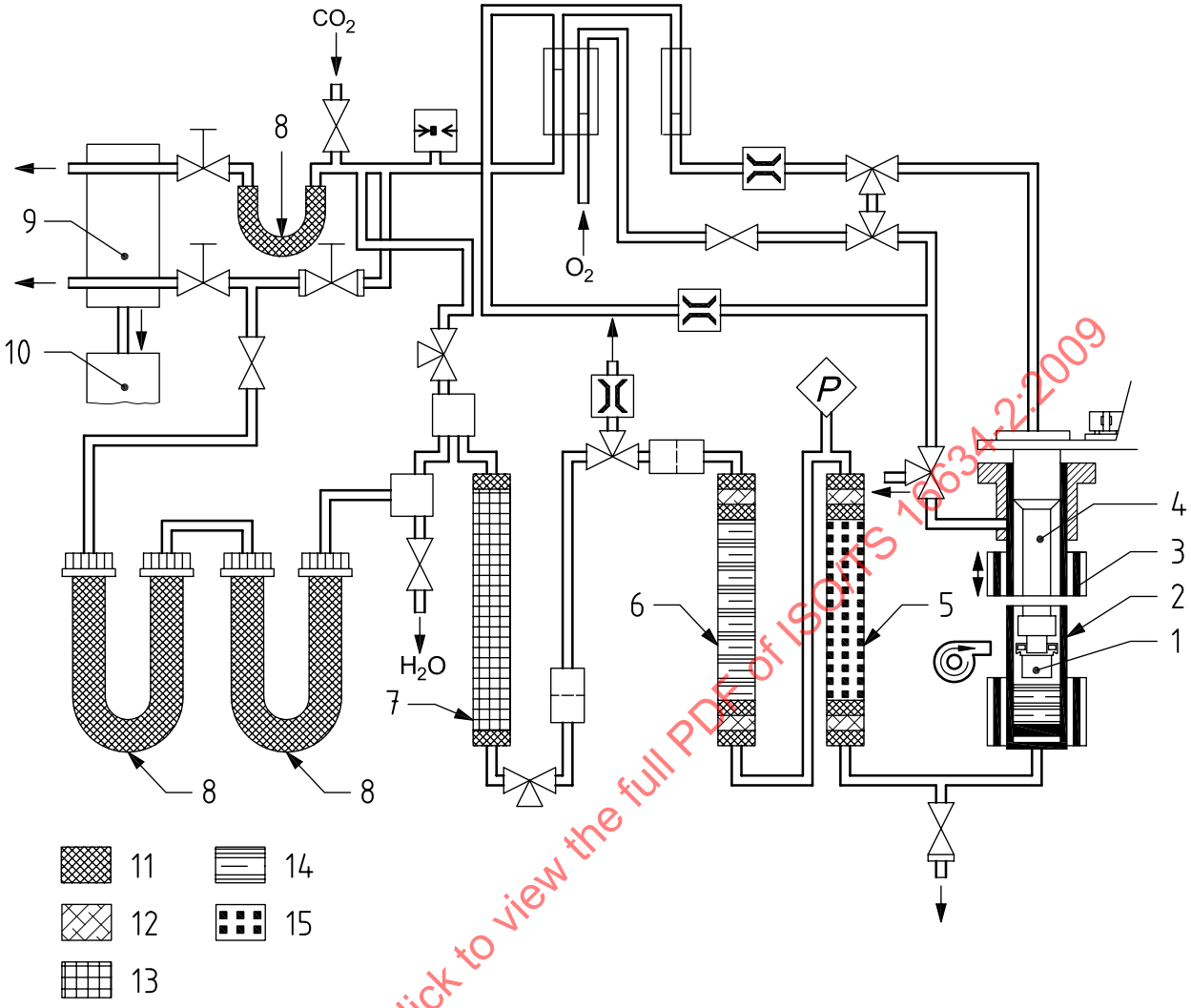


Key

1 oxygen flow controller
2 introduction of test portion
3 resistance furnace with crucible
4 (thermoelectric) cooler
5 mixing container/ballast column
6 dosing device
7 sodium hydroxide on support material
8 magnesium perchlorate
9 copper catalyst (reduces NO_x and O_2)
10 thermal-conductivity detector
11 combustion gases containing N_2

a Surplus combustion gases.
b Measurement flow.
c Reference flow.

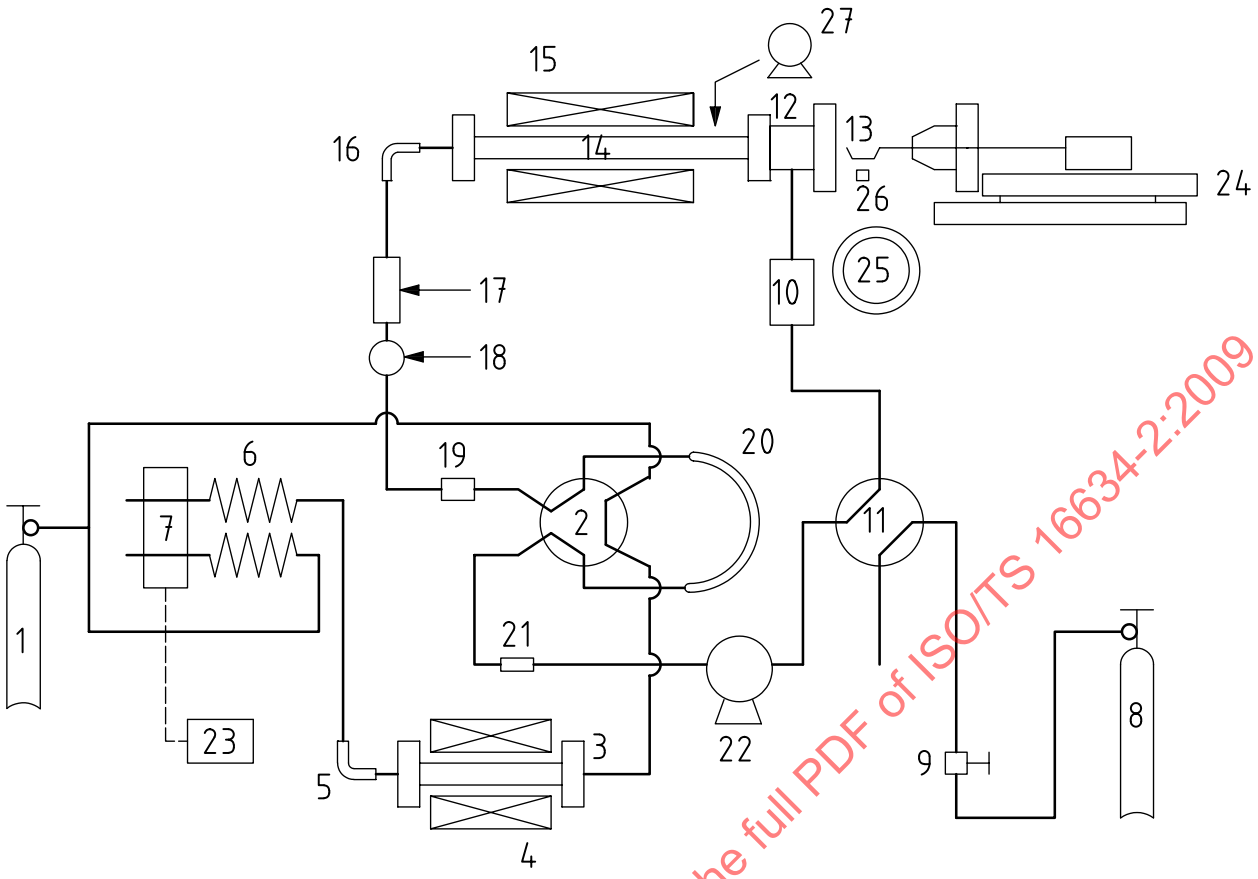
Figure B.1 — First example of a Dumas apparatus (carrier gas He)



Key

1 test crucible
2 combustion column
3 combustion furnace (mobile)
4 crucible holder
5 SO_2 absorption tube
6 post-combustion tube
7 reduction column
8 drying tube
9 thermal-conductivity detector
10 integrator
11 drying agent
12 silver wool
13 copper wire
14 copper wire with platinum catalyst
15 lead chromate

Figure B.2 — Second example of a Dumas apparatus (carrier gas CO_2)



Key

1 helium cylinder
2 valve
3 reduction tube
4 reduction furnace
5 gas absorption tube
6 gas separator column
7 thermal-conductivity detector
8 oxygen cylinder
9 oxygen flow controller
10 flowmeter
11 valve
12 test portion inlet
13 test portion insertion shaft
14 reaction tube
15 reaction furnace
16 tube for checking completeness of combustion
17 condenser for removing water vapour
18 gas-mixing tube
19 filter No. 1
20 measurement tube
21 filter No. 2
22 circulation pump
23 data processor
24 test portion insertion device
25 test portion tray
26 lifting device for test portion tray
27 cooling-air pump

Figure B.3 — Third example of a Dumas apparatus (carrier gas He)

Annex C
(informative)

Equipment calibration

C.1 Calibration compounds

Some of the instruments available require entry of the expected oxygen demand.

The calculations in Clause C.2 are necessary for some types of instrument (those involving a moderate O_2 surplus in the presence of CO_2 as carrier gas). All calculations are based on the assumption that the sample consists only of the elements C, N, H and O.

Table C.1 — Oxygen demand of pure compounds suitable for calibration of the equipment

Compound	Nitrogen content % mass fraction	Maximum theoretical oxygen demand ml/g	Empirical oxygen demand ml/g
Urea	46,65	1 305	560
Aspartic acid	10,53	800	631
Tyrosine	7,73	1 391	1 267
Glutamic acid	9,52	952	800
Phenylalanine	8,48	1 593	1 458
Ethylenediamine-tetraacetic acid	9,59	920	767
Hippuric acid	7,82	1 344	1 219

C.2 Examples for calculation of the estimated oxygen demand

C.2.1 Example 1

Urea (H_2NCONH_2): 1 mol corresponds to 60,06 g; mass of test portion 1 000 mg.

The 1 000 mg test portion of urea therefore contains

— 199,8 mg of C;

— 66,6 mg of H;

— 466,5 mg of N;

— 266,4 mg of O.

The amount of oxygen required for complete combustion to carbon dioxide and water is calculated taking into account the oxygen content of the compound and the following facts:

a) the molar volume of an ideal gas is 22,4 l (at $T = 0$ °C and $p = 0{,}1$ MPa);

b) 1 mol of C corresponds to 12 g (12 000 mg);

c) 1 mol of H_2 corresponds to 2 g (2 000 mg);

d) 1 mol of N_2 corresponds to 28 g (28 000 mg);

e) 1 mol of O_2 corresponds to 32 g (32 000 mg).

As a result, 1 305 ml of oxygen are needed for the combustion of 1 g of urea.

C.2.2 Example 2

Aspartic acid [$HO_2CCH_2CH(NH_2)CO_2H$]: 1 mol corresponds to 133,10 g, mass of test portion 1 000 mg.

The 1 000 mg test portion of aspartic acid therefore contains

— 360,6 mg of C;

— 52,6 mg of H;

— 105,2 mg of N;

— 480,8 mg of O.

The amount of oxygen required for complete combustion to carbon dioxide and water is calculated taking into account the oxygen content of the compound and the following facts:

a) the molar volume of an ideal gas is 22,4 l (at $T = 0$ °C and $p = 0{,}1$ MPa);

b) 1 mol of C corresponds to 12 g (12 000 mg);

c) 1 mol of H_2 corresponds to 2 g (2 000 mg);

d) 1 mol of N_2 corresponds to 28 g (28 000 mg);

e) 1 mol of O_2 corresponds to 32 g (32 000 mg).

As a result, 800 ml of oxygen are needed for the combustion of 1 g of aspartic acid.

Annex D
(informative)

Examples of factors for converting nitrogen content to protein content

Commodity	Nitrogen-to-protein conversion factor
Barley	5,7
Maize, flour	6,25
Oats	6,25
Oats (oatmeal, rolled oats)	6,25
Peanuts (dried), flour	6,25
Rice, brown, long grain	6,25
Rice, home-pounded, undermilled, parboiled	6,25
Rice, husked or brown (only hulls removed)	6,25
Rice, milled, white	6,25
Rye, dark flour	5,7
Soya beans (roasted), flour	6,25
Soya bean seeds, flour or products	6,25
Triticale	5,7
Wheat, hard red	5,7
Wheat bran	5,7
Wheat germ	5,7
Wheat, whole meal or flour or bulgur	5,7

Annex E
(informative)

Results of interlaboratory tests

E.1 General

The values of the repeatability limit and reproducibility limit for this method have been derived from the results of an international interlaboratory test programme carried out in accordance with ISO 5725-1 [2], ISO 5725-2 [3] and ISO 5725-6 [4].

The tests were carried out on 13 samples of cereals and pulses. 17 laboratories in 6 countries took part.

This test programme was organized by ARVALIS — Institut du Végétal in June 2007.

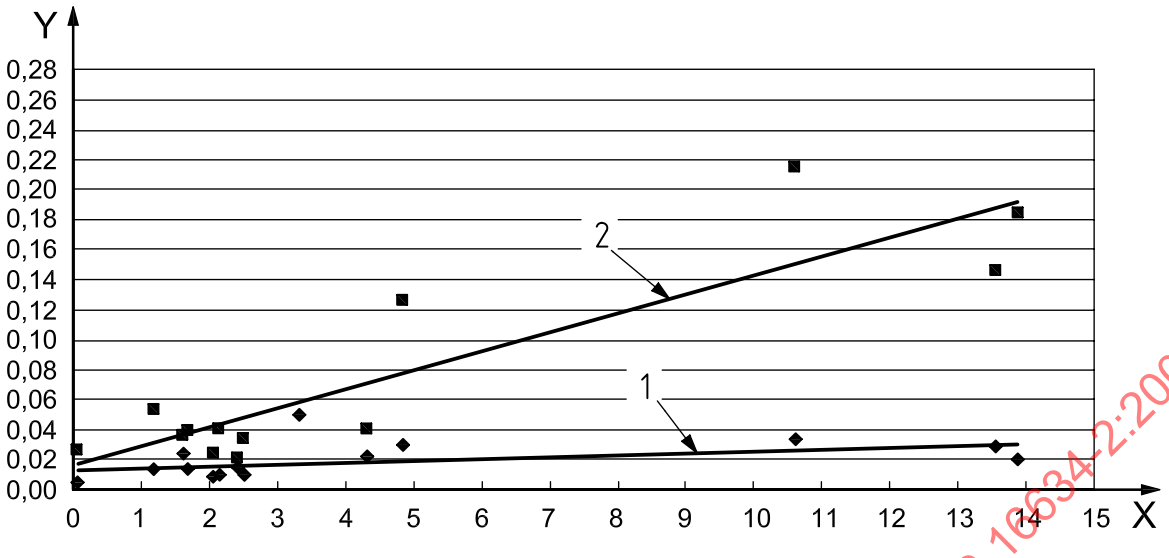
The results obtained were subjected to statistical analysis in accordance with ISO 5725-1, ISO 5725-2 and ISO 5725-6 to give the precision data shown in Tables E.1 and E.4.

E.2 Precision data for nitrogen content

See following pages.

Table E.1 — Interlaboratory test results for nitrogen content

Parameter	Starch	Maize	Rye	Barley	Common wheat flour	Common wheat	Durum wheat semolina	Durum wheat	Pea	Horse bean	Maize gluten	Common wheat gluten	Pea proteins
Number of labs or tests (after elimination of abnormal data)	15	16	16	16	14	15	15	17	17	17	17	17	17
Average nitrogen content, w_N (%)	0,05	1,18	1,63	1,68	2,07	2,16	2,42	2,51	4,33	4,85	10,61	13,55	13,89
Repeatability standard deviation, s_r (%)	0,004 6	0,013 9	0,023 4	0,013 9	0,008	0,010 1	0,015 1	0,010 1	0,022 3	0,031	0,034 5	0,029 4	0,020 3
Repeatability coefficient of variation, CV(r) ($= s_r/w_N$) (%)	0,094	0,012	0,014	0,008	0,004	0,005	0,006	0,004	0,005	0,006	0,003	0,002	0,001
Repeatability limit, r ($= 2{,}8 s_r$)	0,01	0,04	0,06	0,04	0,02	0,03	0,04	0,03	0,06	0,09	0,10	0,08	0,06
Reproducibility standard deviation, s_R (%)	0,027	0,053	0,037	0,039	0,024	0,040	0,022	0,034	0,040	0,126	0,215	0,146	0,184
Reproducibility coefficient of variation, CV(R) ($= s_R/w_N$) (%)	0,543	0,045	0,023	0,023	0,011	0,019	0,009	0,014	0,009	0,026	0,020	0,011	0,013
Reproducibility limit, R ($= 2{,}8 s_R$)	0,07	0,15	0,10	0,11	0,07	0,11	0,06	0,09	0,11	0,35	0,59	0,40	0,51



Key

X nitrogen content (% by mass)
Y standard deviation in nitrogen content
1 repeatability standard deviation
2 reproducibility standard deviation

Figure E.1 — Relationship between the repeatability and reproducibility standard deviations and the nitrogen content

The graph shows that the repeatability and reproducibility values increase (i.e. the precision decreases) with increasing nitrogen content.

Table E.2 — Summary of precision data for nitrogen content

Parameter	Range	Relationship	Repeatability	Reproducibility
Nitrogen content (% by mass on a dry-matter basis)	from 0,05 to 13,89	r: linear R: linear	$s_r = 0{,}001\,3 w_N + 0{,}012$ Correlation coefficient $R^2 = 0{,}452\,9$	$s_R = 0{,}012\,6 w_N + 0{,}017$ Correlation coefficient $R^2 = 0{,}797\,6$

Table E.3 — Example of a practical application of the precision data for nitrogen content

Nitrogen content	Repeatability standard deviation	Repeatability limit	Reproducibility standard deviation	Reproducibility limit	Critical difference between two means	
					Within one lab	Between two labs
%	s_r	r	s_R	R	CD(r)	CD(R)
0,05	0,012	0,03	0,018	0,05	0,02	0,04
0,50	0,013	0,04	0,023	0,06	0,03	0,06
1,00	0,013	0,04	0,030	0,08	0,03	0,08
2,00	0,015	0,04	0,042	0,12	0,03	0,11
3,00	0,016	0,04	0,055	0,15	0,03	0,15
4,00	0,017	0,05	0,067	0,19	0,03	0,18
5,00	0,019	0,05	0,080	0,22	0,04	0,22
6,00	0,020	0,05	0,093	0,26	0,04	0,25
7,00	0,021	0,06	0,105	0,29	0,04	0,29
8,00	0,022	0,06	0,118	0,33	0,04	0,32
9,00	0,024	0,07	0,130	0,36	0,05	0,36
10,00	0,025	0,07	0,143	0,40	0,05	0,39
11,00	0,026	0,07	0,156	0,43	0,05	0,43
12,00	0,028	0,08	0,168	0,47	0,05	0,46
13,00	0,029	0,08	0,181	0,50	0,06	0,50
13,85	0,030	0,08	0,192	0,53	0,06	0,53

E.3 Precision data for protein content

See following pages.