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Milk — Determination of lactulose content — Enzymatic method

Lait — Détermination de la teneur en lactulose — Méthode enzymatique

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Foreword

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ISO 11285 | IDF 175 was prepared by Technical Committee ISO/TC 34, *Food products*, Subcommittee SC 5, *Milk and milk products,* and the International Dairy Federation (IDF), in collaboration with AOAC International. It is being published jointly by ISO and IDF and separately by AOAC International.

Foreword

IDF (the International Dairy Federation) is a worldwide federation of the dairy sector with a National Committee in every member country. Every National Committee has the right to be represented on the IDF Standing Committees carrying out the technical work. IDF collaborates with ISO and AOAC International in the development of standard methods of analysis and sampling for milk and milk products.

Draft International Standards adopted by the Action Teams and Standing Committees are circulated to the National Committees for voting. Publication as an International Standard requires approval by at least 50 % of IDF National Committees casting a vote.

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All work was carried out by the Joint ISO/IDF/AOAC Action Team, *Characterization of milk and milk products according to heat treatment*, of the Standing Committee on *Minor components and characterization of physical properties*, under the aegis of its project leader, Mrs E. Lechner (DE).

This edition of ISO 11285 | IDF 175 cancels and replaces IDF 175:1995, which has been technically revised.

Milk — Determination of lactulose content — Enzymatic method

1 Scope

This International Standard specifies an enzymatic method for the determination of the lactulose content of milk.

2 Terms and definitions

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

2.1
lactulose content
mass of substances determined by the procedure specified in this International Standard

NOTE The lactulose content is expressed as milligrams per kilogram.

3 Principle

Fat and protein are precipitated by the addition of zinc sulfate and potassium hexacyanoferrate(II) solution and are then removed by filtration. Lactose and lactulose are hydrolysed to galactose and glucose, or galactose and fructose, respectively, in the presence of the enzyme β-D-galactosidase (β-gal). The amount of liberated fructose is stoichiometric with the amount of lactulose:

$$\text{lactose} + H_2O \xrightarrow{\beta\text{-gal}} \text{galactose} + \text{glucose} \quad (1)$$

$$\text{lactulose} + H_2O \xrightarrow{\beta\text{-gal}} \text{galactose} + \text{fructose} \quad (2)$$

Lactose is present in milk in significantly higher amounts than lactulose. Thus, the glucose present after hydrolysis would interfere with the determination of fructose. Therefore, the glucose is mostly oxidized by glucose oxidase (GOD) to gluconic acid in the presence of oxygen:

$$\text{glucose} + H_2O + O_2 \xrightarrow{\text{GOD}} \text{gluconic acid} + H_2O_2 \quad (3)$$

By this means it is possible to determine small amounts of lactulose in the presence of excess lactose. The hydrogen peroxide formed in reaction (3) is destroyed by catalase. This reaction is used to provide the oxygen which is required for the oxidation of the glucose:

$$2\,H_2O_2 \xrightarrow{\text{catalase}} 2\,H_2O + O_2 \quad (4)$$

The remaining unoxidized glucose and the fructose produced by the hydrolysis of the lactulose are phosphorylated by means of adenosine triphosphate (ATP) in the presence of hexokinase (HK) to yield glucose-6-phosphate and fructose-6-phosphate, respectively.

$$\text{glucose + ATP} \xleftrightarrow{\text{HK}} \text{glucose-6-phosphate + ADP} \quad (5)$$

$$\text{fructose + ATP} \xleftrightarrow{\text{HK}} \text{fructose-6-phosphate + ADP} \quad (6)$$

Glucose-6-phosphate is oxidized by means of $NADP^+$ in the presence of glucose-6-phosphate dehydrogenase with consequent production of 6-phosphogluconate and NADPH. After completion of the reaction, the NADPH formed is measured by means of its absorbance at 340 nm.

$$\text{glucose-6-phosphate + } NADP^+ \xleftrightarrow{\text{G-6-P-DH}} \text{6-phosphogluconate + NADPH + } H^+ \quad (7)$$

Fructose-6-phosphate is isomerized to glucose-6-phosphate in the presence of the enzyme phosphoglucose-isomerase (PGI). The glucose-6-phosphate is oxidized as given in reaction (7). The increase in NADPH is measured by means of its absorbance at 340 nm and is proportional to the fructose and lactulose content.

$$\text{fructose-6-phosphate} \xleftrightarrow{\text{PGI}} \text{glucose-6-phosphate} \quad (8)$$

In order to compensate for any free fructose which may originally be present, a blank determination is performed with the addition of β-galactosidase omitted. This blank value is taken into account in the final calculation of the lactulose content of the sample.

4 Reagents

Use only reagents of recognized analytical grade.

The reagents for the fructose determination (4.15 to 4.18) are commercially available as test combinations. Take due account of manufacturer's instructions.

4.1 Water used in the preparation of the enzyme solutions and buffer solutions shall be fresh and of at least double glass-distilled purity. Water used for other purposes shall be glass-distilled or of at least equivalent purity.

4.2 Zinc sulfate solution, $\rho\,(ZnSO_4) = 300$ g/l.

Dissolve 30,0 g of zinc sulfate heptahydrate ($ZnSO_4 \cdot 7H_2O$) in water in a 100 ml one-mark volumetric flask (5.2). Dilute to the mark with water and mix.

4.3 Potassium hexacyanoferrate(II) solution, $\rho\,(K_4[Fe(CN)_6]) = 150$ g/l.

Dissolve 15,0 g of potassium hexacyanoferrate(II) trihydrate ($K_4[Fe(CN)_6] \cdot 3H_2O$) in water in a 100 ml one-mark volumetric flask (5.2). Dilute to the mark with water and mix.

4.4 Buffer solution A, pH 7,5.

Dissolve 4,80 g of disodium hydrogenphosphate (Na_2HPO_4), 0,86 g of sodium dihydrogenphosphate monohydrate ($NaH_2PO_4 \cdot H_2O$) and 0,10 g of magnesium sulfate heptahydrate ($MgSO_4 \cdot 7H_2O$) in 80 ml of water (4.1). Adjust the pH to 7,5 ± 0,1 at 20 °C, if necessary, with 1 mol/l sodium hydroxide solution (4.10). Dilute with water to 100 ml and mix (sufficient for approximately 15 analyses).

4.5 Buffer solution B, pH 7,6.

Dissolve 14,00 g of triethanolamine hydrochloride [$N(CH_2CH_2OH)_3 \cdot HCl$] and 0,25 g of magnesium sulfate heptahydrate ($MgSO_4 \cdot 7H_2O$) in 80 ml of water (4.1).

Adjust the pH to 7,6 ± 0,1 at 20 °C, if necessary, with 1 mol/l sodium hydroxide solution (4.10). Dilute with water to 100 ml and mix (sufficient for approximately 60 analyses).

4.6 Buffer solution C.

Dilute 40,0 ml of buffer solution B (4.5) to 100 ml with water and mix (sufficient for approximately 50 analyses).

4.7 Sodium hydrogen carbonate ($NaHCO_3$).

4.8 Hydrogen peroxide (H_2O_2), 30 % (mass fraction).

4.9 Octan-1-ol ($C_8H_{18}O$).

4.10 Sodium hydroxide solutions, c(NaOH) = 0,33 mol/l and 1 mol/l respectively.

4.11 β-D-Galactosidase (β-gal), from *E. coli* (β-gal EC 3.2.1.23), 5 mg/ml suspension in 3,2 mol/l ammonium sulfate [$(NH_4)_2SO_4$] solution, 30 units/mg (at 25 °C, with lactose as substrate); 300 units/mg (at 37 °C, with 2-nitrophenyl-β-D-galactoside (*o*-nitrophenyl-β-D-galactopyranoside) as substrate), respectively.

4.12 Glucose oxidase (GOD), from *Aspergillus niger* (EC 1.1.3.4), degree of purity II, lyophilizate, 200 units/mg (at 25 °C) or 230 units/mg (at 37 °C, both with glucose as substrate), respectively.

4.13 Oxidation solution.

Dissolve 20 mg of glucose oxidase (4.12) in 1 ml of water. Prepare this solution freshly just before use.

4.14 Catalase, from beef liver (EC 1.11.1.6), suspension of 20 mg/ml in water (stabilized), 65 000 units/mg (at 25 °C; with H_2O_2 as substrate).

4.15 Hexokinase/glucose-6-phosphate-dehydrogenase (HK/G6P-DH), mixture of enzymes from yeast (EC 2.7.1.1 and EC 1.1.1.49), suspension in 3,2 mol/l ammonium sulfate ($[NH_4]_2SO_4$) solution, HK and G6P-DH:

— HK: 2 mg/ml; 140 units/mg (at 25 °C; with glucose and ATP as substrate);

— G6P-DH: 1 mg/ml, 140 units/mg (at 25 °C; with glucose-6-phosphate as substrate).

4.16 Phosphoglucose isomerase (PGI), from yeast (EC 5.3.1.9).

Suspension in 3,2 mol/l ammonium sulfate ($[NH_4]_2SO_4$) solution:

— PGI: 2 mg/ml 350 units/mg (at 25 °C; with fructose-6-phosphate as substrate).

NOTE 1 The EC numbers in 4.11, 4.12, 4.14 to 4.16 refer to the Enzymatic Classification number given by the Nomenclature Committee of the International Union of Biochemistry (see [4]).

NOTE 2 The unit in mentioned 4.11, 4.12, 4.14 to 4.16 (often called the International Unit or Standard Unit) is defined as the amount of enzyme which will catalyse the transformation of 1 µmol of substrate per minute under standard conditions.

4.17 ATP solution

Dissolve 50 mg of adenosine-5′-triphosphate disodium salt (5′-ATP-Na_2) and 50 mg of sodium hydrogen carbonate ($NaHCO_3$) in 1 ml of water.

4.18 NADP solution

Dissolve 10 mg of β-nicotinamide adenine dinucleotide phosphate disodium salt (β-NADP-Na_2) in 1 ml of water.

5 Apparatus

Usual laboratory equipment and, in particular, the following.

5.1 Analytical balance, capable of weighing to the nearest 0,001 g.

5.2 One-mark volumetric flasks, of capacity 10 ml, 20 ml and 100 ml.

5.3 Conical flask, with ground glass stopper, of capacity 50 ml.

5.4 Funnel, of diameter 50 mm.

5.5 Fluted filter, medium flow rate, of diameter 125 mm and 70 mm.

5.6 Water bath or **drying oven**, capable of maintaining a temperature of 40 °C ± 2 °C.

5.7 Spectrometer, suitable for making measurements at 340 nm.

Spectral line filter photometers suitable for making measurements at 365 nm and 334 nm (mercury lamps) may also be used. The molar absorption coefficients of NADPH (see 9.1) are then 3,4 (365 nm) or 6,18 (334 nm) ($l \cdot mmol^{-1} \cdot cm^{-1}$).

5.8 Cuvettes, made of glass or plastic, with optical path length 10,0 mm.

In the case of using plastic cuvettes, check the path length.

5.9 Pipettes, of capacity 20 µl, 50 µl, 100 µl, 500 µl, 1 ml, 2 ml, 5 ml and 10 ml, suitable for enzymatic analysis.

5.10 Graduated pipettes, of capacity 2 ml and 10 ml.

5.11 Stirrer rod, for blending the cuvette solutions.

6 Sampling

It is important that the laboratory receive a sample which is truly representative and has not damaged or changed during transport or storage.

Sampling is not part of the method specified in this International Standard. A recommended sampling method is given in ISO 707.

7 Preparation of test sample

Thoroughly mix the test sample to obtain a representative sample.

See 8.6 for the preparation of test samples for the blank test.

8 Procedure

8.1 Preparation of test solution

Weigh, to the nearest 0,001 g, about 50 g of prepared test sample (Clause 7) into a 100 ml one-mark volumetric flask (5.2). Dilute to the mark with water and mix.

8.2 Clarification

Add, using a pipette (5.10), 10,0 ml of the test solution (8.1) into a 50 ml conical flask (5.3). Using each time another pipette, add the following in the given order: 1,75 ml of potassium hexacyanoferrate(II) solution (4.3), 1,75 ml of zinc sulfate solution (4.2) and 6,5 ml of buffer solution A (4.4), swirling thoroughly after each addition. Filter the obtained solution through a fluted filter (5.5) of diameter 125 mm. Discard the first few millilitres of filtrate.

8.3 Hydrolysis of lactose and lactulose

Pipette 5,0 ml of the obtained filtrate (8.2) into a 10 ml one-mark volumetric flask (5.2).Using a pipette (5.9), add 50 µl of β-D-galactosidase (4.11). Mix and stopper the flask. Incubate the contents of the flask in the water bath or drying oven (5.6) set at 40 °C for at least 10 h (overnight).

8.4 Oxidation of glucose

Using the required pipette (5.9), add the following in the given order: 2,0 ml of buffer solution C (4.6), 100 µl of oxidation solution (4.13), 1 drop of octan-1-ol (4.9) as antifoaming agent, 0,5 ml of 0,33 mol/l sodium hydroxide solution (4.10) to neutralize the nascent gluconic acid, 50 µl of hydrogen peroxide (4.8) and 0,1 ml of catalase (4.14) to the hydrolysed solution (8.3), mixing after each addition. Incubate the thus-obtained mixture in the water bath or drying oven (5.6) set at 40 °C for a further 3 h.

8.5 Filtration

After incubation (8.4), dilute with water to the 10 ml mark and mix. Filter through a fluted filter of diameter 70 mm (5.5). Discard the first few millilitres of filtrate.

8.6 Blank test

Carry out a blank test. Proceed as specified in 8.2 to 8.5 for the test sample but without the addition of β-D-galactosidase.

8.7 Determination of glucose and fructose

Proceed as specified in Table 1.

Table 1 — Determination of glucose and fructose

Procedure	Blank	Sample
Pipette into cuvettes:		
buffer solution B (4.5)	1,00 ml	1,00 ml
ATP solution (4.17)	0,100 ml	0,100 ml
NADP solution (4.18)	0,100 ml	0,100 ml
filtrate (8.5)	1,00 ml	1,00 ml
water, double distilled (4.1)	1,00 ml	1,00 ml
Mix.[a] After 3 min read the absorbance (A_1) of the solutions.		
Start reaction by addition of hexokinase/glucose-6-phospahate-dehydrogenase (4.15)	20 µl	20 µl
Mix[a], wait until reaction has stopped (approx. 10 min). Read the absorbance (A_2) of the solutions		
Start reaction by addition of phosphoglucose isomerase (4.16)	20 µl	20 µl
Mix[a], wait until reaction has stopped (approx. 10 min to15 min). Read the absorbance (A_3) of the solutions.		

[a] Mix using the same stirrer rod (5.11) for one cuvette.