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**Cheese — Determination of rheological  
properties by uniaxial compression at  
constant displacement rate**

*Fromage — Détermination des propriétés rhéologiques par  
compression uniaxiale à vitesse constante de translation*

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## Foreword

**ISO (the International Organization for Standardization)** is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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 normative 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order to decide whether it will be confirmed for a further three years, revised to become an International Standard, or withdrawn.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again after a further three years, at which time it must either be transformed into an International Standard or be withdrawn.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 17996|IDF/RM 205 was prepared by Technical Committee ISO/TC 34, *Food products*, Subcommittee SC 5, *Milk and milk products*, and the International Dairy Federation (IDF). It is being published jointly by ISO and IDF.

## 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 in the development of standard methods of analysis and sampling for milk and milk products.

The main task of technical committees is to prepare International Standards. 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.

In other circumstances, particularly when there is an urgent market requirement for such documents, a Standing Committee may decide to publish an other type of normative document which is called by IDF: *Reviewed method*. Such a method represents an agreement between the members of a Standing Committee and is accepted for publication if it is approved by at least 50 % of the committee members casting a vote. A *Reviewed method* is equal to an ISO/PAS or ISO/TS and will, therefore, also be published jointly under ISO conditions.

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

ISO/TS 17996|IDF/RM 205 was prepared by the International Dairy Federation (IDF) and Technical Committee ISO/TC 34, *Food products*, Subcommittee SC 5, *Milk and milk products*. It is being published jointly by IDF and ISO.

All work was carried out by the Joint ISO-IDF Action Team on *Physical properties and rheological tests*, of the Standing Committee on *Minor compounds and characterization of physical properties*, under the aegis of its former project leader, Mrs Y. Noël (FR), who performed most of the work, and its present project leader, Mr P. Watkinson (NZ).



# Cheese — Determination of rheological properties by uniaxial compression at constant displacement rate

## 1 Scope

This Technical Specification describes a method for the determination of rheological properties by uniaxial compression at constant displacement rate in hard and semi-hard cheeses.

The method provides standard conditions for sampling and testing, for data representation and general principles of calculation.

NOTE Sampling might be difficult with some cheese varieties, for example caused by shortness, brittleness, stickiness and soft consistency. In these cases, reliable results cannot be achieved.

## 2 Terms and definitions

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

### 2.1

#### **rheological properties**

deformation under compression of the test sample by the procedure specified in this Technical Specification

## 3 Principle

A cylindrical test sample, of defined dimensions, is compressed at a constant crosshead speed with a compression tool up to a relative deformation sufficient to determine the apparent fracture point. The force, which is the resistance of the cheese sample during compression, is measured with a load cell. The displacement may be measured either from the position of the cross head or calculated from the elapsed time multiplied by the displacement rate.

A schematic representation of the principle of the test is given in Figure A.1.

## 4 Apparatus

Usual laboratory apparatus and, in particular, the following.

### 4.1 **Cork-borer**, such as that shown in Figure A.4 as an example.

It is recommended to mount the cork-borer on a drill-stand in order to drive it slowly and steadily through the test sample.

**4.2 Parallel-wire cutting device**, with a wire of diameter less than or equal to 0,4 mm and with a system to keep the two wires parallel to each other and perpendicular to the plug. It should also include a mechanically driven cutting system to cut the test sample to the required height.

**4.3 Measuring cell**, with a support and compression plate of the same stiff material, with smooth and parallel surfaces (e.g. stainless steel, aluminium or Teflon), of diameter larger (by 20 %) than that of the deformed test portion when at maximum compression. The load cell capacity shall have a reasonable relationship to the expected maximum force.

## 5 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 Technical Specification. A recommended sampling method is given in ISO 707|IDF 50.

## 6 Procedure

### 6.1 Thermal equilibration of test samples

If the storage temperature of the loaf of cheese is above that of the measuring temperature, then the loaf of cheese shall be equilibrated at the measuring temperature for at least 50 h before further preparation of the test sample because of the slow crystallization of milk fat in the cheese.

If the storage temperature of the loaf of cheese is below that of the measuring temperature, before any preparation store the loaf of cheese at the measuring temperature for at least 12 h. If there are specific difficulties that can occur during the sample preparation at the measuring temperature, then sample at the lower storage temperature and then equilibrate the test samples to the measurement temperature. In this case, the sample thermal equilibration time may be less than 12 h.

**NOTE** Examples of specific sampling difficulties are that the cheese is hard to cut, or a heated loaf of cheese changes the storage regime and therefore stops the use of the unsampled portions of the loaf of cheese for future measurements.

The following shall be avoided:

- a) dehydration of the test sample during the period of thermal equilibration;
- b) deformation of the test sample due to its own mass.

### 6.2 Test portion

#### 6.2.1 Location

Take the test portion from the loaf of the cheese with a plug about half a radius, either along a circle of a cylindrical cheese, or along one side of a rectangular cheese (see Figure A.2).

Cut the test portion in the plug in the area representing around half of the length (see Figure A.3, plug A). If the height of cheese is sufficient, two portions can be taken as shown in Figure A.3, plug B and plug C.

#### 6.2.2 Direction

The standard direction for taking the test portion is parallel to the pressure axis in cheese making. See Annex B for non-standard sampling conditions.

#### 6.2.3 Geometry

The shape of the test portion shall be a cylinder with initial height/diameter ratio ( $h_0/d_0$ ) of between 1,1 and 1,5.

The initial height,  $h_0$ , of the test portion shall range from 12,5 mm to 25 mm. The diameter,  $d_0$ , for a given height follows the above-mentioned ratio.

#### 6.2.4 Cutting

Remove the rind or the plastic cover. Take a test portion using a cork-borer (4.1) with shapes shown in Figure A.4. For sticky cheeses, samples are easier to take with corer A than corer B. For cheese varieties showing shortness or brittleness, form B shown in Figure A.4 is more appropriate than form A. It is recommended to use a cork-borer mounted on a drill-stand in order to drive it slowly and steadily through the test sample.

If it is difficult to obtain a good cylindrical form, it is recommended to use mineral oil of low viscosity (e.g. Vaseline oil) to lubricate the cork-borer. Do not test samples with cracks, holes or other visible defects.

Use a parallel-wire cutting device to cut the test sample to the required height. The wire diameter shall be less than or equal to 0,4 mm. It is essential to have a system that keeps the two wires parallel to each other and perpendicular to the plug. Preferably, use a mechanically driven cutting system. Taking these precautions into account reduces the lack in parallelism between the sample surface and the compression plate.

#### 6.2.5 Delay

A delay between the taking of a test portion and its testing allows stress relaxation of the test portion. The recommended delay is between 10 min and 15 min. The upper limit is not strictly fixed but it should not exceed 2 h. This recommendation is not relevant when sampling is done at a lower temperature than the measuring temperature.

Store the test samples at the measuring temperature (6.3.5) and see Annex B for non-standard conditions. Store samples in a pill-box or wrapped in plastic film to avoid dehydration during the delay between sampling and testing.

### 6.3 Test conditions

#### 6.3.1 Relative deformation

Perform the compression to just beyond the apparent fracture point (Figure A.5, curve 1) or to a predefined maximum deformation (Figure 5, curve 2).

#### 6.3.2 Crosshead speed

The standard value of the crosshead speed or displacement rate is 50 mm/min (or 0,83 mm/s) for initial height  $12,5 \text{ mm} \leq h_0 \leq 25 \text{ mm}$ .

#### 6.3.3 Number of compression cycles

Perform one compression cycle.

#### 6.3.4 Number of test portions

Measure at least four test portions, but preferably carry out more than this.

#### 6.3.5 Measuring temperature

Measure at the standardized measuring temperature of  $15 \text{ °C} \pm 1 \text{ °C}$ .

NOTE Although the chosen test temperature of  $15 \text{ °C}$  is a good compromise for a single temperature, the challenge remains that many studies will use other temperatures for good reasons, as outlined in Annex B.

See Annex B for non-standard conditions.

### 6.3.6 Nature of the interface between test portion and plates

Use a low viscosity mineral oil as lubricant between the test portion and the plates. Apply the oil as a very thin layer on the plates.

## 7 Analysis of the compression curves

### 7.1 Data representation and calculation

#### 7.1.1 Data representation

Raw data files contain data pairs  $(s_i, F_i)$  with displacement data,  $s_i$ , of the compression plate and force data,  $F_i$ , in units depending on the system. If the displacement of the plate is recorded right from the beginning of the test (i.e. before the plate is in contact with the sample) then compute the absolute deformation data,  $|\Delta h_i|$ , of the sample before any other calculation is performed. Let  $|s_0|$  be the absolute displacement of the plate when the force becomes significantly different from zero (indicating the start of the compression of the sample). Then calculate the absolute sample deformation data,  $|\Delta h_i|$ , using the following equation:

$$|\Delta h_i| = |s_i| - |s_0| \quad (1)$$

where

$|s_0|$  is the absolute displacement of the plate when the force becomes significantly different from zero;

$|s_i|$  is the absolute displacement of the plate.

The correct sample deformation data,  $\Delta h_i$ , is then found using the following equation:

$$\Delta h_i = -|\Delta h_i| \quad (2)$$

For further processing, it may be useful to remove data from the free precontact displacement of the compression plate.

If the measuring system automatically records the absolute deformation  $|\Delta h|$  of the sample (starting with zero as soon as the contact force becomes significant), then  $|s_i|$  is equal to  $|\Delta h_i|$  and no correction has to be applied. However, the sign assignment  $\Delta h_i = -|\Delta h_i|$  may still be necessary.

The deformation/force data  $(\Delta h, F)$  must be transformed to the normalized measures strain and stress in order to be comparable. Graphical representations, numerical values and computed parameters of compression curves are given in terms of strain and stress. Both of the following representations to evaluate the curves are recommended options. Either one or both of these options may be used:

- a) engineering stress,  $\sigma_u$ , versus Cauchy strain,  $\varepsilon_C$ ;
- b) corrected stress,  $\sigma_c$ , versus Hencky strain,  $\varepsilon_H$

Strain has no dimension; stress is given in pascals (Pa) or kilopascals (kPa).

Examples of compression curves from some cheese varieties are given in Annex C.

NOTE  $\sigma_u$  is also known as uncorrected stress;  $\varepsilon_C$  is the engineering strain or relative deformation. The terms 'true stress' and 'true strain' to denote corrected stress  $\sigma_c$ , and Hencky strain  $\varepsilon_H$ , respectively, are not recommended.

Stress correction is based on the cylindrical shape and volume constancy of the sample during the test, allowing the calculation of the cross section,  $A_t$ , at each time point.

This changing cross section,  $A_t$ , is calculated using the following equation:

$$A_t = A(\Delta h) = \frac{A_0 \cdot h_0}{h(t)} \quad (3)$$

where

$h_0$  is the initial sample height;

$A_0$  is the initial cross section;

$h(t)$  is the height at each time point is derived from  $h_0$  and the deformation  $\Delta h$ ,  $h(t) = h_0 + \Delta h$ . Under compression,  $\Delta h$  is a negative quantity ( $\Delta h \leq 0$ ) because the deformation reduces the height of the sample, thus  $h(t) = h_0 - |\Delta h|$  (see Reference [4]).

### 7.1.2 Calculation of stress and strain

The following equations assume that  $\Delta h \leq 0$ .

The transformations of force into stress and of deformation into strain are applied to all data points ( $\Delta h$ ,  $F$ ).

$$\sigma_u = \frac{F_t}{A_0} \quad (4)$$

$$\varepsilon_C = \frac{\Delta h}{h_0} \quad (5)$$

$$\sigma_c = \frac{F_t}{A_t} = \frac{F_t}{A_0} \cdot \frac{h_t}{h_0} = \frac{F_t}{A_0} \cdot (1 + \varepsilon_C) = \sigma_u \cdot (1 + \varepsilon_C) \quad (6)$$

$$\varepsilon_H = \ln\left(\frac{h_t}{h_0}\right) = \ln\left(\frac{h_0 + \Delta h}{h_0}\right) = \ln(1 + \varepsilon_C) \quad (7)$$

NOTE 1 According to Equations (5) and (6), compressive strain is a negative quantity (see Reference [4]). Although rheologically correct, it is not common practice to indicate the minus sign in graphical representations or in the computed parameters of the compression curves. The use of the sign may be useful if results from compression ( $\varepsilon < 0$ ) and tension ( $\varepsilon > 0$ ) need to be distinguished.

NOTE 2 The application of stress correction according to Equation (6) (see Reference [5]) induces a shift of the apparent fracture point towards lower absolute strain values (apart from decreasing the numerical stress values). This shift is a transformation property of the correction factor  $(1 + \varepsilon_C)$ , applied to curves with local maxima (see Reference [7]).

## 7.2 Parameters characterizing the compression curves

### 7.2.1 General

Descriptive mechanical parameters of the compression curves are evaluated from stress/strain data calculated according to Equations (4) to (7), respectively. The parameters characterize the first part of the curves and that part where fracture occurs. The apparent fracture work characterizes the curve up to the apparent fracture point.

The following four parameters are recommended to characterize the compression curves (see Annex C):

- a)  $M_D$ , which is the modulus of deformability;
- b)  $\varepsilon_f$ , which is the fracture strain (strain at the apparent fracture point);
- c)  $\sigma_f$ , which is the fracture stress (stress at the apparent fracture point);
- d)  $W_f$ , which is the fracture work (total deformation work up to the apparent fracture point, divided by the initial sample volume  $V$ ; its value is equal to the area under the stress/strain curve from zero strain to strain at apparent fracture).

### 7.2.2 Modulus of deformability

The slope of the approximately linear part at small absolute strain values is an estimate of the apparent elastic modulus, also called modulus of deformability,  $M_D$ .

A well-defined estimate of  $M_D$  is accessible by the maximum of the first derivative of the compression curve at  $|\varepsilon| < 0,1$  using Equation (8):

$$M_D = \max \left( \left| \frac{\partial \sigma}{\partial \varepsilon} \right| \right)_{|\varepsilon| < 0,1} \quad (8)$$

The calculation is applied to  $(\varepsilon_C, \sigma_u)$  and to  $(\varepsilon_H, \sigma_C)$  data.

The modulus of deformability,  $M_D$ , is given in pascals (Pa) or kilopascals (kPa).

NOTE 1 The estimation of the modulus of deformability  $M_D$ , according to Equation (8) is justified by the experimentally observed fact that there always exists a maximum of the first derivative at very low absolute strain. Although Equation (8) is recommended, other algorithms may be used to determine the modulus of deformability. The selection of a certain range  $\Delta\varepsilon$  (with  $|\varepsilon| < 0,1$ ) and the corresponding range  $\Delta\sigma$  to calculate  $M_D = |\Delta\sigma/\Delta\varepsilon|$ , or the application of linear regression over a certain number of  $(\varepsilon, \sigma)$  pairs is also possible to estimate  $M_D$ .

NOTE 2 Compression curves without characteristic features (i.e. monotonously increasing stress, no fracture point, no inflection point) may occur in very young hard and semi-hard cheeses. Though this case is outside the scope of this Technical Specification, and the compression test not well adapted to study this behaviour, the curves may be evaluated by determining several data points  $(\varepsilon, \sigma)$  at sensibly chosen strain values. The estimation of the modulus of deformability,  $M_D$ , according to Equation (8) is still possible. In fact, the maximum of the first derivative at low strain is the only feature of such curves.

### 7.2.3 Apparent fracture point

#### 7.2.3.1 General

The local maximum of the compression curve is defined as the apparent fracture point. Therefore, the fracture strain  $\varepsilon_f$  and fracture stress  $\sigma_f$  are also "apparent" quantities. Both parameters are determined from  $(\varepsilon_C, \sigma_u)$ , and from  $(\varepsilon_H, \sigma_C)$  data.

### 7.2.3.2 Determination of curve maximum

The determination of curve maximum is simple if the curve shows one local maximum that is clearly identifiable as the apparent fracture point. In that case, calculate the maximum stress value,  $\sigma_f$ , using Equation (9):

$$\sigma_f = \max(\sigma_i)_{1 \leq i \leq n} \quad (9)$$

where  $n$  is the number of data points describing the compression curve to just beyond the apparent fracture point (see 7.2.3).

Calculate the strain value,  $\varepsilon_f$ , which corresponds to the maximum stress of the curve using Equation (10):

$$\varepsilon_f = \varepsilon(\sigma_f) \quad (10)$$

### 7.2.3.3 Determination from an inflection point of the curve

If there is no maximum assignable to the apparent fracture point but only a well-established inflection point indicating fracture, the coordinates of this point are taken as an approximation of the fracture stress  $\sigma_f$  and fracture strain  $\varepsilon_f$ . The determination of this inflection point is best achieved via the second derivative of the compression curve (the first derivative of the curve shows a local maximum and the second derivative is zero at this inflection point). If it is the only inflection point of the curve, the fracture strain  $\varepsilon_f$  may be found using Equation (11), which is the strain value  $\varepsilon_i$  where the second derivative is zero:

$$\varepsilon_f = \varepsilon_i \text{ with } \frac{\partial^2 \sigma(\varepsilon_i)}{\partial \varepsilon_i^2} = 0 \quad (11)$$

Accordingly, Equation (12) holds for the fracture stress:

$$\sigma_f = \sigma(\varepsilon_f) \quad (12)$$

Fracture strain has no dimension; fracture stress is given in pascals (Pa) or kilopascals (kPa).

The determination of the fracture parameters  $\sigma_f$  and fracture strain  $\varepsilon_f$  from the local maximum of the curve according to Equations (9) and (10) is easy programmable. In the case of approximating the apparent fracture point from the coordinates of an inflection point according to Equations (11) and (12), the algorithm used to find  $\varepsilon_f$  must be such that it finds the correct value (compression curves may have several inflection points!). In practice, it may be sufficient to define the direction of the searching procedure from high to low absolute strain values. It is recommended to check the numerical values found in this way by inspecting the plots.

NOTE It is not possible to calculate  $\varepsilon_f$  (Hencky) and  $\sigma_f$  (corrected) from  $\varepsilon_f$  (Cauchy) and  $\sigma_f$  (uncorrected) by applying Equations (7) and (6), respectively [7]. All four results are correct only if the algorithms are independently applied to both data representations. The reason is the shift of the maximum mentioned in 7.1.2.

### 7.2.4 Apparent fracture work

The apparent fracture work,  $W_f$ , is defined as the total work of deformation applied during the test to the sample in the strain interval  $\{0, \varepsilon_f\}$ , divided by the initial sample volume  $V_0$ . This value is equal to the area under the stress/strain curve from zero strain to strain at apparent fracture.

Calculate the apparent fracture work,  $W_f$ , according to Equation (13), which applies to both representations but is not valid in mixed representations such as  $(\varepsilon_C, \sigma_C)$  or  $(\varepsilon_H, \sigma_U)$ .  $W_f$  is expressed in units of J/m<sup>3</sup> or kJ/m<sup>3</sup>, depending on the units of  $\sigma(\varepsilon)$  used in Equation (13) (Pa or kPa, respectively):

$$W_f = \left| \int_0^{\varepsilon_f} \sigma(\varepsilon) d\varepsilon \right| \quad (13)$$

NOTE The numerical integration can be performed using the discrete data points, replacing the integral sign by the appropriate sum over the work per volume increments  $|\Delta\varepsilon \sigma(\varepsilon)|$ . The approximation has proven to give correct results.

$$W_f = \sum_{i=1}^{i(\varepsilon_f)-1} |\varepsilon_{i+1} - \varepsilon_i| \cdot \frac{\sigma_{i+1} - \sigma_i}{2} \quad (14)$$

### 7.3 Expression of results

Express the test results for the modulus of deformability (unit: kPa) to one decimal place.

## 8 Precision

### 8.1 Interlaboratory test

Details of an interlaboratory test on the precision of the method are given in Annex D. However, this test did not fulfil the requirements of an interlaboratory test according to ISO 5725-1 and ISO 5725-2. This is the reason for changing to a Technical Specification rather than an International Standard.

The values for repeatability and reproducibility limit may not be applicable to ranges and matrices other than those given.

### 8.2 Repeatability

The absolute difference between two individual single test results, obtained with 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 in not more than 5 % of cases be greater than the following values:

|                                                                                  | a)    | b)    |
|----------------------------------------------------------------------------------|-------|-------|
| Modulus of deformability (kPa)                                                   | 324,7 | 278,7 |
| Fracture strain                                                                  | 0,04  | 0,065 |
| Fracture stress (kPa)                                                            | 50,76 | 30,85 |
| Work at fracture (kJ/m <sup>3</sup> )                                            | 13,60 | 9,52  |
| a) Engineering stress vs Cauchy strain.<br>b) Corrected stress vs Hencky strain. |       |       |

### 8.3 Reproducibility

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

|                                                                                  | a)     | b)    |
|----------------------------------------------------------------------------------|--------|-------|
| Modulus of deformability (kPa)                                                   | 343,6  | 457,9 |
| Fracture strain                                                                  | 0,36   | 0,460 |
| Fracture stress (kPa)                                                            | 135,62 | 78,88 |
| Work at fracture (kJ/m <sup>3</sup> )                                            | 32,03  | 25,27 |
| a) Engineering stress vs Cauchy strain.<br>b) Corrected stress vs Hencky strain. |        |       |

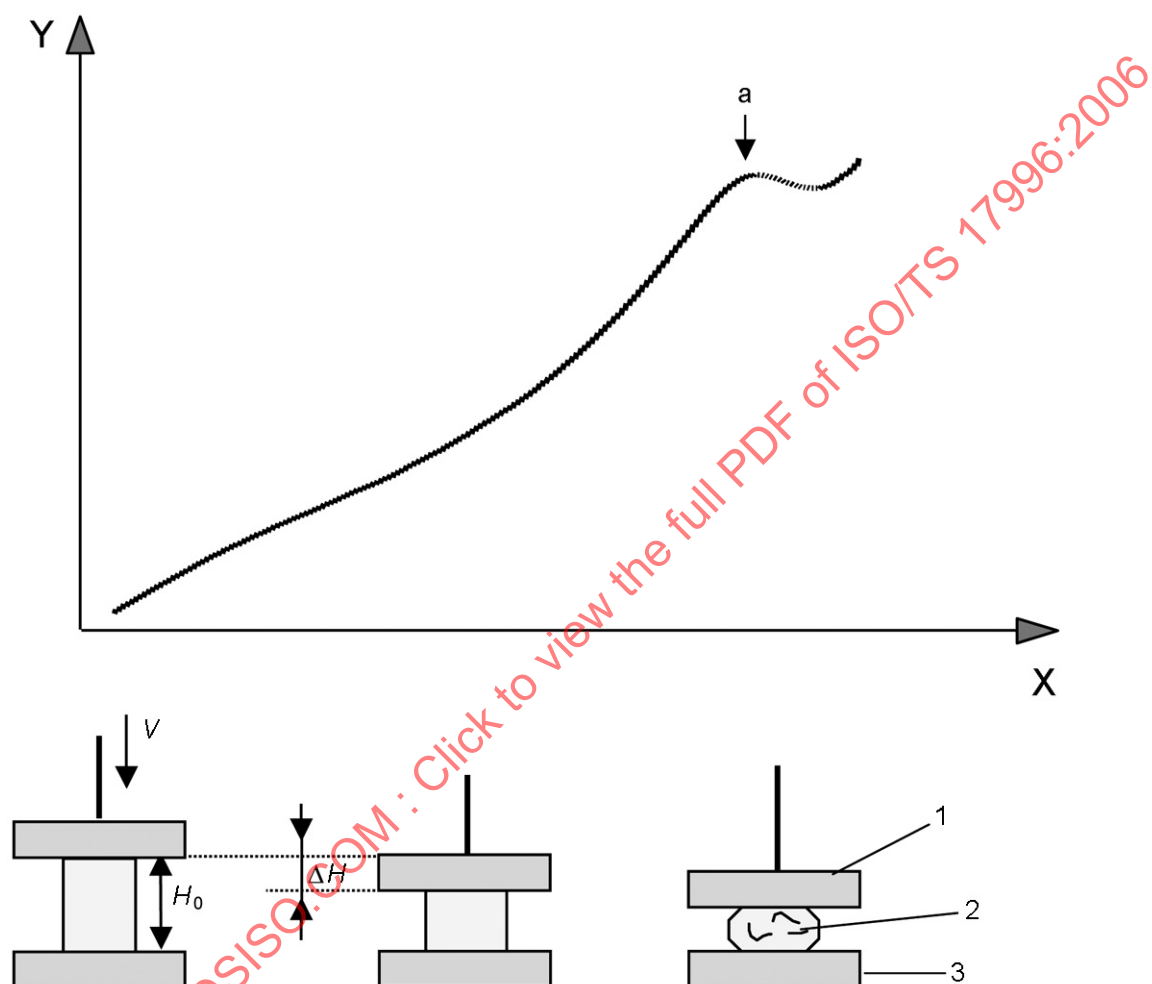
## 9 Test report

The test report shall specify:

- all information necessary for the complete identification of the sample;
- the sampling method used, if known;
- the test method used, together with reference to this Technical Specification;
- all other operating details not specified in this Technical Specification, or regarded as optional, together with details of any incidents which may have influenced the test result(s);
- the test result(s) obtained or, if the repeatability has been checked, the final quoted result obtained.

## Annex A (normative)

### Figures



#### Key

X displacement  
Y force

- 1 compression tool
- 2 sample
- 3 fixed base

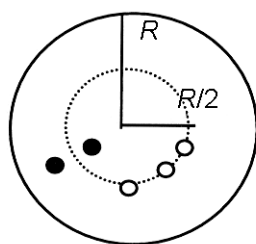
$V$  is the constant displacement rate of the compression tool

$H_0$  is the initial sample height

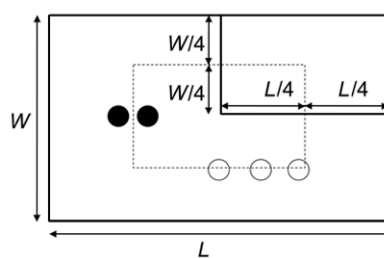
$\Delta H$  is the variation in sample height

<sup>a</sup> Apparent fracture point.

**Figure A.1 — Schematic principle of uniaxial compression at constant displacement rate**



a) Cheese with cylindrical form

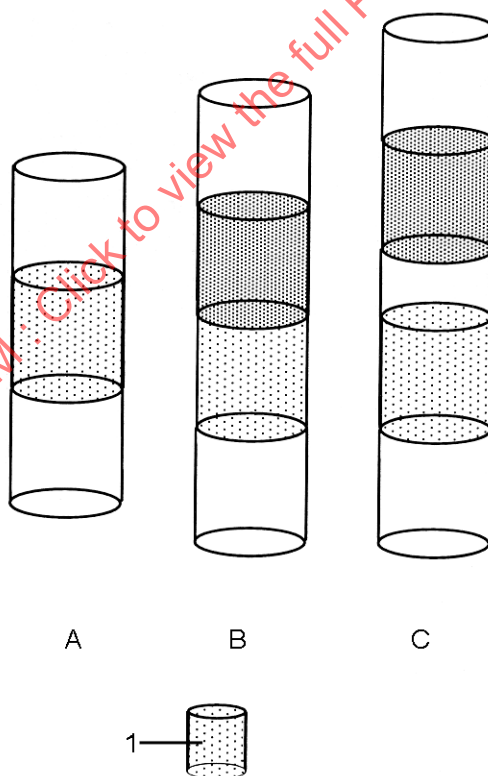


b) Cheese with parallelepipedal form

**Key**

- $R$  is the radius
- $W$  is the width
- $L$  is the length
- plug in case 1
- plug in case 2

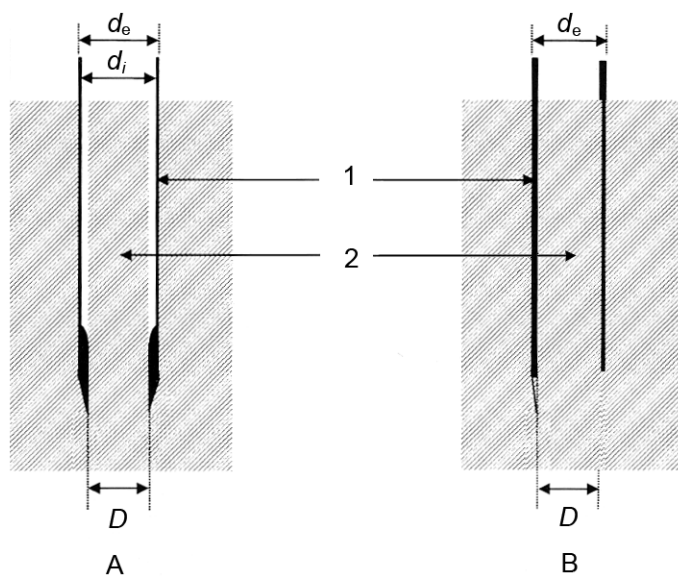
**Figure A.2 — Location of plug for cheese sampling**



**Key**

- 1 sample

**Figure A.3 — Three types of sampling in plug**



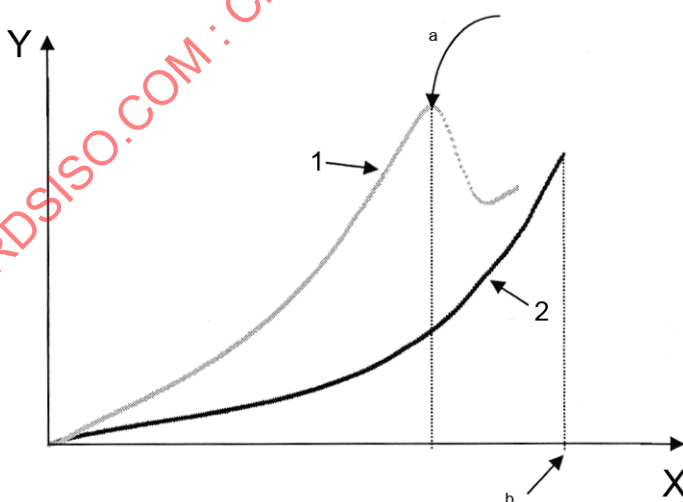
**Key**

- 1 cork borer
- 2 cheese plug

Example A:  $d_e$  is the external diameter ( $d_e = 25$  mm);  
 $d_i$  is the internal diameter ( $d_i = 23$  mm);  
 $D$  is the cutting head diameter ( $D = 20$  mm).

Example B:  $d_e$  is the external diameter ( $d_e = 16,5$  mm);  
 $D$  the cutting head diameter ( $D = d_i$  is the internal diameter of 15,3 mm).

**Figure A.4 — Cork-borers for cutting cylindrical cheese plug**



**Key**

- X deformation
- Y force
- a Apparent fracture point.
- b Maximum deformation.

- 1 curve 1
- 2 curve 2

**Figure A.5 — Examples of compression curves**

## Annex B (normative)

### Non-standard sample conditions

#### B.1 Direction of sampling

Although it is recommended to take a test portion parallel to the pressure axis, for special purposes a test portion at right angles to that may be of interest.

#### B.2 Geometry of the portion

A cylindrical form of the test portion is preferred for the following reasons:

- a) a regular shape is easiest;
- b) there is homogeneity of stress distribution;
- c) the symmetry makes mathematical calculations easier.

If  $h_0$  is at between 12,5 mm and 25 mm, a constant displacement rate of 50 mm/min means an initial strain rate between  $0,067 \text{ s}^{-1}$  and  $0,033 \text{ s}^{-1}$  (see Table B.1). If  $h_0$  is outside the range of 12,5 mm to 25 mm, adjust the displacement rate,  $v$ , so as to reach an initial strain rate equivalent to the reference value obtained with  $h_0 = 15 \text{ mm}$  and  $v = 50 \text{ mm/min}$  by using the following relation:  $v = 0,56 h_0$ .

**Table B.1 — Initial strain rate values corresponding to different initial test portion heights**

| $h_0$ (mm)                                                                                                                                                | Initial strain rate <sup>a</sup> ( $\text{s}^{-1}$ ) |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------|
| 12,5                                                                                                                                                      | 0,067                                                |
| 15                                                                                                                                                        | 0,056                                                |
| 20                                                                                                                                                        | 0,042                                                |
| 25                                                                                                                                                        | 0,033                                                |
| <sup>a</sup> Initial Cauchy strain rate ( $\dot{\epsilon}_C = v/h_0$ ) and Hencky strain rate [ $\dot{\epsilon}_H = v/(h_0 - vt)$ ] at $t = 0$ are equal. |                                                      |

#### B.3 Testing temperature

It is difficult to fix one measuring temperature for several reasons. Often the lack of a temperature controlled room or system limits the choice in practice. When rheological measurements are performed to study changes during maturation, the temperature of the maturing rooms depends on the cheese variety, and may change during ripening. In that case, the maturing temperature preferably determines the choice of the measuring temperature. In other cases, rheological measurements are performed to study relationships with sensory analysis, and then a measuring temperature close to the temperature of the products during sensory tests is preferred. Experiences in sensory tests have shown that a temperature of  $15 \text{ }^{\circ}\text{C}$  to  $16 \text{ }^{\circ}\text{C}$  is quite appropriate<sup>[6]</sup>. Consequently, the optimal measuring temperature strongly depends on the aim of the studies.

#### B.4 Load cell

When these results need to be reported, it is recommended to add explicitly the following to the test report (see Clause 9):

- a) the lowest measurable force;
- b) the resolution of the load cell, i.e. the smallest difference of force that can be measured significantly.

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