International Standard 2169

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION•МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ•ORGANISATION INTERNATIONALE DE NORMALISATION

Fruits and vegetables — Physical conditions in cold stores — Definitions and measurement

Fruits et légumes — Conditions physiques des locaux de réfrigération — Définitions et mesurage

Second edition — 1981-10-01

UDC 634/635 : 664.8.037.1 **Ref. No. ISO 2169-1981 (E)**

Descriptors : agricultural products, fruits, vegetables, food storage, cold storage, temperature measurement, humidity, air conditioning.

ISO 2169-1981 (E)

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards institutes (ISO member bodies). The work of developing International Standards is carried out through ISO technical committees. Every member body interested in a subject for which a technical committee has been set up 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.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 2169 was developed by Technical Committee ISO/TC 34, *Agricultural food products*.

This second edition was submitted directly to the ISO Council, in accordance with clause 5.10.1 of part 1 of the Directives for the technical work of ISO. It cancels and replaces the first edition (i.e. ISO 2169-1974), which had been approved by the member bodies of the following countries :

Australia	India	Romania
Austria	Iran	South Africa, Rep. of
Belgium	Israel	Thailand
Czechoslovakia	Netherlands	Turkey
Egypt, Arab Rep. of	New Zealand	USSR
France	Poland	
Hungary	Portugal	

The member body of the following country had expressed disapproval of the document on technical grounds :

United Kingdom

Printed in Switzerland

Fruits and vegetables — Physical conditions in cold stores — Definitions and measurement

0 Introduction

The International Standards which have been prepared, or which are in the course of preparation, concerning conditions which allow fruits and vegetables to be kept well in cold storage, make reference to the optimum values of physical factors which are used in industrial practice : temperature, relative humidity, air-circulation ratio, rate of air change.

Storage practice has shown that the definitions of these physical factors need either to be made clear or to be repeated in order to avoid frequent confusion (for example, between the temperature applied to the produce and that of the atmosphere in the store, or between the air-circulation ratio and the rate of air change).

This International Standard draws attention to valid methods of measuring the physical factors concerned and renders it unnecessary to repeat systematically the definitions of these factors in each International Standard, which would have the effect of enlarging considerably each text intended for the users of International Standards on the storage of produce of plant origin.

Finally, it has appeared essential to inform users about the difficulties which arise in measuring certain physical factors.

The International Standards concerning the cold storage of fruits and vegetables, which have inspired this document, are intended for cold-storage users. To facilitate their task, it has sometimes been found necessary to adopt in this text definitions which, without being absolutely scientifically rigorous, provide values which are sufficiently accurate and easy to use.

1 Scope and field of application

This International Standard gives definitions of the physical factors usually employed in the industrial cold storage of fruits and vegetables (temperature, relative humidity, air-circulation ratio, rate of air change, etc.), and provides useful information concerning their measurement.

2 Temperature

2.1 Temperatures to be considered

2.1.1 Temperatures applied to the produce

For the cold storage of a produce of plant origin, several temperatures or ranges of temperature have to be considered :

a) **lethal temperature** : That temperature of refrigeration which causes physiological freezing of a produce with the death of the tissues.

b) **critical temperature** : In general, the temperature below which, for a given storage period and for certain kinds of fruits and vegetables, there result physical disorders, such as internal browning (with or without modification of the atmosphere), changes in the texture of the tissues (banana, cucumber, avocados, lemons, etc.).

In some particular cases, it is the temperature below which it is impossible to obtain normal ripening after storage.

c) **optimum long-term keeping temperature** : The temperature of the produce which enables satisfactory conservation and long-term storage to be achieved in a normal or controlled atmosphere until consumption.

The danger of damage at a given temperature depends upon the duration of its application.

In the case of short-term storage, it may be possible to keep certain produce at the critical temperature or at a temperature below this without causing physiological disorders.

For long-term keeping, the temperature of the produce should always be above the lethal temperature and, whenever necessary, above the critical temperature.

However, for certain fruits, such as Williams pears, the critical temperature concerning ripening may be above the optimum refrigeration temperature.

In industrial storage practice, it is necessary to maintain a sufficient safety margin to allow for unavoidable fluctuations in the temperature of the atmosphere provided by the refrigeration plant and its performance.

The consequences of these considerations are that the optimum keeping temperature for a produce for a long storage period will be

— **either the lethal temperature plus the safety margin;**

— **or the critical temperature plus the safety margin.**

2.1.2 Temperatures of the atmosphere in the cold store

a) **temperature at a point** : The temperature of the atmosphere measured at a well-defined point in the cold store.

b) **practical mean temperature** : The different temperatures of the atmosphere in a cold store fall between upper and lower limits. The practical mean temperature of the atmosphere in the cold store, in a period of temperature equilibrium, is the arithmetic mean of the maximum and minimum temperatures.

In the case of long-term storage, the actual temperature of the produce depends on that of the surrounding atmosphere, the nature of the produce, packing, the loading of the cold store and the rate of air circulation in the cold store.

2.2 Cold points and hot points in a cold store

2.2.1 cold points : Points where the temperature of the atmosphere is at a minimum.

NOTE — In a store provided with fans, the cold points are most often near the cooler, in the zone where the air leaves the cooler.

2.2.2 hot points : Points where the temperature of the atmosphere is at a maximum.

NOTE — The hot points are not always accessible and their measurement is often difficult.

2.3 Choice of atmospheric temperature in the cold store

It is recommended that, at the cold points of the cold store, the atmospheric temperature should be equal to or slightly above the optimum long-term keeping temperature of the product, as defined in 2.1.1 c).

2.4 Measurement of temperature

Temperatures may be measured continuously or intermittently.

2.4.1 Continuous measurement

Continuous measurement of the temperature may be effected either by direct reading or by recording.

2.4.2 Intermittent measurement

Intermittent measurements relate

— either to periodic check measurements when recording instruments are not available;

— or to supplementary measurements.

2.4.3 Instruments for temperature measurement

The instruments used at present are as follows :

— liquid dilatation thermometers;

— bimetal thermometers;

— vapour pressure thermometers;

— resistance thermometers;

— thermistors;

— thermocouples.

These devices are used for

— direct reading;

— remote reading;

— recording;

— control.

2.4.4 Verification of thermometers

The verification of thermometers, which should be carried out at least once a year, is an essential and delicate operation requiring great care. The verification should be carried out periodically within the temperature range and conditions of use. It should be done during a period when the operation of the refrigeration plant is stable, in order to eliminate as far as possible any errors which may arise from the difference in inertia between the thermometers being compared. The inertia of the sensitive elements of the thermometers is less in moving air than in still air or in slowly circulating air. It is recommended that thermometers be verified in moving air.

In industrial storage practice, verification can be carried out with mercury thermometers in annealed glass, provided with a certificate from an approved organization.

It is recommended that the reference mercury thermometer be placed in a fixed position, at the cold point of a ventilation circuit, behind glass and near to the temperature-sensing element of a distant-reading thermometer. The thermometer is read through the glass, the thermometer being illuminated; this facilitates verification.

In every case, it is desirable to protect the bulb of the reference thermometer from any external thermal radiation (human body, source of illumination, etc.). It is recommended that reference be made to methods of checking temperature.

2.4.5 Measurement points

2.4.5.1 Choice of points

The measuring instruments should preferably be placed where they will be shielded from condensation, abnormal air movements, radiation, vibration, and possibly shocks. The number of points depends on the volume of the enclosure.

The sensitive elements of the thermometers (sensors) should be placed, as far as possible, at representative points in the cold store (cold points and hot points when this is possible).

2.4.5.2 Definition of measurement

Each measurement should be defined by the nature of the temperature measured (for example, temperature of the produce concerned, temperature of the atmosphere) and by an indication of the place of measurement.

3 Relative humidity

3.1 General

The measurement of relative humidity is especially delicate and the accuracy is less than that obtainable with temperature measurements.

The relative humidity of the atmosphere in the cold store depends on many factors, among which may be cited :

— the nature of the produce and the packages;

— the loading of the cold store;

— the surface area and the structure of the evaporators, and the surface area and arrangement of the fins;

— the difference between the evaporator surface temperature and the practical mean temperature of the atmosphere;

— the insulation of the cold store;

— the ventilation system (rate of air circulation, means of distribution of the air in the cold store, air changes, etc.);

— the change in the number of working-hours of the machinery.

As a consequence the relative humidity can vary throughout the period of operation.

NOTE — In order to obtain the high relative humidity (80 to 90 %) recommended for cold storage, it is necessary to have available evaporators with a large heat-exchange surface and to ensure that the difference between the temperature of the refrigerant fluid and that of the atmosphere of the cold store is as small as possible, taking losses from heat transmission into account.

In practice a difference of the order of 5 °C between the mean temperature of the store and that of the refrigerant fluid can be accepted. Thus, for a cold store controlled between 0 and + 2 °C and suitably insulated, the evaporation temperature of the fluid should be of the order of − 5 °C to − 3 °C. In the case of produce requiring lower relative humidities (70 to 75 %), the difference in temperature between the refrigerant fluid and the atmosphere in the cold store may be greater (up to 8 °C).

3.2 Principles of measurement

In the long-term keeping of fruits and vegetables, the aim is to obtain a relative humidity which is as constant as possible. The relative humidity depends on the constancy of the temperature in the store.

To obtain a practically stable relative humidity requires a certain period of time, and measurements should be carried out only during a period of approximate equilibrium.

The state of equilibrium in relative humidity in a cold store may be influenced by

— the loading of the store (which may vary considerably, especially at the beginning and end of storage);

— the variations in intensity of transpiration of fruit (this is greater for produce in course of being cooled);

— the dryness of the packages, which may be made of hygroscopic materials (wood, cardboard, etc.) able to absorb or desorb water at a comparatively rapid rate. If packages which are too dry are put into the store, they will tend to absorb a large percentage of their mass of water, to the detriment of the relative humidity of the store. If the packages are too damp, the opposite effect will occur.

In consequence, it is necessary to try to determine at what time the state of comparative equilibrium is established, as indicated by limited variations in relative humidity, and it would be desirable to begin measurements of relative humidity as soon as the store has been loaded, so as to show the period of stabilization which is characterized by variations of small amplitude. It is recommended that any corrections to the relative humidity be made only after the stable period has been reached.

3.3 Instruments

3.3.1 Hair hygrometers

These instruments are of low precision, low sensitivity and low accuracy, especially in the region of high relative humidities (80 to 90 %), but they are easy to use.

It is recommended that they be standardized regularly (once per month for example) with a psychrometer (standard instrument or whirling psychrometer).

The standardization of hygrometers against a psychrometer under the usual conditions of cold storage of produce of plant

origin is difficult and not very accurate because the difference in temperatures between the dry bulb and wet bulb thermometers is small (for example, 1 °C with a relative humidity of 85 % and dry bulb temperature of + 1 °C).

In order to obtain favourable conditions for the measurement of relative humidity, the following precautions are recommended :

— leave the psychrometer and its accessories at the site of measurement for a sufficient period (2 h before taking the measurement for example);

— wet the sleeve of the wet-bulb thermometer with demineralized water;

— read the temperature of the thermometers and of a psychrometer when a constant difference between the dry-bulb and wet-bulb temperatures has been reached;

— preferably make several measurements at the same place;

— avoid making measurements at the moment when the fans of the refrigerating plant stop or start, if they do not operate continuously.

If a standard psychrometer or a whirling psychrometer is not available, a hair hygrometer can be placed in a saturated atmosphere for at least 48 h and the needle on the scale or the recorder brought to 100 %. This practice, however, has the disadvantage of giving only one check point.

If the relative humidity is high, it is recommended that an aspiration psychrometer or a whirling psychrometer be used.

3.3.2 Electrical hygrometers

Electrical probe hygrometers allow measurements to be made at a distance and allow the determination of relative humidity of the microclimates which occur in piles of packages, provided that in every case the temperature of the atmosphere at the point of measurement is accurately measured. Such apparatus is accurate for relative humidities not exceeding 95 %.

The principle of operation of these hygrometers is based on the relationship between the concentration of a sodium chloride solution (measured by electrical conductivity) and the relative humidity of the atmosphere in equilibrium with it.

3.3.3 Psychrometers

Aspiration psychrometers or whirling psychrometers are especially recommended if the relative humidity is high.

4 Air circulation

A distinction should be made between the circulation of the atmosphere which takes place in a closed circuit and the air change which consists in introducing outside air into a cold store.

4.1 Circulation of the atmosphere

4.1.1 Purpose

The circulation of the atmosphere is intended :

— to initiate the cooling of the produce on entry into the cold store;

— to make uniform the temperature of the produce and to a certain extent the relative humidity in the store;

— to draw from the packages the gases and volatile compounds produced by metabolism of the stored produce.

4.1.2 Air-circulation ratio

The **air-circulation ratio** is defined as the ratio of the volume of air passed in 1 h by the fans, to the volume of the empty chamber. It varies according to the period of refrigeration of the produce or the period during which the temperature is maintained.

4.2 Air change

4.2.1 Purpose

Plant organs, especially fruits, emit respiratory carbon dioxide, ethylene (which accelerates the ripening of certain fruits at temperatures of + 3 °C and above and the effect of which becomes noticeable at temperatures of + 7 °C and above), and volatile substances.

In order to avoid the harmful accumulation of these substances, it is necessary to change the atmosphere of the cold store, particularly during the first days of the cooling period, in the course of which the produce has a high metabolic activity, and also in the case of ripening fruits during the final weeks of storage since they emit large quantities of volatile substances when they have reached full maturity.

4.2.2 Rate of air change

The **rate of air change** is the ratio of the volume of outside air introduced into the cold store in 1 h, to the volume of the empty closure. The air change can be effected continuously or intermittently, the latter case being defined by the rate and frequency of change, which depend on the loading of the refrigerated enclosure and the species and varieties of the fruits and vegetables.

The choice of conditions of air change will depend, for certain fruits, on their degree or ripeness.

4.3 Measurement of air circulation

4.3.1 Principles of measurement of the flow and circulation of air

Whether circulation or change of air is in question, two factors have been to be considered :

— the flow of air introduced (rate of air change) or circulated (air-circulation ratio) in a given time;

— the uniformity of the distribution of the fresh air or of the circulated air.[1)]

The measurement of the air-circulation ratio should be carried out whenever possible at the exit from, or the inlet to, the coolers.

The measurement of the rate of air change should preferably be carried out at the point where air is introduced into the store.

The measurement of the distribution of air in a cold store is difficult and is not included in current cold storage practice. It can be carried out only within the framework of well-defined experimental tests.

The object of achieving good ventilation is to eliminate irregularities in the air circulation and to obtain the best possible contact between the air and the packages.

4.3.2 Measuring instruments

The measurement of air speed is carried out

— either with directional instruments measuring the dynamic pressure of the air for speeds above 2 m/s (Pitot tubes, Prandtl probes, cup-type anemometers, etc.);

— or with non-directional instruments for speeds below 2 m/s (for example, hot-wire anemometers).

Measurements of air speeds are delicate and it is recommended that reference be made to specialized documents in this field.

1) It may be necessary to take account of the effect of recirculation.

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