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Apples — Storage in controlled atmospheres

Pommes — Entreposage en atmosphère contrôlée

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Foreword

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International Standard ISO 8682 was prepared by Technical Committee ISO/TC 34, *Agricultural food products.*

Users should note that all International Standards undergo revision from time to time and that any reference made herein to any other International Standard implies its latest edition, unless otherwise stated.

Apples — Storage in controlled atmospheres

0 Introduction

Storage in a controlled atmosphere is based on the regulation of three factors: temperature, relative humidity and the chemical composition of the atmosphere in the store.

By using this method of storage, metabolic processes in the fruits are reduced in intensity and ripening is slowed down, while the nutritive value and appearance for sale are maintained; thus the keeping period is prolonged. As a result of the reduction in oxygen content and increase in carbon dioxide content, the development of pathogenic micro-organisms and the appearance of physiological diseases are greatly retarded.

1 Scope and field of application

This International Standard gives general guidance for the storage of apples in controlled atmospheres.

Because of numerous factors influencing the quality and keeping characteristics of apples, the optimal conditions of storage in controlled atmospheres differ according to the variety and area of production.

2 References

ISO 2169, *Fruits and vegetables — Physical conditions in cold stores — Definitions and measurement.*

ISO 3659, *Fruits and vegetables — Ripening after cold storage.*

ISO 6949, *Fruits and vegetables — Principles and techniques of the controlled atmosphere method of storage.*

3 Conditions of harvesting and putting into store

3.1 Varieties

For storage in controlled atmospheres over long periods, it is preferable to store apples (notably winter varieties) having good keeping characteristics.

3.2 Harvesting

Harvesting of apples intended for storage in controlled atmospheres is carried out when their degree of ripening ensures good keeping characteristics. The principal criteria used to determine, for a given variety, the time of harvesting are as follows:

a) the shade of colour of the seed;

b) the presence of starch in the transverse section of the apple (iodine test or potassium iodide test);

c) the structural firmness and texture of the flesh;

d) the number of days between flowering and harvesting;

e) the ground colour (green-yellow) of the skin;

f) the onset of increase in ethylene production.

Harvesting of apples intended for storage in a controlled atmosphere should only be carried out manually.

At the same time as harvesting, presorting should be carried out to separate the fruits not suitable for storage, particularly those attacked by disease (notably bitter pit) or insects, those showing traces of rot, those damaged or having shape and growth defects.

Apples should be handled and transported to the store in bins or boxes.

3.3 Qualitative characteristics of storage

Apples intended for storage in a controlled atmosphere should correspond to quality "I" or "extra" specified in quality standards.

Apples showing the following characteristics are not suitable for storage over long periods in controlled atmospheres:

a) apples having poor keeping characteristics;

b) oversized apples;

c) apples harvested overripe or underripe;

d) apples which have remained for long periods at ambient temperature after harvesting;

e) apples taken from orchards which have been fertilized or irrigated 2 or 3 weeks before harvesting.

3.4 Putting into store

3.4.1 Chambers

The chambers intended for storage of apples in controlled atmospheres are cells which can accommodate approximately 50 t to 300 t (volume 1 200 to 1 500 m^3) of apples. These are provided with insulation against escape of the atmosphere, with doors forming hermetic seals and with apparatus for regulating the composition of the atmosphere within the cell.

The chambers should be prepared before starting the storage operation (cleaning, disinfection, extermination of rats, checking of the tightness to gas exchange, checking of the correct functioning of the refrigeration system, etc.).

After harvesting, apples should be put into the refrigerated cells within 24 h.

In general, do not store more than one variety of apple in a cell. However, if two or more varieties have the same keeping characteristics and the same degree of ripeness, they may be stored together.

3.4.2 Arrangement within the cells

The stacking of the packages should ensure good circulation of the atmosphere. The height of the stacks should not exceed about 6 m for boxes and about 7,5 m for bins. Depending on the dimensions of the cooling unit, a space of about 0,5 to 1 m should be left above the stacks.

Orientate the pallets in a system which allows good penetration of the atmosphere circulating in the cell.

Along the wall opposite to that where the refrigeration equipment is installed, leave a space clear so that the atmosphere distributed by the fan can descend to floor level.

In the main direction of flow of the atmosphere, leave a space of about 10 cm between stacks to permit circulation. The orientation of the pallets and bins should allow them to be opened in the direction of atmospheric flow.

The stacking of the packages gives an average loading of 200 to 300 kg/m^3, which corresponds to about 1,6 t/m^2.

3.5 Precooling

Before storage, cells should be refrigerated to 0°C. Cells should be filled up within 4 days. Then reduce the temperature to that indicated for storage and close the doors tightly.

4 Optimal storage conditions

(see ISO 2169 and ISO 6949)

4.1 Temperature

The optimal storage temperature (see annex A) should be attained within 1 week after the cells have been filled and should be maintained throughout the storage period.

During the storage period ensure that the cell temperature does not vary by more than ±1 °C.

4.2 Relative humidity

The relative humidity of the atmosphere in controlled atmosphere cells should be between 90 % and 95 %. To attain these high values, the difference between the temperature of the evaporator and that of the atmosphere in the chamber should be as small as possible (2 to 4 °C).

4.3 Atmosphere circulation

4.3.1 Rate of flow

The velocity of storage atmosphere circulation between the stacks should be at least 0,25 m/s.

4.3.2 Rate of atmosphere circulation

The rate of circulation should be equal to 40 times the volume of the empty store per hour during cooling and 20 times the volume of the empty store per hour when the fruits have cooled down.

4.4 Chemical composition of the atmosphere

Regulation of the composition of the atmosphere in the storage chambers should be carried out immediately after the optimal storage temperature is attained. By using installations for maintaining controlled atmospheres (oxygen converter, scrubber for absorption of carbon dioxide), this regulation may be realized in 2 to 3 days.

The chemical composition of the atmosphere in the chambers should be kept between the optimal limits for the variety stored.

The carbon dioxide and oxygen content in the chambers should be maintained constant during the keeping period, or the proportions of these two components should be modified according to the physiological state of the apples (dynamically controlled atmosphere).

4.5 Checking

The keeping conditions (temperature, relative humidity and atmosphere composition) should be checked daily, using either a direct reading or recording instrument.

Periodic checks of the quality of the product should be carried out, the frequency increasing to once per week towards the end of the storage period. (The samples for quality control are obtained through the control window of the door.) Analyse the deterioration in quality of the apples (see annex B) and from that determine the storage life.

4.6 Storage life

The storage life depends on the period for which the apples maintain their eating quality and on their degree of ripeness to allow handling and transportation in good condition (see annex A).

5 Operations at the end of storage

Before taking apples out of store, open the doors and leave the fans operating for 1 to 2 h. Excess carbon dioxide is thus dispersed, making it safe for workers to enter without a protective mask.

To avoid condensation, increase the temperature in the chamber to that recommended for storage in air.

If it has not been done before storage, grade the apples by category, variety, size and quality, in accordance with the relevant quality standards.

For ripening after cold storage, see ISO 3659.

6 Bibliography

[1] RYALL and LIPTON. *Handling, transportation and storage of fruits and vegetables, Volume 1: Vegetables and melons.* De Avi Publishing Company, Westport, Connecticut, 1972.

[2] RYALL and PENTZER. *Handling, transportation and storage of fruits and vegetables, Volume 2: Fruits and tree nuts.* De Avi Publishing Company, Westport, Connecticut, 1974.

[3] SMOCK, Robert M. Nomenclature of internal storage disorders of apples. *Hort. Sci.*, August 1977 (Vol. 12, No. 4).

Annex A

Optimal conditions for storage in controlled atmospheres and storage life for the principal apple varieties

(This annex does not form an integral part of the standard.)

Table 1

Variety	Temperature	Relative humidity	Carbon dioxide content in the atmosphere in the chamber	Oxygen content in the atmosphere in the chamber	Storage life (estimated)
	°C	%	% (m/m)	% (m/m)	days
Belle de Boskoop	3 to 4	92 to 95	0 to 3	2 to 4	180 to 240
Reinette du Canada	4	90 to 92	3	3	180 to 240
Cox's Orange	3 to 4	92 to 95	1 to 4	1,5 to 3	120 to 150
Golden Delicious	0 to 2	90 to 95	1 to 4	1,5 to 3	210
Granny Smith	0 to 4	90 to 95	2 to 5	2 to 3	180 to 240
Richared	0 to 4	90 to 93	2 to 5	2 to 3	180 to 240
Jonathan	0 to 4	90 to 95	1 to 4	1,5 to 3	180 to 240
McIntosh	2 to 4	90 to 95	1 to 4	1,5 to 3	150 to 210
Morgenduft (Imperatore)	0 to 2	90 to 95	2 to 3	2 to 3	180
Mutsu	0 to 2	90 to 95	3 to 5	3	210
Delicious	0 to 1	90 to 95	1 to 4	1,5 to 3	210
Stayman Winesap	0 to 1	90 to 95	2 to 5	2 to 3	—
Spartan	0 to 2	90 to 95	2 to 3	2 to 3	180 to 210
Gravenstein	2 to 4	90 to 95	3 to 5	2 to 3	150
Cortland	0 to 3	90 to 95	3 to 5	2 to 3	180 to 210

NOTE — The optimal conditions for storage may vary according to local cultivars.

Annex B

Defects arising during storage

(This annex does not form an integral part of the standard.)

B.0 Introduction

During the period of storage in a controlled atmosphere the quality of apples may be affected by the development of microbial and physiological defects.

B.1 Microbial damage

Diseases are caused by various micro-organisms such as *Penicillinum expansum*, *Botrytis* sp., *Gloesporium* sp., and *Monilinia fructigena*.

The principal measures to be taken to prevent their appearance and development are

a) systematic removal of sources of contamination in the orchard (cankers, rotten fruit, etc.);

b) care in all handling operations;

c) sorting of sound from unsound fruit immediately before putting the fruit into the controlled storage atmosphere;

d) previous disinfection of the chamber by spraying the walls with a solution containing 0,3 % (m/m) active chlorine and by calcination with sulfur at a concentration of 2,5 g/m^3;

e) frequent disinfection of sorting rooms;

f) maintenance of the specific conditions for each variety of apple.

B.2 Physiological damage

The main physiological disorders of apples which may occur during storage in a controlled atmosphere are given in table 2.

Table 2

Designation and description of the disorder	Horticultural factors (ecology, date of harvesting) and factors relating to conditions in cold store provoking or revealing the disorder	Remedies, preventive measures	Susceptible varieties
Freezing injuries Glassy appearance of the flesh and epidermis, general softening	— Lowering of temperature below the freezing point (−2,6 to −3 °C)	— Prevent the lowering of temperature	All
Carbon dioxide injury Brown, depressed, roughened spots with well-defined margins, often on the greenish areas of the skin; browning of the flesh particularly at the core	— Excess carbon dioxide in the controlled atmosphere	— Maintain the carbon dioxide and oxygen concentration within optimal limits	All
Low temperature breakdown The flesh acquires a brown colour, and finally the skin becomes brown	— Excess of nitrogenous fertilizer — Large fruit and fruit from crops in which the apples are small and few in number — Long duration of storage at critical temperature (apples at 0 °C instead of +4 °C)	— Raise the storage temperature to +3 °C for susceptible varieties	— Belle de Boskoop — Jonathan — Canada Reinette — McIntosh — Cox's Orange
Internal browning due to ageing (overripening) The flesh becomes brown, more or less dark; it is dry and mealy	— Late harvest — Delay in placing in the cold store — Large fruit and fruit from crops in which the apples are small and few in number — Appearance of water core at the time of harvesting — Too long a duration of storage	— Determine the optimum degree of ripening — Storage should not be continued when the risks of internal browning are considerable — Put sooner into store	All
Scald Browning of the skin, in bad cases over the whole surface	— Premature harvesting — Large fruit — Insufficient renewal of the atmosphere	— Harvest at the optimum degree of ripening — Thorough and frequent changing of the atmosphere in the cold store	— Delicious — Belle de Boskoop — Starkrimson — Grimes Golden — Cortland — most cultivars to some extent
Bitter pit Small depressed areas of irregular shape on the skin with dark green to brownish discolouration penetrating into the flesh, sometimes purple on the blushed sectors of the fruit	— Mineral (particularly calcium) imbalance in the soil and the tree — Large fruit and fruit from lightly loaded trees — Premature harvesting	— Spraying of orchard with calcium nitrate or calcium chloride (red varieties). First treatment: 2 weeks after fall of petals [0,5 % (*m*/*m*) solution], then every fortnight	— Canada Reinette — Belle de Boskoop — Delicious
Russeting Small brown spots below the skin. Small brown spots may occur anywhere in the flesh and in the core zone. When the deficiency is acute the shape of the fruit is markedly distorted	— Lack of boron	— Application of borax to the orchard (30 kg/ha) or spraying with sodium pentaborate [0,02 % (*m*/*m*) solution] in the preflowering stage and at the setting of young fruit	— McIntosh
Water core Translucent appearance of the flesh, starting at medium depth, continues towards the periphery and then towards the core	— Hot period accompanied by heavy rains or irrigation	— Suspend the cold storage — Do not continue storage too long	— Delicious
Soft scald Light chestnut coloured in isolated depressed spots sometimes forming a nearly continuous band round the fruit	— Excess of nitrogen — Influence of cold and damp weather — Delay in placing in the cold store — Keeping at too low a temperature	— Use a higher storage temperature	— Delicious — Jonathan
Jonathan spot Small superficial spots, in an advanced stage over the whole surface	— Calcium imbalance — Late harvest — Too high a storage temperature	— Harvest at the optimum degree of ripening	— Idared — Jonathan — Northern Spy

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