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**INTERNATIONAL STANDARD**



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## **Green bananas — Ripening conditions**

*Bananes vertes — Conditions de maturation*

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## FOREWORD

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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 3959 was developed by Technical Committee ISO/TC 34, *Agricultural food products*, and was circulated to the member bodies in September 1975.

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It has been approved by the member bodies of the following countries :

Australia	Iran	Romania
Austria	Israel	South Africa, Rep. of
Bulgaria	Mexico	Spain
France	Netherlands	Turkey
Ghana	New Zealand	Yugoslavia
Hungary	Poland	
India	Portugal	

No member body expressed disapproval of the document.

# Green bananas – Ripening conditions

## 0 INTRODUCTION

Bananas continue to develop physiologically after they have been harvested, and their state of ripeness when they are placed in the ripening room will depend on their state when harvested and on different conditions to which they have subsequently been submitted.

The ripening of the bananas consists of a preliminary heating and a supplementary heating, followed by the actual ripening, in the course of which two phases may be distinguished :

- a first phase characterized mainly by an extensive release of heat, without change in the colour of the skin but in connection with intense physiological activity;
- a second phase characterized mainly by a decrease in the release of heat, associated with continuation of hydrolysis of the starch with the formation of reducing sugars and sucrose, by a rapid change in the colour of the skin and by the development of the odour.

## 1 SCOPE AND FIELD OF APPLICATION

This International Standard lays down conditions to be observed in order to obtain satisfactory ripening of green bananas following possible storage and transport in accordance with ISO/R 931.

It applies to green bananas from cultivars which form the subject of international trade, of which the following indicating though not limiting list may be given :

- Gros Michel
- Lacatan
- Poyo-Robusta
- Valery
- Grande Naine (Giant Cavendish)
- Petite Naine (Dwarf Cavendish)

## 2 REFERENCE

ISO/R 931, *Green bananas – Guide to storage and transport.*

## 3 FACTORS INFLUENCING THE DEGREE OF RIPE-NESS OF THE BANANAS WHEN THEY ARE PLACED IN THE RIPENING ROOM

### 3.1 State of bananas when harvested

The assessment of the degree of ripeness of the bananas when harvested is based on the fullness of a given fruit on the bunch. It is a dimensional criterion which corresponds appreciably to the degree of ripeness when the fruit is normal.

Unfavourable ecological conditions may produce the following effects :

- to predispose the bananas to a more rapid development of the flesh than expected;
- possibly, to favour the development of fungal deterioration of the skin, and in particular of the stalks and the ends of the cushions.

### 3.2 Conditions to which the bananas are submitted from the time they are harvested to the time they are placed in the ripening room

After harvesting, the development of the banana is influenced by certain external or physiological factors, such as the following.

#### 3.2.1 External factors :

- the time period between harvesting and the beginning of cooling as well as the temperature to which they are submitted during this period;
- the duration of cooling;
- the temperature and relative humidity during transport and up to the time they are placed in the ripening room;
- incorrect handling, particularly when this results in bending of the stalks.

### 3.2.2 Physiological factors :

- the reaction to certain antifungal treatments or to certain injuries;
- the heterogeneity of the degree of development of the fruit within the same package.

## 4 PLACING OF THE BANANAS IN THE RIPENING ROOM

### 4.1 Hands or parts of hands (clusters) of bananas

Hands of bananas or parts of hands of bananas (clusters) should be despatched, with or without a polyethylene<sup>1)</sup> covering, in corrugated fibreboard cases, with or without perforations, containing between 10 and 18 kg of fruit.

The cases of bananas are generally stacked on pallets. In general, they should not be superimposed more than eight rows high on one or two pallets.

It is recommended that a narrow corridor (for example from 10 to 20 cm) be left between the rows of pallets in the direction of circulation of the air.

NOTE — It is possible to use a more elaborate technique involving placing the pallets hard against each other, using a cover over the stack, an extractor-type fan, and perforated fibreboard cases.

### 4.2 Bunches of bananas<sup>2)</sup>

When placed in the ripening room :

- bunches of bananas with straw-paper packaging should be unpacked, inspected and trimmed if necessary;
- bunches with polyethylene covering may be unpacked or left in their packaging.

Bunches hung with the large end of the stem downwards should not be placed in the same ripening room as hands or parts of hands packed in fibreboard cases (see 4.1), since their ripening conditions are different; gas exchange and heat exchange are more difficult, and it is necessary to provide ventilation of greater efficiency for the ripening room.

### 4.3 Density of loading

The recommended density of loading is from 150 to 200 kg of bananas per cubic metre of the volume of the ripening room, when the method of heating used does not consume oxygen.

## 5 HEATING OF THE BANANAS

The heating of the bananas to the temperature selected for the ripening is carried out in two stages, as described in 5.1 and 5.2.

### 5.1 Preliminary heating

5.1.1 When the external temperature is above 12 °C, natural heating normally occurs before the bananas are placed in the ripening room. The extent depends on the external temperature, and on the duration and conditions of transport.

5.1.2 When the external temperature is below 12 °C, it is necessary to carry out artificial heating to protect the bananas from deterioration due to cold, by maintaining the temperature above 12 °C in the means of transport being used.

### 5.2 Supplementary heating

Supplementary heating is carried out in the ripening room so that the flesh of the fruit reaches the temperature which has been fixed for ripening (usually from 16 to 18 °C).

This heating is carried out progressively in a humid atmosphere using closed-circuit air circulation to encourage heat exchanges and to homogenize the temperature of the bananas within the packages. The relative humidity should be maintained at around 95 % (spraying of the ground and walls in simple installations, use of vaporizers or atomizers in more sophisticated installations).

The duration of this period of heating (generally from 12 to 24 h) depends on the choice of the temperature and the duration of ripening.

When the bananas have been exposed to the cold, they must be heated very gradually.

1) When hands or parts of hands arrive in a package of non-perforated plastic film, it is recommended that the upper part of this packaging be opened.

2) With the general use of the despatching of hands or parts of hands in corrugated cardboard cases, the ripening of bananas in bunches now represents only a small part of the overall tonnage of bananas which are ripened (less than 10 %).

## 6 ACTUAL RIPENING

### 6.1 First phase of ripening

At the end of the heating, the ripening of the bananas generally begins following a period which varies according to their state.

The beginning of the ripening is characterized by an increase in the intensity of respiration of the bananas, up to a maximum of the climacteric phase (at 18 °C, the maximum value of the intensity of respiration is 100 mg of carbon dioxide per kilogram of the product per hour, i.e. four times the value of the intensity of respiration of the green banana) and by a considerable production of heat. The oxygen content of the atmosphere decreases and the carbon dioxide content increases. Therefore, the ripening room should hold a sufficient quantity of oxygen for the process of ripening not to be slowed down. The relative humidity should be maintained at around 95 % and the air circulation kept working to encourage heat exchanges. The beginning of the ripening is encouraged by ethylene, by the volatile materials which permeate the walls of the room, and by those which are given off by the first bananas to ripen.

### 6.2 Second phase of ripening

After reaching a maximum, the intensity of the respiration decreases. The skin of the bananas, which has changed little in colour during the first phase of ripening (from green to greenish-yellow) becomes progressively more yellow following the accelerated degradation of the chlorophyllian

pigments while the existing xanthophyllian pigments are revealed. During this phase, the odour of the fruit develops. The air circulation of the ripening room should be maintained and the temperature should be lowered slightly. The relative humidity should be reduced if the installation includes a humidity regulating device (see 6.3).

### 6.3 Conduct of the ripening

The ripening may last from 4 to 8 days according to the manner in which it is carried out, which varies according to

- the degree of development of the bananas;
- the physiological and health state (injuries; fungal diseases of the ends of the cushions, of the stalks and of the skin; etc.);
- the time fixed for the sale to the consumer.

There are three types of ripening :

- rapid ripening : duration 4 days;
- normal ripening : duration 5 to 6 days;
- slow ripening : duration 8 days (in special cases).

The information given in tables 1 to 3 concerning these three types of ripening is given as an indication for the case of the ripening of normal bananas in fibreboard cases. The temperatures indicated in the tables are those of the internal flesh of the bananas. They do not necessarily reflect the temperature of the air in the different parts of the ripening room.

TABLE 1 – Rapid ripening

	1st day	2nd day	3rd day	4th day
Temperature	18 °C	18 °C	17 °C	14 to 16 °C
Relative humidity	95 to 100 %	95 to 100 %	85 to 90 %	80 %
Air circulation	Continuous in closed circuit; ratio 30 to 60	Continuous in closed circuit; ratio 30 to 60	In closed circuit at reduced speed	In closed circuit at reduced speed
Air change <sup>1)</sup>	Once, for 20 to 30 min at the end of the 1st day			
Ethylene or nitrogen/ethylene mixture treatment <sup>2)</sup>	1 ‰ <sup>3)</sup>			

1) From the 2nd to the 4th day, if necessary, a moderate change of air may be carried out.

2) This treatment is in general use but is not obligatory.

3) i.e. an ethylene concentration of 1 000 parts per million, or 1 litre per cubic metre; if a 95 %/5 % nitrogen/ethylene mixture is used, this corresponds to 20 000 parts of the mixture per million, or 20 litres of the mixture per cubic metre.

TABLE 2 – Normal ripening

	1st day	2nd day	3rd day	4th day	5th day	6th day
Temperature	18 °C	16 °C	15 °C	15 °C	14 °C	14 °C
Relative humidity	95 to 100 %	95 to 100 %	90 %	90 %	80 %	80 %
Air circulation	Continuous in closed circuit; ratio 30 to 60	Continuous in closed circuit; ratio 30 to 60	Continuous in closed circuit; ratio 30 to 60	In closed circuit at reduced speed	In closed circuit at reduced speed	In closed circuit at reduced speed
Air change	Once, for 20 to 30 min at the end of the 1st day					
Ethylene or nitrogen/ethylene mixture treatment <sup>1)</sup>	1 ‰ <sup>2)</sup>					

1) This treatment is in general use but is not obligatory.

2) i.e. an ethylene concentration of 1 000 parts per million, or 1 litre per cubic metre; if a 95 %/5 % nitrogen/ethylene mixture is used, this corresponds to 20 000 parts of the mixture per million, or 20 litres of the mixture per cubic metre.

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TABLE 3 – Slow ripening

	1st day	2nd day	3rd day	4th and 5th days	6th and 7th days	8th day
Temperature	17 °C	15 °C	14 °C	14 °C	14 °C	14 °C
Relative humidity	95 to 100 %	95 to 100 %	90 %	90 %	80 %	70 % to 80 %
Air circulation	Continuous in closed circuit; ratio 30 to 60	Continuous in closed circuit; ratio 30 to 60	Continuous in closed circuit; ratio 30 to 60	In closed circuit at reduced speed	In closed circuit at reduced speed	In closed circuit at reduced speed
Air change	Once, for 20 to 30 min at the end of the 1st day					
Ethylene or nitrogen/ethylene mixture treatment <sup>1)</sup>		1 ‰ <sup>2)</sup>				

1) This treatment is in general use but is not obligatory.

2) i.e. an ethylene concentration of 1 000 parts per million, or 1 litre per cubic metre; if a 95 %/5 % nitrogen/ethylene mixture is used, this corresponds to 20 000 parts of the mixture per million, or 20 litres of the mixture per cubic metre.

## 6.4 Modification of the conduct of the ripening

The conditions of ripening given in the tables refer to normal bananas which have reached a satisfactory degree of ripeness when harvested, with an average time of sea transport (from 10 to 15 days) and with normal conditions of transport between the port of import and the ripener.

When the bananas have been submitted to abnormal conditions (for example, too long an interval between cutting and loading, too low or too high a transport temperature, excessive dehydration, etc.), the normal conditions of ripening should be modified in consequence.

The modifications consist

- 1) in increasing the temperature on the first day, notably
  - if the bananas are not well developed (thin);
  - if very rapid ripening is necessary to limit the development of fungal diseases (rotting of the skin, of the ends of the cushions, and of the stalks);
- 2) in carrying out slow ripening at a comparatively low temperature (17 °C)
  - if the bananas have been submitted to too low a temperature (curling).

## 7 ACTION OF ETHYLENE ON THE BANANAS<sup>1)</sup>

### 7.1 Effect of ethylene

The use of ethylene is indicated

- when the bananas show differences in the degree of development, or
- when they have been submitted to the effect of too low a temperature during transport, or too great a dehydration.

The ethylene which is introduced into a ripening room diffuses into the cells of the flesh of the banana and increases the concentration of this gas, up to a critical value which causes the beginning of ripening. This addition of ethylene completes the action of this gas which normally forms directly in the cells of the flesh of the banana following the preclimacteric phase.

Ethylene has no effect on bananas which have already begun to ripen. Its role consists of initiating and standardizing the beginning of the ripening of the bananas which are placed in the same ripening room. For economic reasons, its use is often a necessity.

### 7.2 Method of using ethylene

Chemically pure ethylene may be introduced directly into the ripening room in the proportion of 1 part per 1 000<sup>2)</sup>. Since it is explosive at a concentration of 3 % in air, it is preferable to use a mixture of nitrogen and ethylene having an ethylene concentration of about 5 %, which is not explosive. The ethylene, or the nitrogen/ethylene mixture, is supplied in compressed-gas cylinders which should be placed outside the ripening room in a well-ventilated corridor. The quantity of gas introduced should be controlled with a flow meter and circulation of the air is essential in order to obtain a high degree of homogeneity of the atmosphere in the ripening room. It may be necessary in some cases to effect the introduction of ethylene twice, at lower concentration (1 part per 4 000), the first time after heating the bananas for 24 h, and the second time – when it appears to be necessary – after 48 h. With certain consignments, in fact, a single introduction of ethylene at the concentration indicated above is sufficient to initiate rapidly the ripening of the bananas.

After the introduction of the ethylene, the room should remain closed for a period of 24 h.

## 8 STORAGE TEMPERATURE OF THE BANANAS AFTER RIPENING

The storage temperature of the bananas after ripening must be selected according to their state.

### 8.1 Bananas at the stage of turning yellow

The bananas still release a certain amount of heat since the ripening process is not complete, and it is recommended that the temperature of the air should be adjusted to 1 °C below the flesh temperature, which should be 13,5 °C.

### 8.2 Bananas in the yellow stage

In this case, the temperature to which the air is adjusted should be the same as that of the flesh, i.e. 13,5 °C or 14 °C.

## 9 DEGREE OF RIPENESS AT THE TIME OF SUPPLY OF BANANAS TO THE RETAILER

The degree of ripeness of the bananas which are supplied to the retail trade should depend on the season and the temperature conditions in the retail shop.

### 9.1 Supply of bananas in the summer

In summer, the bananas should be supplied at the stage when they are turning yellow (see 8.1), with a flesh temperature of 13 to 14 °C.

1) The use of ethylene remains, however, subject to national regulations in each country.

2) See the note concerning this ratio under tables 1 to 3.

9.2 Supply of bananas in cold weather

In cold weather, the bananas should be supplied with a more marked colour than in summer (yellow, with green at the end) and with a flesh temperature of 16 °C. The keeping of bananas in a place where the temperature is too high or too low reduces the length of time they can be stored and alters their organoleptic qualities.

10 CAUSES OF DEFECTIVE RIPENING OF BANANAS

Table 4 gives the principal factors which give rise to the defective ripening of bananas.

NOTE — The criteria of deterioration because of the cold are the following :

- jellification of the sap, which ceases to ooze out;
- turning brown of sections of the skin's lactiferous channels in a transverse section of a fruit;
- appearance of brown streaks when a strip of the skin is lifted in a longitudinal direction on one of the external faces of the banana.

Depending on the extent of deterioration :

- fruits slightly injured by the cold ripen with difficulty with a pale, greyish colour, their organoleptic qualities being reduced;
- fruits badly injured by the cold do not ripen further, even with the use of ethylene.

TABLE 4 — Causes of defective ripening

Uneven ripening	<ul style="list-style-type: none"> <li>— non-homogeneous temperature in the ripening room</li> <li>— bananas with uneven degrees of ripeness</li> </ul>
Ripening too slowly	<ul style="list-style-type: none"> <li>— bananas altered by the cold (see note)</li> <li>— considerable dehydration of the bananas before they were placed in the ripener</li> <li>— insufficient degree of development when harvested</li> <li>— temperature too low in the ripening room</li> <li>— relative humidity too low in the ripening room</li> <li>— leaky ripening chamber, or insufficient quantity of ethylene</li> </ul>
Defective colour	<ul style="list-style-type: none"> <li>— deterioration of the bananas because of the cold (see note) (in the plantation or during transport)</li> <li>— ripening temperature too high</li> </ul>
Flesh soft and skin too tender	<ul style="list-style-type: none"> <li>— physiological deterioration due to excessive temperature before shipping</li> <li>— temperature of the flesh too high during ripening due to defective regulation of the room temperature, or insufficient ventilation with too high a temperature of the bananas inside the fibreboard cases</li> </ul>
Development of rotting*	<ul style="list-style-type: none"> <li>— defective physiological state of the bananas : sensitiveness of the skin, the stalks and the cut sections to fungal infections</li> <li>— injuries due to rough handling</li> <li>— defective anti-fungal treatment after harvesting</li> <li>— insufficient disinfection of the ripening room</li> </ul>

\* When the bananas are liable to rot, it is necessary that their ripening be carried out quickly.