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THE USE OF A STORABILITY DIAGRAM FOR MUSHROOMS

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SUMMARY

Storability diagrams based on quality evaluation during storage experiments can be used to evaluate the storage life of a product after a sequence of different climatic conditions.
This is allowable if the additivity and commutativity of the effects can be validated.
A storability diagram of mushroom, is constructed for 15, 7 and 0°C as storage temperatures. Changing the storage conditions after 1 or 2 days and daily determination of the quality of the mushrooms, indicates that the commutativity assumption is valid.

SAMENVATTING

Houdbaarheidsdiagrammen kunnen worden gebruikt om de bewaarduur van een produkt na opeenvolgende verschillende klimaatcondities te berekenen of te construeren. Dit is toegestaan als kan worden aangetoond dat de effecten opstelbaar en omkeerbaar zijn.
Voor champignons is een houdbaarheidsdiagram ontwikkeld door te bewaren bij 15,7 en 0°C. Door de temperaturen na 1 of 2 dagen te veranderen en de produktkwaliteit dagelijks te beoordelen, werd de omkeerbaarheid van de behandelingen bevestigd.

Introduction

The Sprenger Institute developed methods to describe the post-harvest in terms of quality or keepability of foods with time-temperature-tolerance diagrams. (= storability diagram). The advantage of this diagram is the easy description of quality development and storability of food during post-harvest life under changing climatic conditions.
The reliability of the diagram depends on the assumptions that the effects of climatic conditions on the storability of the foods are additive and commutative.
We tested these assumptions for the product mushroom, because of the possibility to keep record of the quality of mushrooms by means of photography.

The time-temperature-tolerance hypothesis (TTT)

Storage life: the time required for various physiological and physical changes to accumulate to such an extent that quality is just unacceptable.

Quality: a complex function of many attributes of a food used as criterion for acceptability.

Quality indicator: a major quality attribute of a food, readily measurable (firmness, surface colour). (fig. 1).

Keepability: indication of the length of a storage life of a product at known conditions.

Storability: the fraction of the keepability (= storage life) of a product stored at one climatic condition.

The quality of a product is a continious function in time, describing the integral effect of all attributes of a product from fresh to just unacceptable.

The storability is a discrete function describing the fraction of the storage life.
The function has only 2 points for each climate condition. At time = 0 (harvest time for example) the storability is 100%, while the other point is the storage life at storability 0% (fig. 2).
A time-temperature-tolerance or storability diagram compiles information on the effect of constant climate conditions, on storability by straight lines representing different storage temperatures.
Instead of temperature, every combination of climatic condition factors (r.h., CO_2-concentration dark/light) can be used (fig. 3).

The relation between a quality indicator-diagram and storability diagram is shown in fig. 4
If by agreement the quality indicator has reached the level of 40% the storability of the product can be found by drawing line A-B. The storability is about 20%.

Possibilities of storability diagrams

1. Keepability of product stored at different conditions during its post harvest life

The use of a storability diagram rests on three important assumptions: additivity, commutativity and non-existence of additional effects due to climatic condition change itself. Fig. 5 shows the keepability of a product stored 1 day at 20 and 5°C for the rest of the post-harvest life.
The first day the change of the storability follows the line of 20°C. Then the products temperature is at once 5°C and without a lagtime or other additional effects, the change of the storability follows the direction of the line of 5°C.

2. Cooling down time of chilled products

Assume that chilled products in a cold room are judged homogeneous if the difference in storability of the best quality and the poorest quality product is less than 20%. During cooling down of a bulk of products the differences in storability depend on the temperature regime. Fig. 6 shows the storability line of the slowest cooling product, giving the storage life of the bulk at storability 0%. At that time the storability of the fastest cooling product is still 20%.
The longest cooling down time is the intercept of the storability line at harvest temperature and the line 20% below the storability line at storage temperature (or conditions).

3. Temperature spread in a cold room

The center of a heat generating unit of product (palletload, bulkbin) shows principally an overtemperature against the surrounding air.
Adding this overtemperature to the airtemperature difference in the cold room, one gets the total temperature spread at product level.

To calculate the allowable spread of storage temperature a sume again that the maximum difference of the storability is 20%. Fig. 7 shows the development of storability at the end of the storage period.
Point A indicates the storability at the highest product temperature and point B at the lowest temperature in the cold room. This fig. 7 also shows that the temperature spread must be minimised for smaller diffferences in storability or maximum storage life.

Storability diagram for mushrooms

The aim of the storability diagram is a simple quantitative description of very important information about development of the product during its post-harvest life. This report shows the results of experiments with mushrooms, to prove the usability of storability diagrams.
This is done by showing the validity of the additivity and commutativity assumptions.

The quality indicators of mushroom are:

- Freshness, normally indicated by closed veils (thin membrane) around the base of the cap. For unacceptable products the veil is stretched and broken, showing the black coloured gills.
- The colour of the cap, normally white.
- The firmness of the fruiting body.

In this study the condition of the veil is the major quality indicator. Commutativity and additivity are tested by storing mushrooms at different climate conditions and changing the conditions after the same time intervals for a part of the products. Mushrooms (fresh) stored 1 day at 5°C and 1 day at 20°C have a storability D after two days (fig. 8). The property of commutativity is proved if the storability is D after storage of fresh mushrooms at 20°C for 1 day and then 5°C for 1 day.

The property of additivity is proved if the changes of quality in the food persist and can be added to all other changes that may be produced subsequently. The quality changes must be irreversible, so a jump to a better quality or higher storability (from 50% to 70%) cannot take place.

Experiments

Mushrooms were kept at temperatures of 15, 7 and 0°C using very high relative humidities.
Wilting of the mushrooms didn't occur during the experiments. Every day colour pictures were taken, showing the development of the breaking of the veils, resulting in dark shells around the base of the cap. Fig. 9 shows the keepability diagram of mushrooms.
Mushrooms are unacceptable if veils were broken. Fig. 10 shows the storability diagram indicating that after 4 days storage at 7°C none of the veils were broken, but a few were broken after 5 days.

To prove the hypothesis of the storability diagram it is more convenient to use as just acceptable the first occurence of broken caps. Fig. 11 shows the measured storability diagrlam using this acceptability criterion.
The quality of 15°C/2 days and 7°C/7 days stored mushrooms was equal and just acceptable.
After 1 day mushrooms were transferred from 15°C to 0°C.
Showing pictures to objective persons the quality of 15°C/1 day + 0°C/10 days (ca. 1 day) stored products is equal to the just acceptable quality. Fig. 12 shows that the additivity concept holds for this conditions, because the constructed storage life of mushrooms stored 1 day at 15°C and the rest of the storage time at 7°C, is 12 days.
This is the same time as objective persons indicated (10 to 12 days).
Mushrooms stored 2 days at 0°C and the rest of the days at 15°C have a just acceptable quality after 2 days at 15°C, thus having a total storage life of 4 days. Fig. 13 shows that the constructed storage life is 3, 6 days, which is close to the judgment of objective persons (4 days).

Conclusions

- The experiment shows the possibility to design a storability diagram for mushrooms under sequential climatic conditions. The assumptions of additivity and commutativity seem to be valid if the major quality indicator is the condition of the veil.
- For the experimental verification the temperature levels 15, 7 and 0°C, are not the most suitable ones.
  The levels 10, 7 and 4°C are more convenient. At 0°C the slope of the storability line is to flat and at 15°C to steep, which gives rise to interpretation errors.

Interesting literature

- S.N. Thorne
  Development in Food Preservation - 1 Applied Science Publishers London, New Jersey, 1981.

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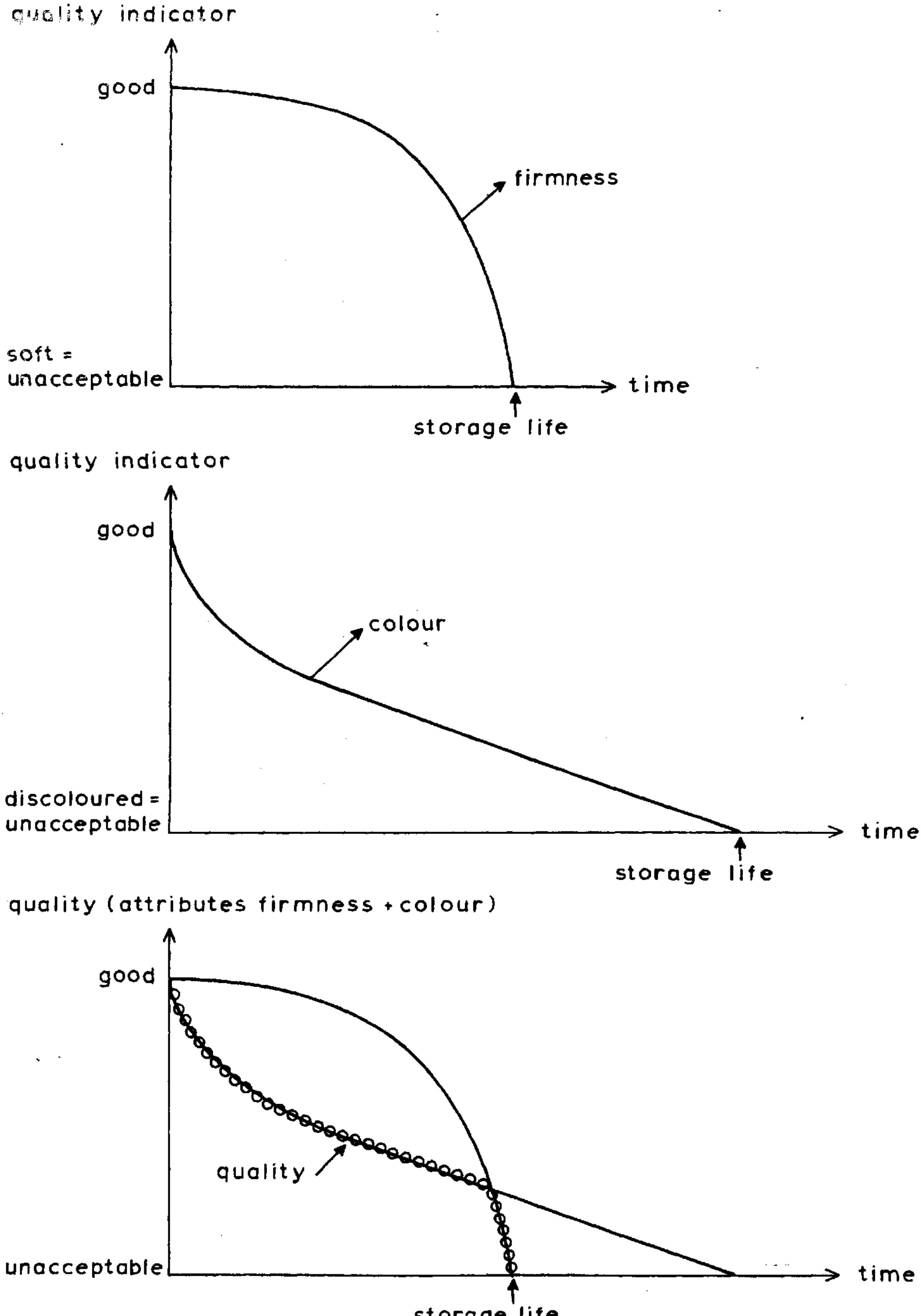

Figure 1. Quality of a product

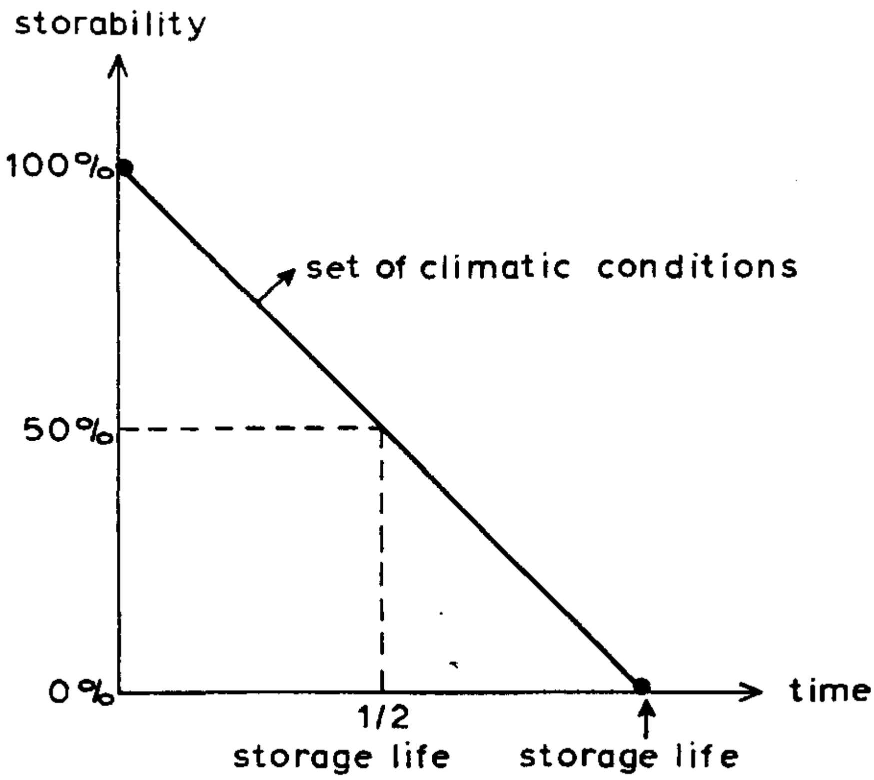

Figure 2. Definition of storability

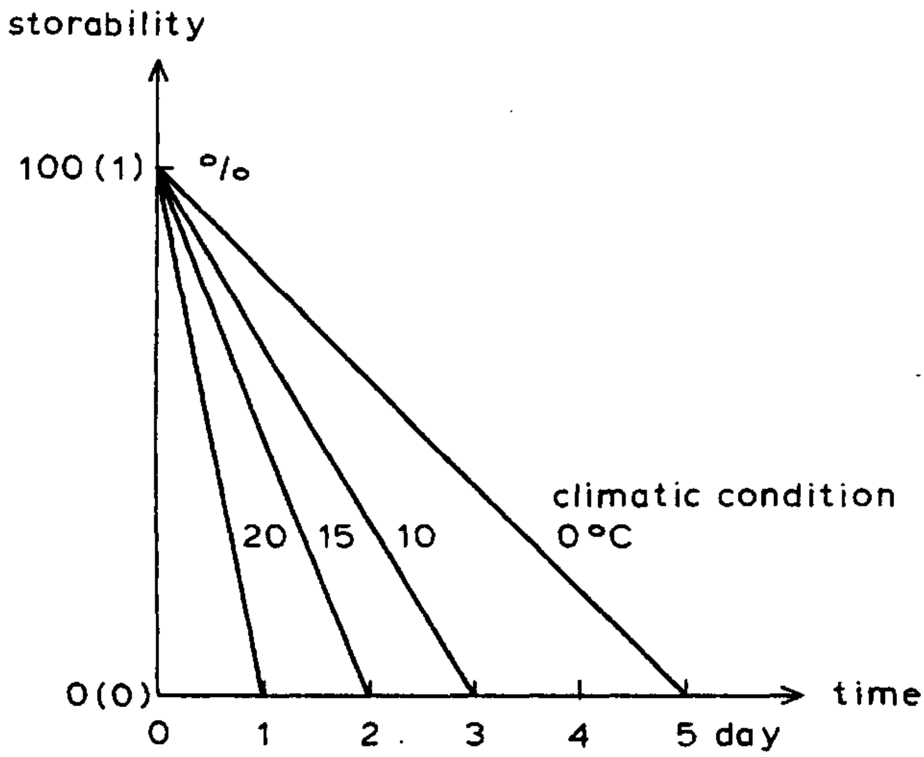

Figure 3. A typical TTT-diagram

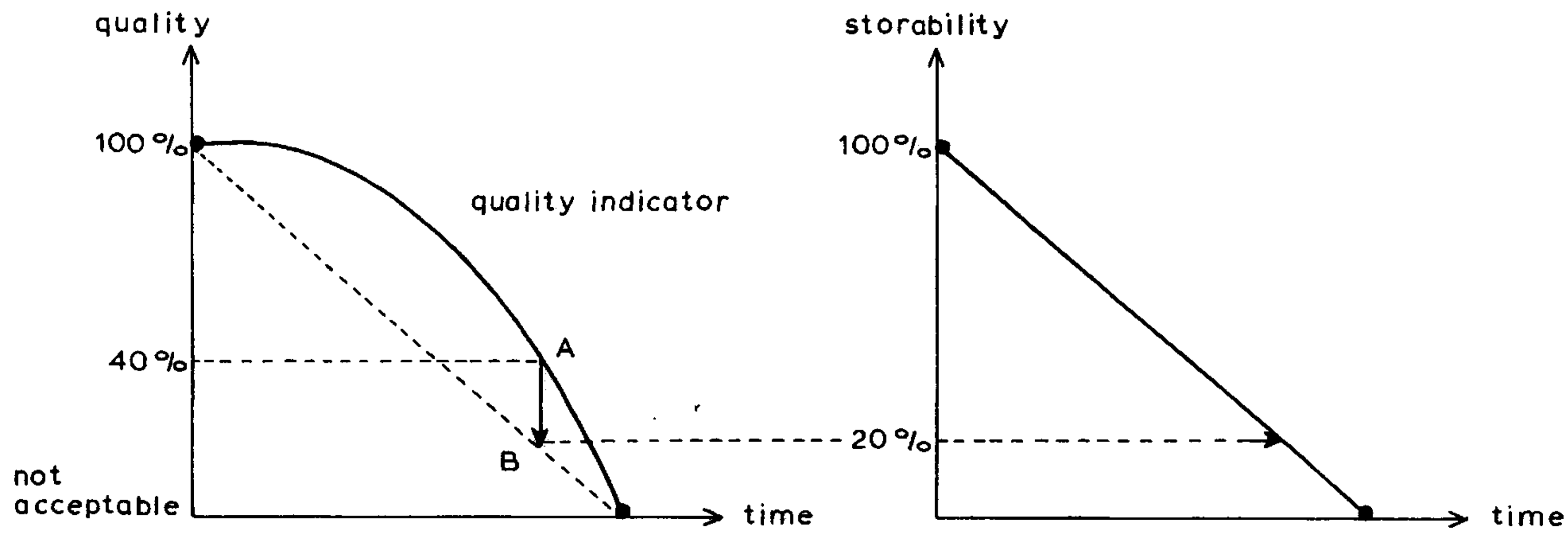

Figure 4. Relation between a quality and storability diagram

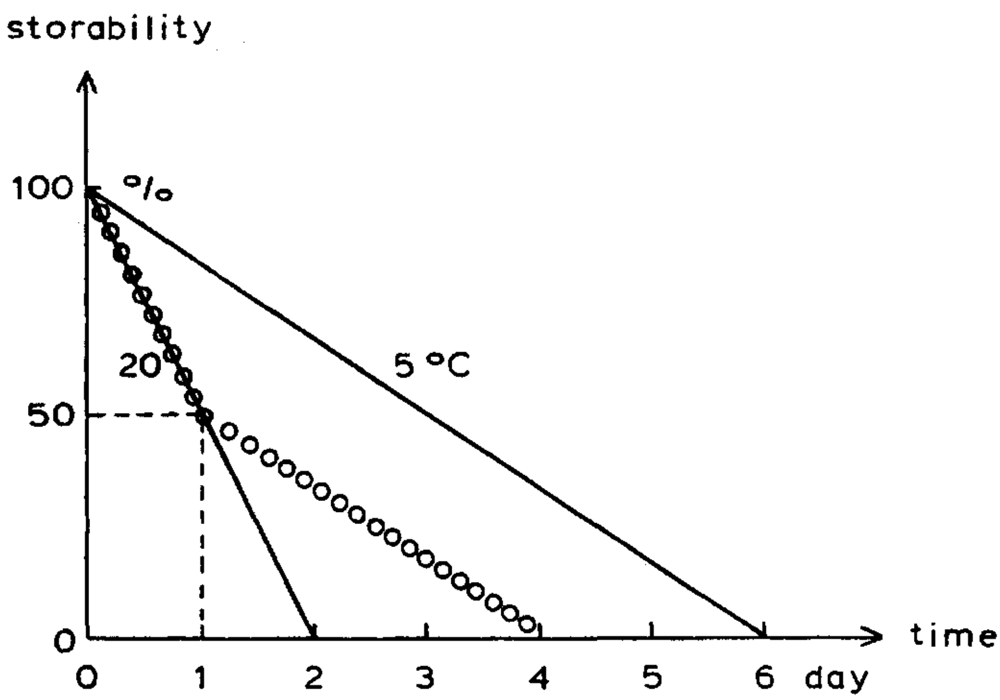

Figure 5. Storability of a product stored sequentially
at two different temperatures

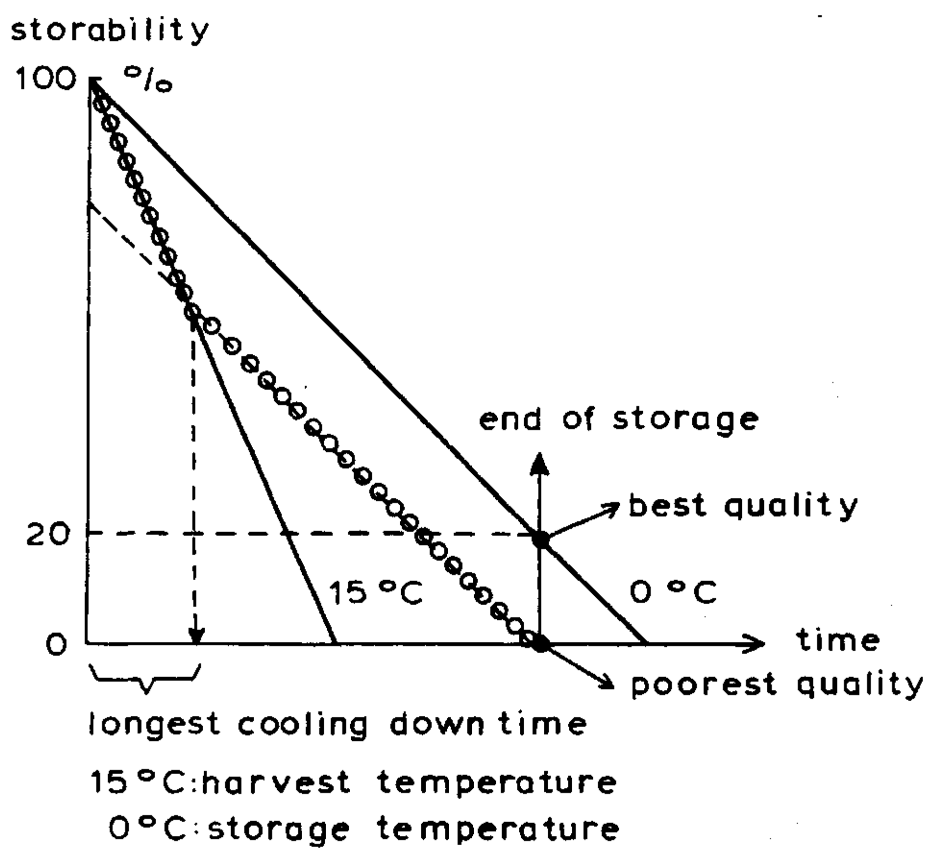

Figure 6. Determination of the cooling down time of a product

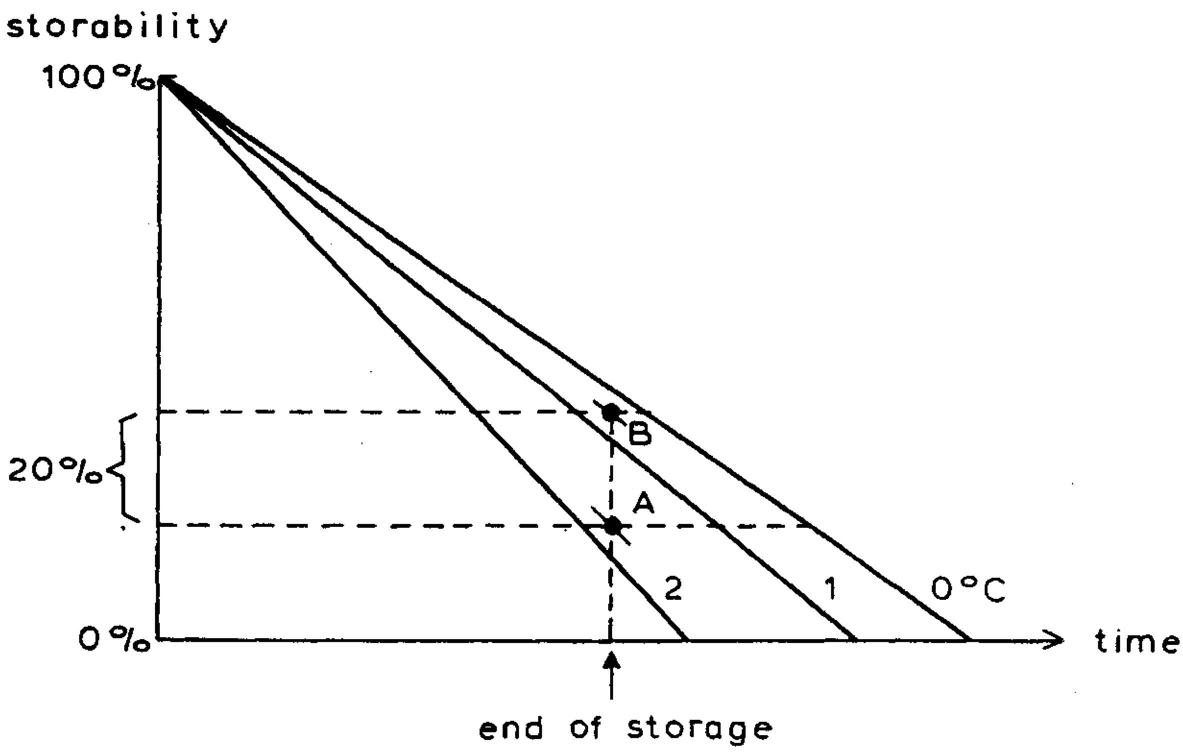

Figure 7. Determination of the tolerable temperature
spread in a cold room

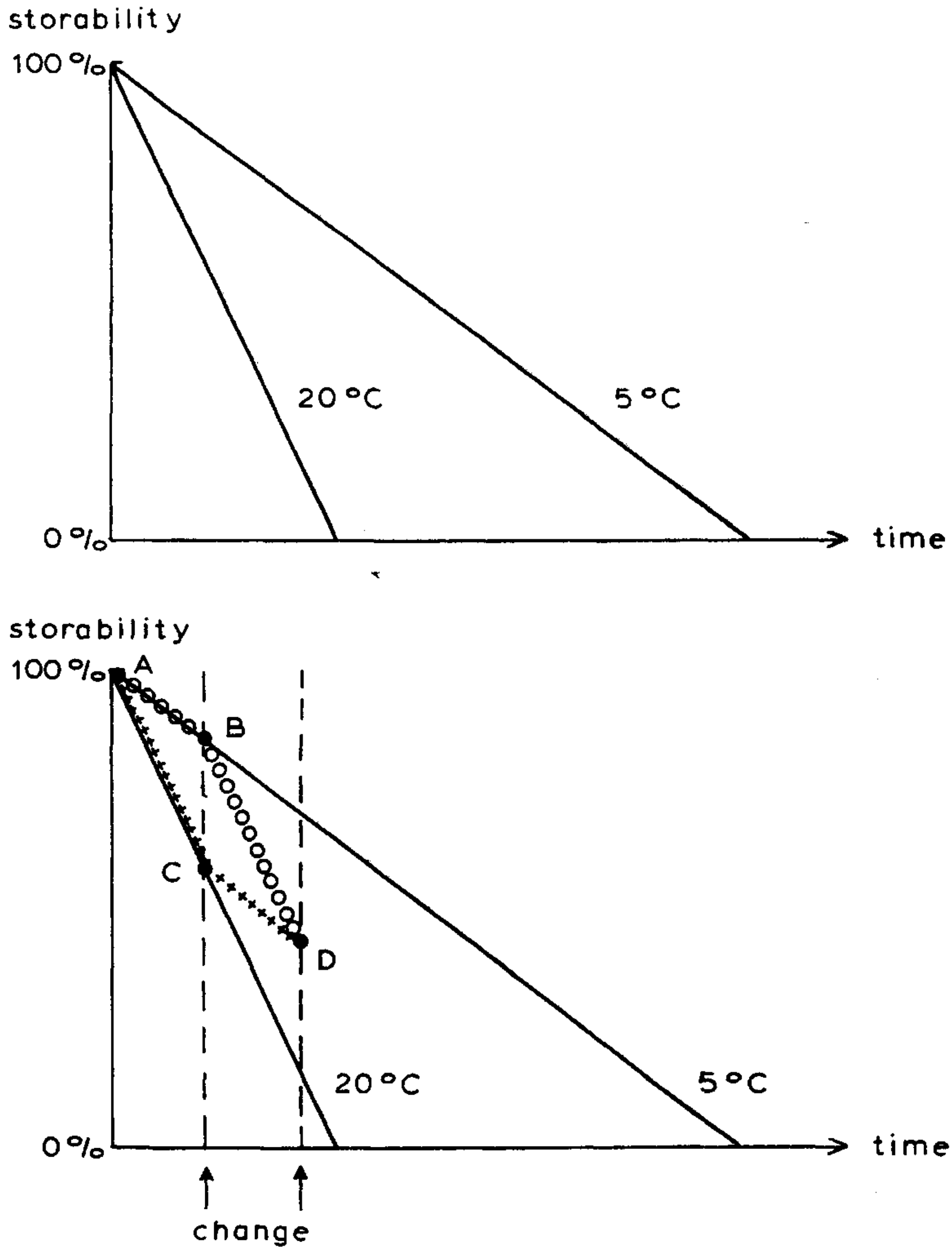

Figure 8. Commutativity of storability diagrams

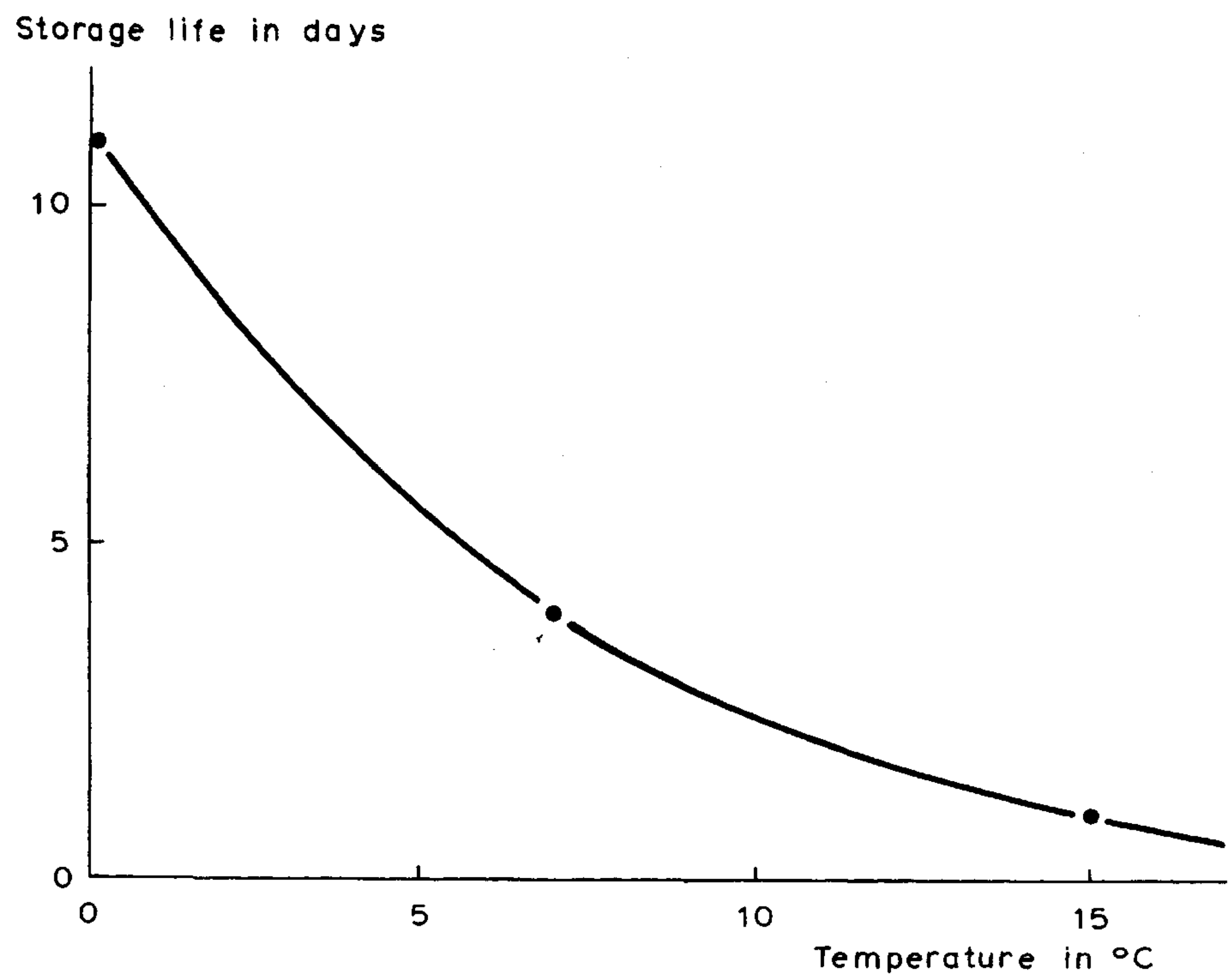

Figure 9. Keepability diagram of mushroom

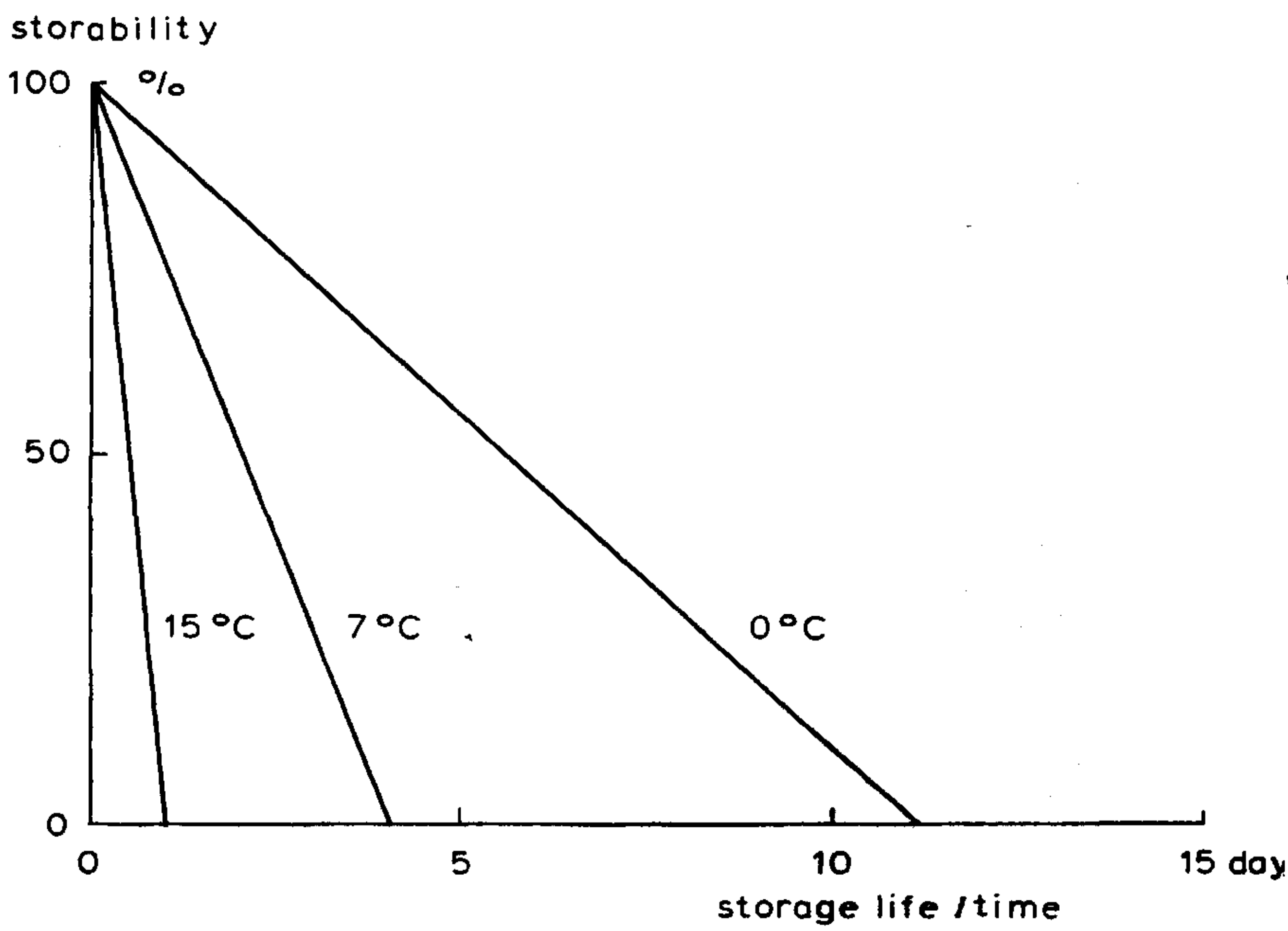

Figure 10. Storability diagram of mushroom.
Just acceptable if none of the veils are
broken (practical)

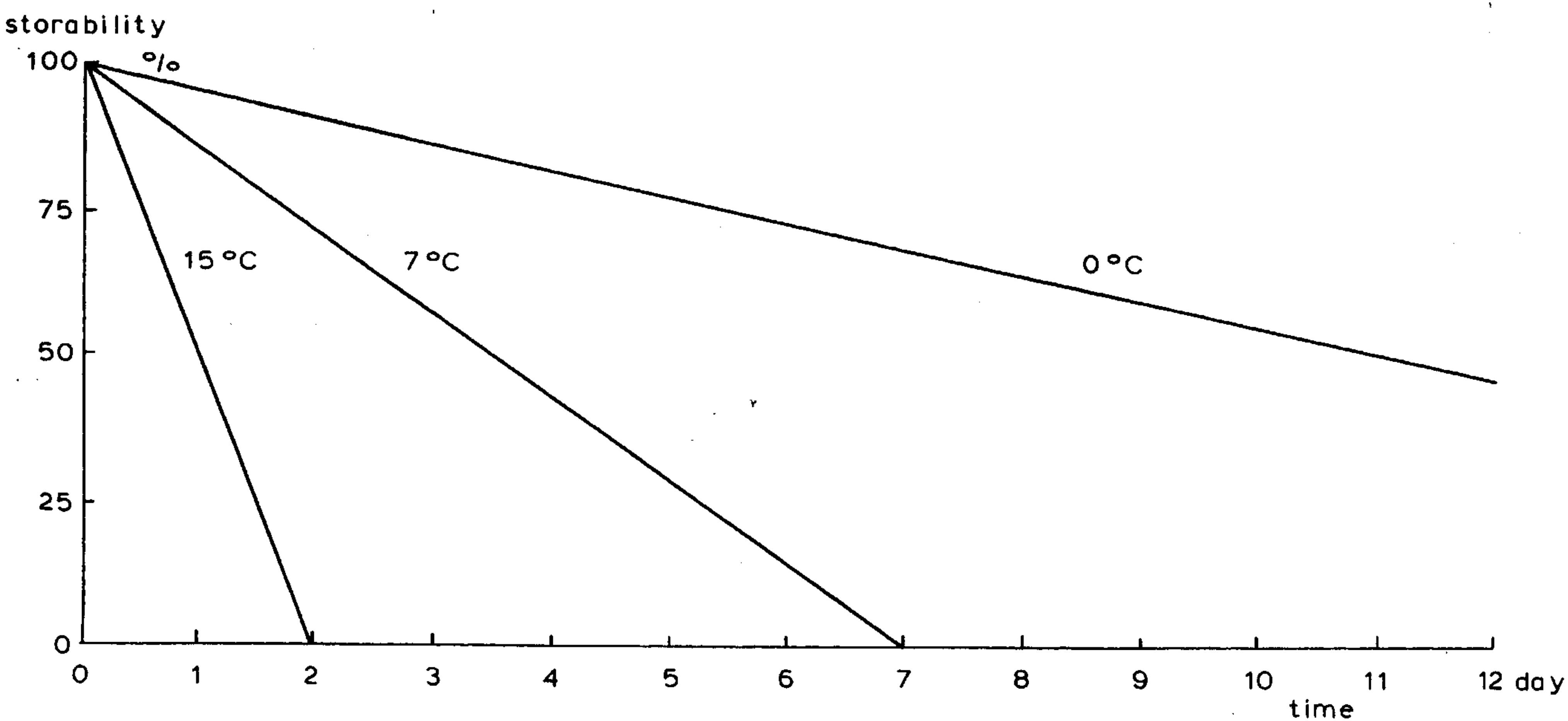

Figure 11. Storability diagram of mushrooms. Just acceptable if some veils are broken the day before (experimental condition)

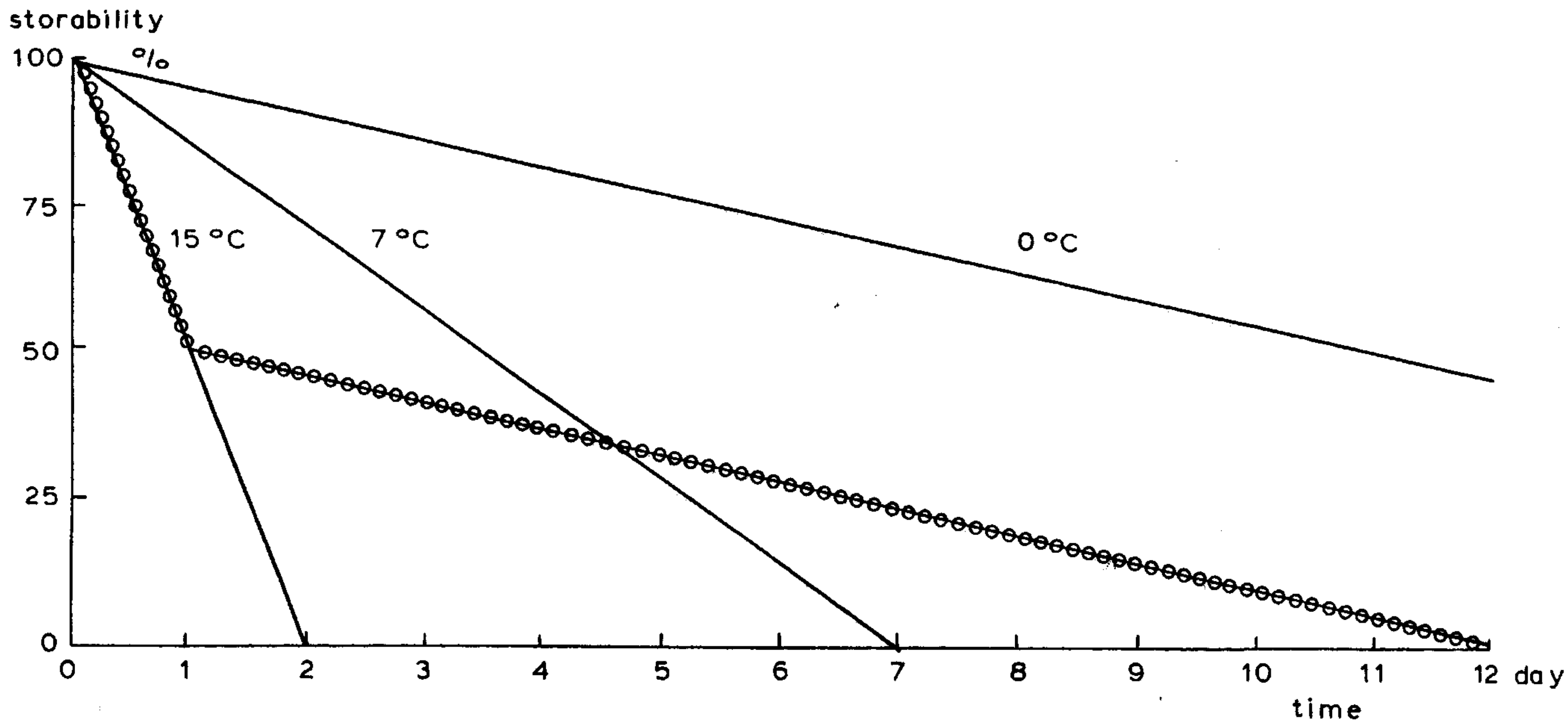

Figure 12. The storability of mushrooms stored 1 day at 15°C and then at 0°C

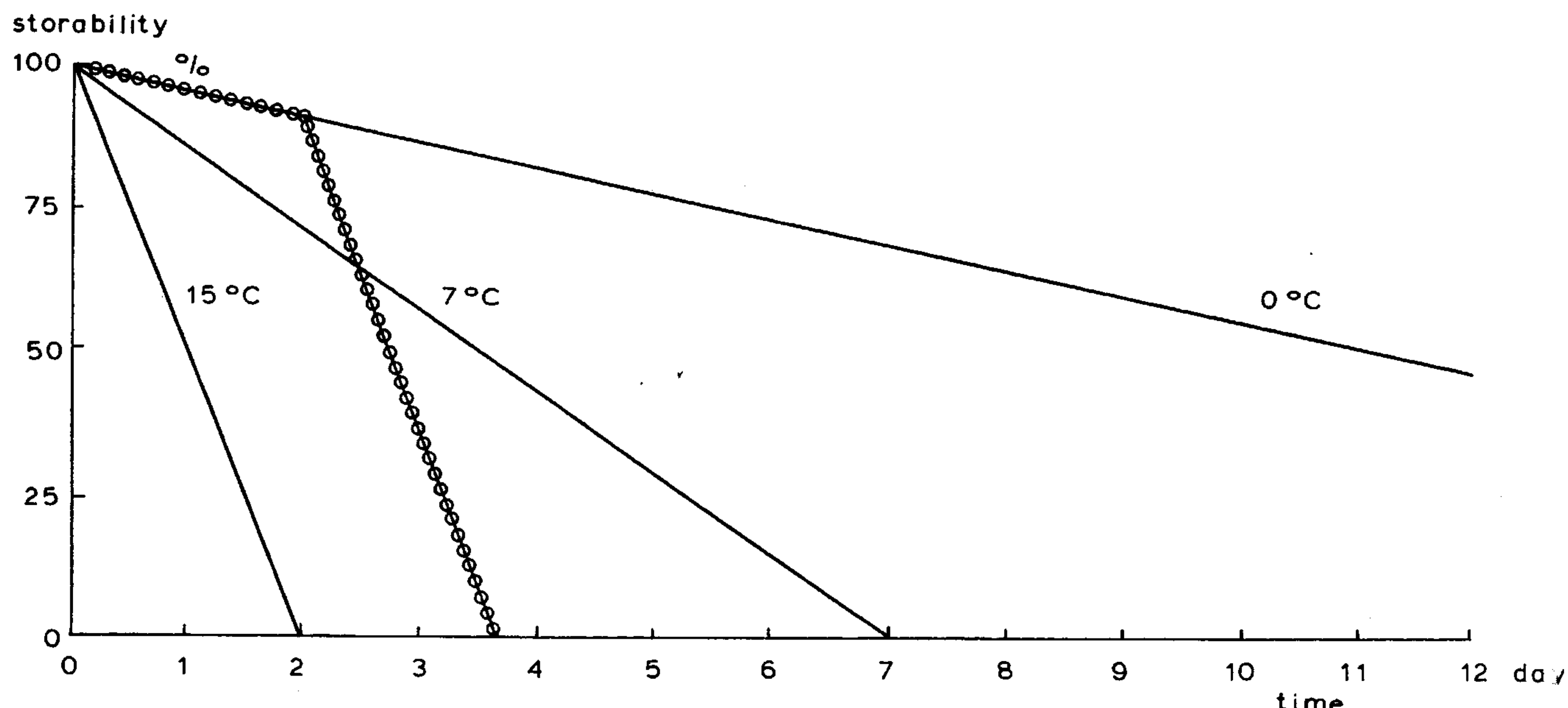

Figure 13. The storability of mushrooms stored 2 days at 0°C and then at 15°C