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Technical Report

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Fine bubble technology — Agricultural applications —

Part 5:

Practical data collection to promote the germination of typical vegetable seeds using ultrafine bubbles

ISO/TC 281

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Contents

| | Page |
|---|-----------|
| Foreword..... | iv |
| Introduction..... | v |
| 1 Scope..... | 1 |
| 2 Normative references..... | 1 |
| 3 Terms and definitions..... | 1 |
| 4 Test subjects..... | 1 |
| 5 Judgement of significant difference in T_{50}..... | 2 |
| 6 Seeds and measurement device..... | 2 |
| 6.1 Seeds for germination test..... | 2 |
| 6.2 Measurement device for UFB size and concentration..... | 2 |
| 6.3 Examination range of UFB number concentration for vegetable seeds and adjustment of dissolved oxygen concentration (DO)..... | 2 |
| 7 Test data..... | 3 |
| 7.1 General..... | 3 |
| 7.2 Carrot seeds of positive photoblastic..... | 3 |
| 7.3 Tomato seeds of negative photoblastic..... | 4 |
| 7.4 Spinach seeds of neutral photoblastic..... | 5 |
| 7.5 Effect of DO (Dissolved oxygen concentration)..... | 6 |
| 7.6 Effect of UFB number concentration..... | 7 |
| 7.7 Presence or absence of seed size effect on the promotion by UFB..... | 8 |
| 7.7.1 General..... | 8 |
| 7.7.2 Carrot seed of comparatively large size..... | 8 |
| 7.7.3 Carrot seed of comparatively small size..... | 9 |
| 8 Suggestion..... | 10 |
| Annex A (informative) Example of measured UFB data of size distribution and number concentration of UFB used in this document..... | 11 |
| Annex B (informative) 95 % confidence intervals of T_{50} values corresponding to Figures 1 to 7..... | 14 |
| Bibliography..... | 21 |

Foreword

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This document was prepared by Technical Committee ISO/TC 281, *Fine bubble technology*.

A list of all parts in the ISO 23016 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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Introduction

The market for technologies using fine bubbles has been rapidly growing in many applications throughout the industrial, domestic, and academic sectors. Especially, application of ultrafine bubble (UFB) technology to the agricultural area is arousing great interest. It is thought to be one of the advanced technologies improving the productivity and efficiency of agriculture, thereby contributing to the United Nations Sustainable Development Goals (SDGs) by means of providing sufficient food and maintaining water resources on land, as an example.

In this context, ISO 23016-2:2019 has been published, describing the test method for promoting barley seed germination by application of a UFB water generation system. Although the promotion of germination of barley seed is closely related to UFB number concentration, effects of the concentration were not specified at that time.

Thus, in order to provide users with a guideline for selecting an appropriate UFB generation system, ISO/TR 23016-3:2021 has been published to indicate the minimum viable number concentration of ultrafine bubbles that promotes the germination of barley seeds.

Furthermore, based on the continual accumulation of data revealing positive and negative effects of UFB on germination depending on the variety of barley seeds, ISO 23016-4 has been published to provide a method to evaluate the UFB number concentration ensuring the promotion of germination of the barley seeds without taking into account their varieties.

This document describes the data collected from the experimental observations on applying UFB water to promote the germination of vegetable seeds, based on ISO 23016-2, ISO/TR 23016-3 and ISO 23016-4. It was developed to support the application of the UFB technology to vegetables specially grown in hydroponic culture system, which market is quite large and still growing.

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Fine bubble technology — Agricultural applications —

Part 5:

Practical data collection to promote the germination of typical vegetable seeds using ultrafine bubbles

1 Scope

This document provides practical data collection of promoting the germination of typical vegetable seeds by applying ultrafine bubbles (UFBs) within the effective number concentrations for barley seeds specified in ISO 23016-2, ISO/TR 23016-3 and ISO 23016-4. While the application of UFB to barley seeds is systematically standardized, reports on UFB application to vegetable seeds germination are scattered worldwide. Therefore, this document intends to illustrate the effectiveness of UFBs to promote the germination of vegetable seeds depending on their response to light, i.e.:

- a) require light to germinate (positive photoblastic),
- b) require darkness to germinate (negative photoblastic), and
- c) neutral to light^[1].

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 23016-2, *Fine bubble technology — Agricultural applications — Part 2: Test method for evaluating the promotion of the germination of barley seeds*

ISO/TR 23016-3, *Fine bubble technology — Agricultural applications — Part 3: Guidelines for the minimum viable number concentration of ultrafine bubbles for promoting the germination of barley seeds*

ISO 23016-4, *Fine bubble technology — Agricultural applications — Part 4: Test method for evaluating the number concentration of ultrafine bubbles (UFB) achieving the promotion of barley seed germination*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 23016-2, ISO/TR 23016-3 and ISO 23016-4 apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

4 Test subjects

The items subjected to the test are air UFB water stored in bottles or other containers for preservation and transport in accordance with ISO 21255, and the UFB generating system used to generate the UFB water.

UFB water is generated by supplying raw water to the UFB generating system. Distilled water with a quality of Grade 2 according to ISO 3696 or greater is used as raw water that is distilled water supplied as a raw material for both UFB water and control water according to ISO 23016-2:2019, 3.6.

The size, quantity and concentration of UFB in UFB water were measured. Examples of measured data are given in [Annex A](#).

5 Judgement of significant difference in T_{50}

After determining the correlation curve using ISO 23016-2:2019, Formula (2), the sum squared of residual (SSR) and standard error (SE) around the time T_{50} are calculated. From this curve, the 95 % confidence interval of T_{50} is determined. The results are shown in [Figures B.1](#) to [B.7](#) in [Annex B](#).

6 Seeds and measurement device

6.1 Seeds for germination test

The following vegetable seeds of different responses to light were used as the seeds for the germination test:

- a) require light to germinate (positive photoblastic),
- b) require darkness to germinate (negative photoblastic), and
- c) neutral to light (neutral photoblastic)^[1].

It is not necessary to rinse the seeds in water before use; the test is initiated using the dry seeds as supplied. The germination test was conducted at the constant temperature of 25 °C.

6.2 Measurement device for UFB size and concentration

The UFB generating system is capable of supplying the UFB water described in ISO 23016-2. The air UFB water samples had their size and concentration measured using a particle tracking analysis instrument (see ISO 19430:2016). The size, quantity and concentration of UFB in UFB water were measured. Measurements were carried out at a room temperature around 22 °C.

6.3 Examination range of UFB number concentration for vegetable seeds and adjustment of dissolved oxygen concentration (DO)

As the UFB generation system given in ISO 23016-2 stably generates UFB in the number concentration ranges from 10^7 /ml, 10^8 /ml and greater, the UFB in the range from 10^7 /ml to 10^8 /ml was applied to vegetable seeds to ensure the effect of germination promotion. The air UFB number concentration in this range is known to be within the range that can be measured by the commercially available measurement device in [6.2](#).

Although an example of size distribution and number concentration of UFB used for barley seed germination is given in ISO/TR 23016-3:2021, Annex A, this case illustrates small-scale fluctuation. In this document, examples with fluctuation to some extent are shown in [Figure A.1](#) for UFB number concentration of $1,5 \times 10^7$ /ml and [Figure A.2](#) for UFB number concentration of $1,1 \times 10^8$ /ml.

The DO of water containing UFBs was adjusted to be the same as that of control water by introducing air and nitrogen gases through a mixed-gas flow regulator^[2] in order to observe only the effect of UFBs on vegetable seed germination by cutting out the effect of DO.

7 Test data

7.1 General

This document covers the following studies:

- The promotion effect on the germination for each of three types of seeds, which is described in [7.2](#) to [7.4](#).
- The effects of DO and number concentration of UFB on the germination promotion, which are described in [7.5](#) and [7.6](#).
- An effect of the seed size on the germination with using UFB is described in [7.7](#). In order to confirm the significant differences of T_{50} values between UFB and control sections, 95 % confidence intervals of T_{50} of UFB and control section were calculated and shown as [Figures B.1](#) to [B.7](#), each of those is relating to [Figures 1](#) to [7](#).

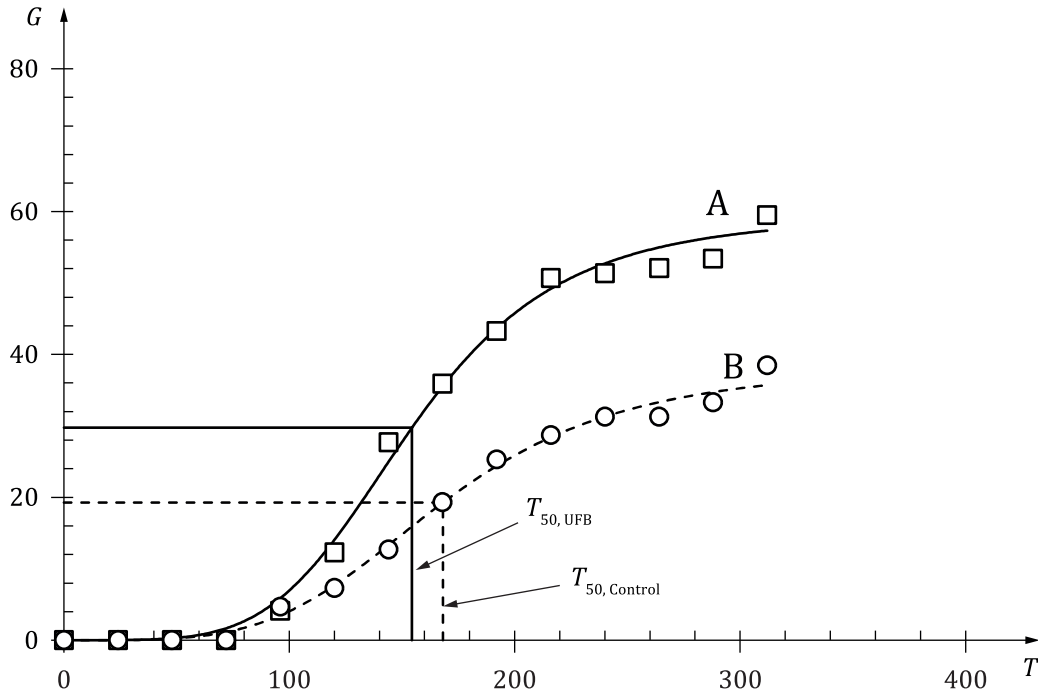
7.2 Carrot seeds of positive photoblastic

The analysis result of germination processes of carrot seeds is shown in [Figure 1](#) indicating the germination promotion effect of UFB. The number concentration of UFB was $4,4 \times 10^7$ /ml. Dissolved oxygen concentration (DO) was adjusted to 8,0 mg/l for both UFB and control water. A remarkable improvement at the final germination ratio of 59,5 % in UFB section was observed compared to 38,5 % for control section. Furthermore, 95 % confidence intervals of T_{50} of UFB and control section were not overlapped as shown in [Figure B.1](#). Thus, the promotion effect of UFB was verified on the germination of carrot seed which requires light for germination (positive photoblastic).

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Key

- data at control section
- data at UFB1 section
- T measurement time, expressed in hours
- G germination ratio, expressed in per cent
- A regression curve of germination ratio of seeds in UFB water
- B regression curve of germination ratio of seeds in control water
- $T_{50, Control}$ crossing time with 50 % of maximum germination ratio and the curve of control section, expressed in hours
- $T_{50, UFB}$ crossing time with 50 % of maximum germination ratio and the curve of UFB section, expressed in hours

Figure 1 — Promotion effect of UFB with number concentration of $4,4 \times 10^7$ /ml on germination of carrot seeds when DO of both control and UFB water is adjusted to 8,0 mg/l

7.3 Tomato seeds of negative photoblastic

The analysis result of germination processes of tomato seeds is shown in [Figure 2](#) indicating the germination promotion effect of UFB. The number concentration of UFB was $1,1 \times 10^8$ /ml. Dissolved oxygen concentration (DO) was adjusted to 7,6 mg/l to 7,7 mg/l for both UFB and control water. A remarkable improvement in the final germination ratio of 97,0 % for UFB section was observed compared to 79,0 % for control section. Furthermore, 95 % confidence intervals of T_{50} of UFB and control section were not overlapped as shown in [Figure B.2](#). Thus, the promotion effect of UFB was verified on the germination of tomato seed which requires darkness to germinate (negative photoblastic).