Hoya australis

Air purifying test

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Air purifying test

Produced for:
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https://www.teknologisk.dk/ydelser/planters-luftrensende-egenskaber/40089

Report 787797T1
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Test material:	Four replicates of *Hoya australis*. Measuring dates: 2018-06-13, 2018-06-16, 2018-06-20, 2018-06-23. Dimensions: Average weight of replicates = 671.4 ± 47.1 g, plant fresh weight = 241.2 ± 35.7 g, plant dry weight = 21.9 ± 3.8 g, pot surface area = 63.6 cm^2.
Sampling:	The test material was sampled by the client and received at the Danish Technological Institute on 2018-01-30.
Method:	The test developed by the Danish Technological Institute is described in Appendix 3. The following changes were made to adjust the test to *Hoya australis*: Climate chamber: volume 225 L Light cycle: 12 hours light (07:00-00:00 h), and 12 hours dark (00:00-07:00). Light level: 70 µmol m^{-2} s^{-1} at pot height. VOC-source: formaldehyde (FA) in the form of MDF boards Air exchange: 0.45 m^3 h^{-1} Number of measurements: 3 - 6 day^{-1}
Result:	*Hoya australis* removes (in light): 25.3 ± 8.7 µg FA/h At an air inlet concentration of: 119.3 ± 1.9 µg FA/m^3 Results in detail are given in the appendices: Appendix 1: Determination of formaldehyde removal Appendix 2: Formaldehyde Emission Trend Appendix 3: Test method
Terms:	The test was carried out according to the General Terms and Conditions regarding Commissioned Work Accepted by the Danish Technological Institute, which apply at the time of signing the agreement. The test is only valid for the tested specimen.
Date/place:	2018-11-27, Danish Technological Institute, Plant Technology, Taastrup
Signature:	Test responsible Co-signatory

Determination of Formaldehyde removal

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Initials: KKJA/JSP

Test material: Four plants of *Hoya australis*. Pot surface area 63.6 cm^2. Mean plant FW 203.2 ± 27.1 g.

Samples as received, and placed in chamber:

The formaldehyde concentration in air was determined by the method:
The test chamber air is collected in aqueous phase and detected by Hantzsch reaction and fluorometry by instrumentation Aerolaser AL4021. The detection of formaldehyde is based on the liquid phase reaction of formaldehyde with acetyl-acetone (2,4-pentadione) and ammonia. The yellow reaction product 3,5-diacetyl-1,4-dihydrolutidine (DDL) absorbs light at 410 nm and shows a strong fluorescence at 510 nm.

Table 2: Formaldehyde concentration in light, calculated values of RE (reduction efficiency) and EC (elimination capacity) for all four replicates.

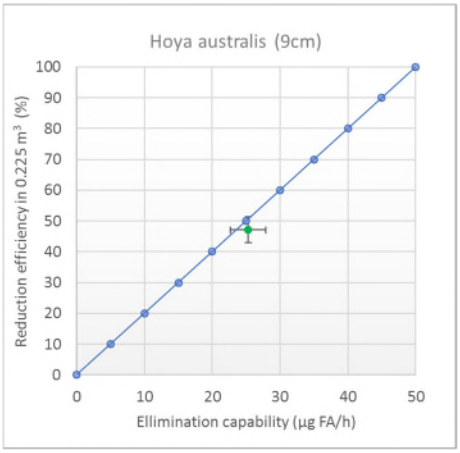
Date	Inlet (µg FA/m^3)	Outlet (µg FA/m^3)	RE (%)	EC (µg FA/kg/h)	EC (µg FA/h)
13.06.2018	109.3 ± 1.5	54.0 ± 6.9	50.6	35.9	24.9
16.06.2018	114.8 ± 1.5	62.7 ± 11.3	45.4	33.3	23.4
20.06.2018	125.4 ± 2.2	73.3 ± 8.6	41.6	40.0	23.5
23.06.2018	127.7 ± 3.0	62.5 ± 11.8	51.0	42.7	29.3

Figure 2: The trendline represent all plants tested. Green circle represents mean and standard error for four replicates of *Hoya australis*. EC is the capacity at ~ 100 µg FA/m^3. RE is the effect in the measuring conditions.

Conclusion

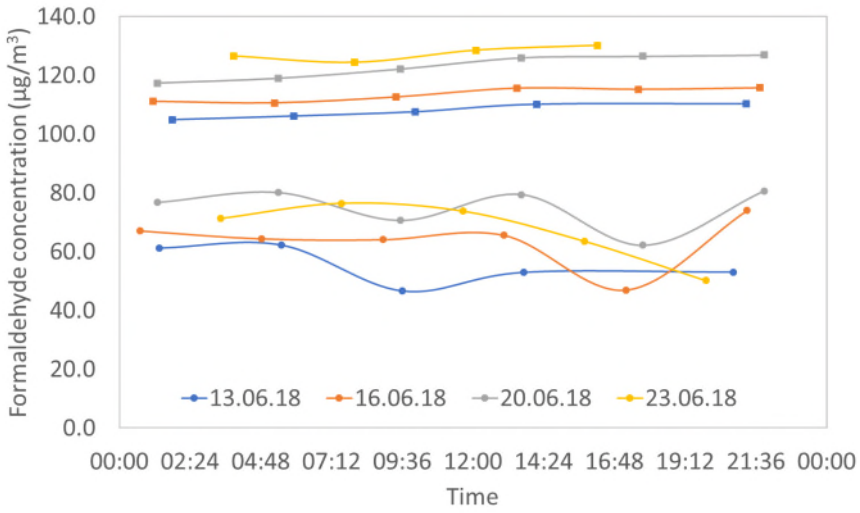
Hoya australis in a 9 cm pot (weight 0.7 kg) has a High aircleaning capacity removing on average 37.7 µg FA/kg plant solution/h. In total for the plant solution ~ 25.3 µg FA/h in light conditions.

Rating list:
Low (0 - 10 µg FA/h)
Medium (10 – 20 µg FA/h)
High (20 - 30 µg FA/h)
Very high (> 30 µg FA/h)



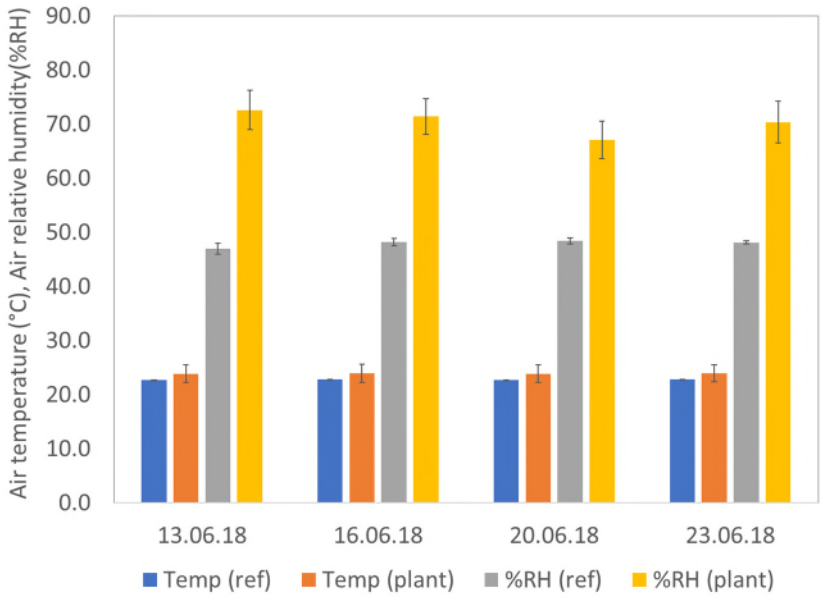
Formaldehyde emission trend and climate

Figur 1. The plot below merely illustrates the semi-quantitative trend of formaldehyde emission during the four measuring days in the test period in the reference chamber (squares) and in the plant chamber (circles). Symbols indicate measuring time points.



Measured by automatic fluorometric on-line analyser: Aero-Laser AL4021.
Method of analysis: Acetylacetone (Hantzsch-reaction).
Limit of quantification (LOQ): 10 µg/m³

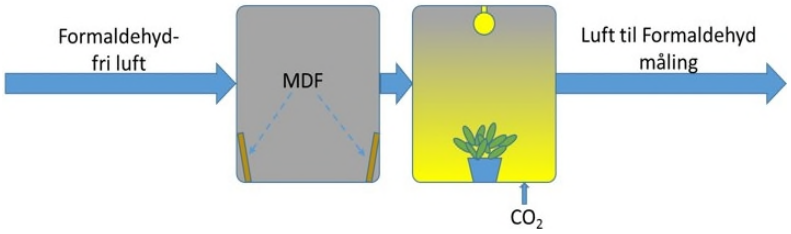
Figur. 2. Average values of air temperature (°C) and air relative humidity (%RH) during the four measuring days



Introduction

This test method defines a standard solution for measuring and estimating the air purifying efficiency and capacity of different types of plant solutions. The method is a two-chamber system (figure 1), which allows steady state emissions of volatile compounds (VOC's) from materials under controlled constant climate conditions in the reference chamber. The air from the reference chamber is directed into the plant chamber, where the air purifying efficiency of the plant solution is estimated together with it's effect on the chamber climate. The estimation of the air purifying plant parameters is based on the inlet and outlet concentration of the VOC, the chamber size and the air exchange of the chamber.

Figure 1: Experimental design



1. Definition af plant solution

A plant solution is, in relation to this specific test method, defined as a specific plant species, or plant cultivar in an unspecified and not sterile growth media, placed in an unspecified plant container. The plant solution has a specific weight, water content and leaf area of which the air purifying capacity can be related to.

2. Request and storage of plant solution

For each test, at least three identical plant solutions are requested from the company. The plant solutions are placed under greenhouse conditions or in an indoor environment and watered when needed, until the test is carried out.

3. Preparation of the plant solution for the test

Before the test, each of the plant solutions are placed in a water bath for one hour, and left to drain for one hour under laboratory conditions, before weighed. The irrigation procedure ensures that the plant solution is fully irrigated before the test, in a standardized way.

4. Experimental setup

The experimental setup is a two-chamber system. A reference chamber connected to a plant chamber with an air tube (fig.1). Both chambers are made of stainless steel. The climate conditions are controlled in relation to air humidity, CO_2 concentration and temperature in the reference chamber, whereas the plant effects on the climate in the plant chamber is allowed and logged. The size of the plant chamber can vary in relation to the needs (e.g. 225 L, 1000 L, 15000 L). In the plant chamber a given lighting solution is installed and connected to a timer. The chosen light level, light duration and light spectrum can vary in relation to the desired test conditions of the plants. A VOC-

source with steady state emission is established in the reference chamber, e.g. a formaldehyde source in the form of MDF plywood panels. In the experimental setup, the supply air is filtered for the reference chamber is first cleaned for VOC's in a water filter before it enters the reference chamber. The VOC-enriched air in the reference chamber is then directed to the plant chamber by an airtight tube. The air exchange rate can vary, but is in general 0.45 m^3/h in the 225 L chamber and 1 m^3/h in the 1 m^3 chamber.

5. Measurements

Air samples are sampled from the inlet and outlet of the plant chamber at a minimum of six time points during the day, and analysed by a specialized formaldehyde analyser (Aero-laser GmbH, Garmish Partenkirchen, Germany). Samples can also be measured for other VOC's by GC/MS or HPLC. Sensors for measuring photosynthetic light intensity (LI-190 Quantum Sensor fra LI-COR, Lincoln, Nebraska USA), temperature and humidity (HMP110 fra Vaisala Oy, Vantaa, Finland) are mounted in the plant chamber and connected to a CR1000 datalogger (Campbell Scientific, Logan, Utah, USA). Climate data are logged throughout the experimental period. The light sensor are positioned at the height of the plant container. CO_2 concentration can also be measured using gas exchange (CIRAS SC CO_2/H_2O analyser, PP systems, Amesbury, Massachusetts, USA).

6. Experimental design

- Number of plants /replicates: Measurements are carried out on a minimum of three replicates per plant solution.

- Experimental plan: The reference chamber and plant chamber are stabilized for a minimum of two days – it will be checked whether the VOC-concentration are at the expected level, and at the same level in the two chambers. The climate measurements are checked for anomaly. At the start of the test the plant solution is watered, drained and weighed before placed in the plant chamber on day 1. Data are collected on day 2, and the plant can be removed from the chamber again on day 3. A maximum of two plant experiments are run, before checking the reference VOC concentration in the two chambers. Before each experiment, each plant is weighed (FW). After the experiment the plant is weighed again. The shoot is separated from the plant container and weighed (FW), then dried at 80°C and weighed again (DW). It is also a possibility to measure total leaf area before drying.

- Calculations: Based on the measurements in the reference chamber and in the plant chamber the relative air purifying efficiency (relative elimination efficiency – RE) and air purifying capacity (elimination capacity – EC) can be calculated.

  $RE = (C_{in} - C_{out})/C_{in}) \times 100 = \%$

  $EC = Q\ (C_{in} - C_{out}) / S_L = \mu g\ FA/m^3/t$

  Q ~ Air exchange rate in the plant chamber (m^3/h)

C_{in} og C_{out} ~ Inlet og outlet concentration of the VOC

S_L ~ total leaf area, total weight of plant solution (FW) or just "plant solution".

RE describes the efficiency of the plant solution to remove a given VOC in the test conditions, of which the size of the climate chamber, the air exchange rate and the VOC concentration in the chamber have great influence. Furthermore, the volume and surface area of the plant container and the plant, the water content, type of growing media and the unspecified content and composition of the microflora is also important. Also, it matters how active growing and transpiring the plant is.

EC describes the capacity of the plant solution to remove a given VOC. The capacity increase with increased concentrations of the VOC. EC is independent of the size of the chamber and the air exchange rate, but depending on the specific plant solutions size, form and activity. EC can be compared between different types of plant solutions as long as the experimental conditions are comparable at ~ 100 µg FA m^{-3} in a chamber of 225 L, a temperature of 23°C, an air humidity of 50% (reference chamber) and a light level of 50 µmol m^{-2} s^{-1} at table height (plant chamber).

General Terms and Conditions regarding Commissioned Work Accepted by the Danish Technological Institute*

General stipulations

These General Terms and Conditions shall apply to all commissioned work performed by the Danish Technological Institute ("the Institute") for a contract party (the "customer"), including, but not limited to, counselling, instruction, information retrieval and communication, testing, research, sale and leasing. Unless otherwise agreed, these General Terms and Conditions shall also apply to any other and subsequent agreements between the Institute and the customer. Unless specifically accepted in writing by the Institute, any deviating provisions or provisions to the contrary contained in the order placed by the customer or in his acceptance shall not apply.

However, the Institute's "General Terms and Conditions regarding Certification, Inspection or Approval Bodies Associated with the Danish Technological Institute" shall apply to commissioned work relating to certification, inspection or approval schemes.

1. Scope of commissioned work

1.1 The nature, contents and financial conditions of the commissioned work shall be stated in a written agreement. Any amendments to the agreement shall be in writing.

1.2 Time schedules, price estimates, etc. are approximate unless otherwise agreed in writing. If the Institute foresees major delays or budget overruns compared to the agreed terms or material obstacles to the performance of the commissioned work, the customer shall be informed thereof, following which he shall be entitled to change or stop the work, cf. clause 6.1.

1.3 The Institute shall be entitled to a fee for work performed regardless of whether the results expected by the customer are achieved, unless it has been agreed in writing between the parties that the Institute's fee is contingent upon the achievement of concrete, specified results.

1.4 The Institute shall be entitled to have commissioned work performed by a sub-contractor.

2. Professional discretion

2.1 The Institute will observe customary professional discretion with respect to disclosure of the performance of commissioned work and with respect to any agreements. A special agreement in writing shall be concluded if the customer requires secrecy as such, for example regarding know-how of the customer that may come to the knowledge of the Institute during the performance of commissioned work.

2.2 If any test or development work leads to results of interest to the general public, the Institute may publicly announce such results unless otherwise agreed in a secrecy agreement as mentioned under clause 2.1.

2.3 When the Institute undertakes work that involves an assessment of a service provided by a third party, the customer accepts and understands that the Institute may approach such third party and other relevant bodies in order to obtain information for use in performing the work.

2.4 The Institute shall at any time be entitled to pass on information, which the Institute is under a statutory obligation to disclose.

2.5 If, in the course of performing commissioned work, the Institute becomes aware of factors that in the opinion of the Institute may cause material damage to health or environment, the Institute may, if required, inform the customer thereof. In the event that the customer does not, as quickly as possible, take the steps necessary to prevent or limit the risk of material damage to health or environment, the Institute shall, notwithstanding any separate agreement on discretion or secrecy, be entitled to pass on such knowledge to the relevant authorities.

3. Reference to results, etc.

3.1 The customer may only publish the reports of the Institute in their entirety.

3.2 The customer may not mention or refer to the Institute or the Institute's employees for advertising or marketing purposes unless the Institute has granted its written consent in each case. Such consent shall lapse if the customer stops or postpones the work, cf. clause 6.1.

3.3 Course material issued by the Institute may not be copied or duplicated. Course material on loan from the Institute shall remain the property of the Institute.

3.4 The Institute shall be entitled to demand that the customer returns reports, etc. prepared by the Institute together with the pertinent documents if the Institute discovers any errors or defects in such material.

4. Rights relating to the results of the commissioned work

4.1 The tangible material produced by the Institute in connection with commissioned work and the right to utilise such material, shall be the property of the customer.

4.2 Know-how and other intangible property rights developed by the Institute or ascertained by the Institute in connection with performing the work shall be the exclusive property of the Institute.

5. Fees and terms of payment

5.1 Commissioned work shall be performed according to account rendered based on the hourly rates from time to time fixed by the Institute including transport charges and other outlays.

5.2 In respect of long-term work, the Institute shall be entitled regularly to adjust the hourly rates stated under 5.1. The customer shall receive notice of such adjustments 30 days prior to the date on which they come into force.

5.3 The Institute shall be entitled to issue invoices on account once a month for work performed in the past month.

5.4 In case of overdue payment of balances due to the Institute, interest shall be charged at the rate of 1.5% for each commenced period of one month.

6. The right to change and cancel orders

6.1 If the customer issues instructions to stop or postpone the work, cf. clause 1.2, work already performed shall be paid for according to invoice, just as the customer shall reimburse the Institute for any costs incurred in connection with the cancelled or postponed work that the Institute has already undertaken to pay, such as expenses to a third party, special equipment or premises, etc.

6.2 Moreover, the nature or scope of commissioned work may only be changed subject to the written consent of the Institute.

7. Liability

7.1 The Institute shall be liable towards the customer for any errors and negligence in connection with the performance of the work pursuant to the general rules of compensation of Danish law, subject to such limitations as follow from clauses 7.2 to 7.12. the Institute shall in no event be liable for circumstances or events causing a loss that are not attributable to any errors or negligence on the part of the Institute.

7.2 If the performance of commissioned work is stopped or postponed (cf. clause 6), the Institute shall not be liable for any defects or errors in work already performed.

7.3 The Institute shall not be liable for injury or damage arising in connection with the use of counselling provided by the Institute or test or control reports prepared by the Institute if the use thereof is outside the scope of the commissioned work or the specified objects.

7.4 If the Institute's work is not concluded with a report or the delivery of a service, or if the service provided consists of a statement in which it is specified that it is based on an estimate or assessment, the Institute shall not be held liable unless the Institute is guilty of gross negligence.

7.5 Unless the Institute has issued a written warranty for the completion of the work at a specific time, the Institute shall not accept liability for loss or damage caused by delays in the performance of commissioned work.

7.6 The Institute shall not be held liable for tortious acts on the part of any one of the Institute's sub-contractors, unless such sub-contractor has been appointed by the Institute without being proposed or approved by the customer.

7.7 In case of joint liability between the Institute and one or more parties, the Institute shall only accept liability for such proportion of the loss suffered by the customer as is accounted for by the share of the overall liability attributable to the Institute.

7.8 If the Institute has undertaken, on behalf of the customer, to verify that services provided by a third party to the customer are according to contract, the Institute shall only be held liable for loss or damage that the customer might suffer owing to the Institute's failure to point out, in due time, that a specific service is not according to contract. Thus, the Institute's liability shall be subordinated to the claim for compensation that the customer may make against the third party in question, and the Institute's liability shall moreover by subject to the other limitations stated in this clause 7.

7.9 If the Institute has received samples or equipment from the customer, the Institute shall exclusively be held liable for loss of or damage to such samples or equipment if an agreement in writing has been made with the customer to return such samples and equipment. In addition, in such event, the Institute shall only be held liable if it can be substantiated that the Institute is guilty of gross negligence, and the compensation can in no event exceed the cost of the material necessary for manufacturing the samples or equipment in question. If the return of samples and equipment has not been agreed upon, the Institute will only keep such samples and equipment for a period of up to six months after the completion of the work.

7.10 The Institute cannot be held liable for more than the direct loss suffered by the customer. Thus, the Institute shall not be held liable for losses on operations, loss of earnings or any other indirect losses. The Institute's total liability shall not exceed DKK 1,000,000 for each individual claim except for bodily injury according to Danish law.

7.11 If any third party holds the Institute liable for bodily injury or damage to property caused by work performed by the Institute, including, but not limited to, product liability, the customer shall be obliged to indemnify and hold the Institute harmless from any claim exceeding the amount of any claim(s) that can be brought against the Institute pursuant to the provisions of this clause 7. The Institute may request the customer to defend any such claim on behalf of the Institute.

7.12 The Institute cannot be held liable for claims regarding loss, damage or injury that have not been made in writing within three years after delivery by the Institute of the service in respect of which the claim is made. In addition, the Institute's liability is contingent upon the customer complaining in writing as soon as he has become aware of, or should have become aware of, the existence of a potential claim for compensation against the Institute. Notwithstanding the said time limit of three years, the Institute shall not be liable for any damage or injury that was impossible to foresee in view of the know-how and technology available at the time of the performance of the commissioned work.

7.13 If the Institute is prevented from performing its obligations under the agreement as a result of extraordinary external factors which should not have been foreseen by the Institute at the time when the agreement was concluded (force majeure), this will not be deemed to constitute breach.

8. Disputes

8.1 Any dispute or controversy arising between the Institute and the customer shall be settled according to Danish law by the Court in Glostrup, Denmark, however, if the case is within the jurisdiction of the Danish Maritime and Commercial Court, the case will be brought before the said Court.

Marts 2015

* In Danish, the name “Teknologisk Institut” is used.

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