Developing and implementing formaldehyde online-senor systems in wood-based panel processing (*WoodSens*)

FINAL REPORT

Title of the research project	**Developing and implementing formaldehyde online-senor systems in wood-based panel processing**
Coordinator of the project	Dr. Carsten Mai

BASIC PROJECT DATA

Project period	01.10.2010 - 31.03.2014 / 30.04.2014 [UGOE]
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URL of the project	http://www.woodsens.com

FUNDING

Total budget in EUR	1 270 068 EUR

Public funding from WoodWisdom-Net Research Programme:	Total funding granted in EUR by source:	
France Ministry of Agriculture, Food and Forestry	110 000,00	EUR
Germany Federal Ministry of Food and Agriculture (BMEL)/ Project Management Agency FNR	658 793,40	EUR
Spain Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria INIA	73 245,10	EUR

Other funding INDUSTRY PARTNERS etc:		
Fagus-GreCon Greten GmbH & Co KG, Germany, self financing	109 052,42	EUR
Glunz AG, Germany, self financing	121 394,08	EUR
FCBA Institut technologique, France, self financing	56 000,00	EUR
Ecole supérieure du Bois (ESB), France, self financing	51 802,00	EUR
IMPIVA, Spain	89 781,00	EUR

PROJECT TEAM (main participants)

Carsten Mai, Dr., Senior scientist	M	University of Göttingen	Germany	Federal Ministry of Food and Agriculture (BMEL)/ Project Management Agency FNR
Sarah Himmel, PhD-student	F	University of Göttingen	Germany	Federal Ministry of Food and Agriculture (BMEL)/ Project Management Agency FNR
Sascha Brinker, PhD-student	M	University of Göttingen	Germany	Federal Ministry of Food and Agriculture (BMEL)/ Project Management Agency FNR
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Jörg Hasener, Dr. R&D	M	Fagus-GreCon-Greten GmbH & Co KG	Germany	Federal Ministry of Food and Agriculture (BMEL)/Project Management Agency FNR
Vera Steckel, Dr. R&D	F	Fagus-GreCon-Greten GmbH & Co KG	Germany	Federal Ministry of Food and Agriculture (BMEL)/ Project Management Agency FNR

Alfred Pfemeter, Dr. Corporate R&D Manager	M	Glunz AG	Germany	Federal Ministry of Food and Agriculture (BMEL)/ Project Management Agency FNR
Mark Irle, Dr. Research Director	M	Ecole supérieure du Bois	France	Ministry of Agriculture, Food and Forestry
Guillaume Legrand, Technical Manager (Adhesives and panels testing)	M	FCBA Institut technologique	France	Ministry of Agriculture, Food and Forestry
Rosa Perez,	F	AIDIMA	Spain	Instituto Nacional de Investigación y Tecnología Agrariay Alimentaria INIA
Pablo Rodríguez,	M	AIDIMA	Spain	Instituto Nacional de Investigación y Tecnología Agrariay Alimentaria INIA
Miquel Angel Abián,	M	AIDIMA	Spain	Instituto Nacional de Investigación y Tecnología Agrariay Alimentaria INIA

DEGREES
Degrees earned or to be earned within this project.

2012	Master of Science	F	Christine Martino, 1984, M.Sc. in 2012	University of Göttingen	Dr. Carsten Mai, UGOE Dr. Christoph Lenth, LLG
2013	Master of Science	M	Peter Grimann, 1984, M.Sc. in 2013	University of Göttingen	Dr. Carsten Mai, UGOE

ABSTRACT

The main objective of the project was the development of systems to determine formaldehyde emissions of wood-based panels both in a laboratory and online or atline during production of the panels. The system to be used in the laboratory should be capable of complementing, or, at best, replacing the established methods for determination of formaldehyde release / content during production control. With the online / atline system, measuring formaldehyde emission parallel to production should be established in order to integrate the results into statistic process control. Another focus of the project was to study the effects of various raw materials (e.g., recycled wood), and of production parameters on the formaldehyde release of particle boards. Furthermore, a process model based on multivariate data analysis should be build to improve the understanding of interrelations between process and product.

The system for determining formaldehyde release from wood-based panels established in this project consists of a combination of Solid Phase Micro Extraction (SPME) for sample preparation with a GC-FAIMS-system (Gaschromatography-High Field Asymmetric Waveform Ion Mobility Spectrometry) for qualitative and quantitative analysis. The GC-FAIMS-device was adapted to the requirements of the task and in part newly developed during the project. The system was tested during several trials at a manufacturer's site. It was shown that particles as well as small blocks were suitable as sample material for SPME-GC-FAIMS. The measuring interval was 20 to 25 minutes, thus being much quicker than standardised methods (perforator, gas analysis) which need several hours to yield results. A correlation between the results of SPME-GC-FAIMS and of the standardised methods was established. Because of the short intervals between the measurements the developed system is well suited for process control. But the precision has to be improved in order to substitute the established methods for production control. This can be realized by further automating the system.
Regarding the effects of raw materials and production parameters on the formaldehyde release of particle boards, laboratory trials showed that using recycled wood has an influence on the formaldehyde release of the product. Even when employing formaldehyde free resins, the use of moderate amounts of relatively high-emitting recycled wood can be a challenge when producing very low-emitting particle boards. In contrast, no effect of pressing factor or resin load was observed.

Other experiments determined that formaldehyde is relatively mobile within a particleboard mattress during hot-pressing. It was found that formaldehyde emission is relatively uniform across a panel immediately after hot-pressing. This is indicates that the use of a single sensor to estimate panel emission is valid.

1.1 Introduction

1.1.1 Background

Consumer products containing wood-based panels (WBP) may release gaseous formaldehyde depending on the environmental conditions and the way the product was made. These potential emissions have resulted in a significant amount of health-related debates, research on the development of non-formaldehyde based adhesives and changes in regulations. In 2004, formaldehyde was classified as a carcinogenic agent by the IARC (International Agency for Research on Cancer; WHO). This has caused governments and industry to establish lower formaldehyde emission limits. In addition, the markets increasingly demand ultra-low formaldehyde emitting products. Lower formaldehyde standards challenge production processes as margins and tolerances become narrower. Therewith, the requirements (resolution, repeatability) of standardized test methods increase accordingly. In addition, the volume actually tested relative to the volume produced is miniscule, increasing the possibility that the actual result is not representative of the panels produced. Therefore, there is a need to provide industry with the capability to continuously control formaldehyde emissions whilst the products are made.

There is strong support for the recycling of wood into new products such as particleboard. New challenges, however, arise from recycling. For example, recovered wood contains glued wood products that were made using “old” adhesive technology. Thus, when recovered wood is included there is a danger that formaldehyde emission levels may exceed current and forthcoming strict regulations. There is, however, a lack of studies concerning formaldehyde content of recovered wood and of the effects of heterogeneous raw material assortments on the formaldehyde release of particleboards made from recovered wood. Moreover, mutual factors for formaldehyde emission from particleboards such as process parameters and adhesive properties are insufficiently known.

1.1.2 Objectives

WoodSens aimed at developing and applying a new sensor technology to the manufacture of WBP products such as particleboards, in order to significantly improve their quality and safety, particularly with regard to their formaldehyde emissions. The new sensor technology should enable WBP manufacturers to ensure that their products conform to the latest and forthcoming regulations on formaldehyde emission by monitoring and controlling formaldehyde emissions from the WBP in real time.

To achieve the main outcome, the key objectives of the project were:

a) The development of a laboratory sensor system to directly detect the gaseous formaldehyde emissions of WBP-samples.
b) The development and verification of an atline-sensor system in industrial plant trials. In parallel a statistical process model should be developed to predict the final formaldehyde emissions from the WBP in real time.

c) Fundamental research on the relationships between raw material characteristics, process parameters and formaldehyde emissions during and after hot-pressing.

1.2 Results and discussion

Main achievements of the project, quality, innovativeness, industrial relevance and contribution to competitiveness, environmental and societal impact.

- The first main objective, direct detection of gasous formaldehyde from WBP, has been achieved with the SPME-GC-FAIMS system. Due to problems regarding the originally used installation, the device and methods had to be adapted and partially redesigned to fit requirements. The current system uses Solid Phase Micro Extraction (SPME) for sampling and a GC-FAIMS system (Gaschromatography-High Field Asymmetric Waveform Ion Mobility Spectrometry) for analysis. The combination of both techniques allowed a qualitative and quantitative analysis of formaldehyde emissions and might even detect VOCs.
  The next aim was the development and verification of the system for an atline application. Therefore several field trials have been conducted using the laboratory device at a production site, which revealed further improvement opportunities. It has been shown that sample preparation was possible either with particles or small blocks and the measuring interval was 20 to 25 minutes. The short measuring time and the independence of the sample preparation demonstrated the superiority of the SPME-GC-FAIMS system over the standardised methods (perforator, gas analysis). Correlation between the different methods was also established. On the one hand, a final evaluation concluded that the available system cannot be used for production control due to its complexity and its current level of uncertainty about new predictions. On the other hand, it could be used as a fast on-site method for process management based on the real time study of trends. Because of the short intervals between the measurements the developed system is well suited for process control. But precision and user friendliness have to be improved in order to substitute the established methods for production control. This can be realized by further automating the system.
- Influence of raw material characteristics and process parameters on the mechanical properties and formaldehyde emissions have also been investigated in laboratory trials. It has been shown that recycled wood has an influence on the formaldehyde release of the new product. Determination of formaldehyde content and emission from old furniture revealed a high contamination and consequently a high potential of increasing the values in new products. Even particleboards bonded with formaldehyde free resins but containing moderate amounts of highly contaminated recycled wood particles could exceed the permitted emission levels of standards for low emitting products.
- The envisaged final application of a fully developed FAIMS-based sensor is for a single sensor placed soon or immediately after the hot-press. Such a system would not be accurate if the formaldehyde emission from recently pressed products varied from place to place. Consequently, experiments were conducted to assess the mobility of formaldehyde during hot-pressing. It was found that when formaldehyde is added to a

mattress prior to pressing that it became uniformily distributed across the panel. When pieces of high emitting product were included in a mattress then it was found that the emission was not uniform, but, that the formaldehyde free zones of the panel did become contaminated by the end of hot-pressing. Consequently, the differences between the contaminated and non-contaminated zones were significantly reduced. It is therefore concluded that formaldehyde is highly mobile within the mattress during the hot-pressing step.

1.3 Conclusions

The most important contributions to the state-of-the-art, derived from the results and discussion.

From the results reported above it can be concluded that *WoodSens* has successfully

- developed a laboratory measuring device and method that is capable of directly detecting gaseous formaldehyde from various WBP sample preparations in a qualitative and quantitative way.
- shown that the SPME-GC-FAIMS system might also be used for the detection of VOCs
- shortened the measuring interval from several hours to 20 – 25 minutes in comparison to standardised methods
- provided a good basis for enhancing the SPME-GC-FAIMS system to an online / atline system
- generated new knowledge about the mutual influences of raw material characteristics and process parameters in the production of particleboards

1.4a Capabilities generated by the project

Knowledge generated in the project / outcomes of the project, such as unpublished doctoral theses, patents and patent applications, computer programs, prototypes, new processes and practices; established new businesses; potential to create new business opportunities in the sector.

New processes and practices:
Fast method to measure formaldehyde emissions from WBP by SPME-GC-FAIMS was developed.

Computers programs:
A software to analyse 2-dimentional and 3-dimentional FAIMS chromatogrammes was develpoed by LLG and Schumann-Analytics and is marketed by Schumann-Analytics (Einbeck, Germany).

Prototypes:
A GC-FAIMS device for general applications (not formaldehyde) is marketed by Schumann-Analytics (Einbeck, Germany).

Patents and patent applications:
- European Patent (EP 2 511 703 A1, 2012)
- German Patent (DE 10 2011017 280 A1, 2012)

Potential to create new business opportunities in the sector:
- In addition to the fast detection of formaldehyde, a new method for measuring VOCs could be developed based on this technique.

Unpublished doctoral thesis and student works:
A number of students and young scientists have been engaged in different *WoodSens* projects and two of them have been working in *WoodSens* projects as part of their doctoral studies.

1.4b Utilisation of results

Give a brief description of how the results of the research and development have been used and/or what is the exploitation plan or plans for transferring the results into practice.

- During the project the SPME-GC-FAIMS has been adapted to the requirements of measuring formaldehyde in a much faster and possibly more precise way than the established standards. It now provides a good basis for a progression to the desired online / atline system when the degree of automation can be enhanced.

- The results show that the SPME-GC-FAIMS system is also able to detect VOCs which increases the competitiveness of the device. It is conceivable to develop a new method for measuring VOCs based on the generated technologies of *WoodSens*.

- Subcontractor Schumann Analytics has developed a GC-FAIMS and evaluation software for general use which are marketable now.

- The knowledge obtained about the influences of raw materials and process parameters on the formaldehyde emission could help further research projects to design optimized processes for the production of low emitting boards.

- Dissemination of results has been done by various publications and conference participations. Further publications are planned.

1.5 Publications and communication

a) Scientific publications

1. Articles in international scientific journals with peer review

Schumann A, Lenth C, Hasener J, Steckel V (2012). Detection of volatile organic compounds from wood-based panels by gas chromatography-field asymmetric ion mobility spectrometry (GC-FAIMS). Int J Ion Mobil Spec. 15 (3):157-168.

Himmel S, Irle M, Legrand G, Perez R, Mai C (2013). Effects of recovered wood on the formaldehyde release of particleboards. Holzforschung, DOI: 10.1515/hf-2013-0131

Himmel S, Mai C, Schumann A, Hasener J, Steckel V, Lenth C (2014). Determination of formaldehyde release from wood-based panels using SPME-GC-FAIMS. Int J Ion Mobil Spec. 17:55–67

IRLE, M.A. & BELLONCLE, C. (2014). A study of the mobility of formaldehyde during hot-pressing of particleboard mattresses. Accepted for the International Wood Products Journal. Originally presented at International Panel Products Symposium, Llandudno, 9-10 October, 2013.

2. Articles in international scientific compilation works and international scientific conference proceedings with peer review

Lenth C, Schumann A, Hasener J, Steckel V, Himmel S, Mai C (2013). Developing a new method of measuring formaldehyde emission of wood-based panels. International Panel Product Symposium 2013, Bangor Wales UK. Conference proceeding. 49-57.

Irle M, Belloncle C (2013). A study of the mobility of formaldehyde during hot-pressing of particleboard mattresses. International Panel Product Symposium 2013, Bangor Wales UK. Conference proceeding. 75-81.

Himmel S, Irle M, Legrand G, Perez R, Mai C (2013). The influence of the presence of recovered wood on the formaldehyde release of particleboards. International Panel Product Symposium 2013, Bangor Wales UK. Conference proceeding. 179-188.

3. Articles in national scientific journals with peer review

4. Articles in national scientific compilation works and national scientific conference proceedings with peer review

5. Scientific monographs

Martino C (2012). Exploration of a method for quantitative determination of formaldehyde emissions from wood-based materials by coupling of SPME, GC and IMS. University of Göttingen, Master thesis.

Grimann P (2013). Aging behaviour of urea- formaldehyde adhesives. University of Göttingen, Master thesis.

Ghorbel M. (2014) Progress of the calibration and measurement with the Aerolaser & Analysis of formaldehyde emission from old furniture. Second year mark (equivalent to the first year of an MSc at the EU level); Ecole supérieure du Bois.

6. Other scientific publications, such as articles in scientific non-refereed journals and publications in university and institute series

a) Other dissemination

Anual Report 2013 Laser-Laboratorium Göttingen e.V.
Anual Report 2012 Laser-Laboratorium Göttingen e.V.
Anual Report 2011 Laser-Laboratorium Göttingen e.V.

b) Conferences and international fairs

Irle M.A., Belloncle C (2012). Dynamic Measurement of Formaldehyde Emissions from Wood-based Panels. BioComp-2012, 11th Pacific Rim Bio-Based Composites Symposium, 27-29 November 2012, Shizuoka, Japan Keynote presentation

Perez R. (2012). Diffusion by slides. Presentation during the HABITAT FAIR, Valencia, Spain

Schumann A, Lenth C, Steckel V, Hasener J (2012) Detektion von VOCs aus Holzwerkstoffen mittels GC-FAIMS; 4. Anwendertreffen Ionenmobilitätsspektrometrie; Conference presentation.

Lenth C, Schumann A, Hasener J, Steckel V, Himmel S, Mai C (2013). Developing a new method of measuring formaldehyde emission of wood-based panels. International Panel Product Symposium 2013, Bangor Wales UK. Conference presentation.

Irle M, Belloncle C (2013). A study of the mobility of formaldehyde during hot-pressing of particleboard mattresses. International Panel Product Symposium 2013, Bangor Wales UK. Conference presentation.

Himmel S, Irle M, Legrand G, Perez R, Mai C (2013). The influence of the presence of recovered wood on the formaldehyde release of particleboards. International Panel Product Symposium 2013, Bangor Wales UK. Conference presentation.

Himmel S, Mai C, Schumann A, Hasener J , Steckel V, Lenth C (2014). Bestimmung von Formaldehyd aus Holzwerkstoffen mittels SPME-GC-FAIMS. 5. Anwendertreffen Ionenmobilitätsspektrometrie, Essen, Germany. Conference presentation.

Hasener J., Steckel V. (2014). Weiterentwicklung in der Emissionsmesstechnik der Formaldehydabgabebestimmung, Präsentation, 4. Fachtagung Umweltschutz in der Holzwerkstoffindustrie, 15.-16. Mai 2014, Göttingen, Germany. Conference presentation.

1.6 National and international cooperation

Give a brief description of the cooperation/ networking (partnership between the project participants and how this has developed; industrial involvement; synergies of industrial and research expertise; Has the project collaborated with similar projects in the WW-Net countries or other regions, or established new links with/ between local or international organisations involved in the respective research field? Describe how these partnerships have supported the project.
National vs. transnational aspects in the project; added value for the project and its impacts which result from transnational cooperation.

International and interdisciplinary collaboration between specialized departments of sensor technology and wood technology, research facilities and industrial partners led to a lively exchange of knowledge and experiences as well as the success of the whole project.

- The number of participants in the *WoodSens* project can be described as ideal.
- The cooperation of five research institutes and two industry partners was fruitful and productive over the total project duration.
- Round-Robin tests gave project results and allowed research institutes to compare their procedures
- The involvement of the WBP producer and a producer of measuring devices for the WBP industry was beneficiary. The good cooperation enabled industrial trials with the measuring device and revealed further improvement opportunities.
- The transnational cooperation was helpful to strengthen relationships in the European sector of wood sciences and technologies and allowed to generate new perspectives

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Dr. Carsten Mai, Project Coordinator