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# Odorant Emissions from the Storage and Combustion of Agricultural Biomasses

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**Abstract.** Actions against global warming have allowed the development of new fuels from renewable sources such as agricultural biomasses for direct combustion. However, emerging biomasses are susceptible to create social concerns e.g. unpleasant odour emissions producing cohabitation issues. The present study aims (1) to explore the potential of agricultural biomass to create discomfort and problems related to odour emissions during storage and direct combustion and (2) to develop a method for sampling and measuring odours emissions at these conditions. Three agricultural biomasses were tested: switchgrass, willow and dried solid fraction of pig manure. Emissions from wood were also measured for comparison purposes. Odours were measured from a small-scale set-up which simulating closed biomass storage. On the other hand, each biomass was burned in a 17kW multi-fuel pellet burner and released gases were sampled at the chimney for odour analysis. All odour samples were analyzed by dynamic olfactometry in accordance with European Standard NF-EN-13725 (2003). Results showed that, at the storage, the odour emission and the hedonic tone of the agricultural biomass evaluated are not significantly different than wood emissions. Similarly, at the direct combustion tests, even if the odour resulting from the solid fraction of pig manure was the most noticeable and the least pleasant, agricultural biomass are not significantly different than wood. According to the results obtained in this study, storage, handling and burning of agricultural biomass do not cause olfactory trouble larger than wood practices. Thus, in terms of cohabitation, exploitation of biomass for energy production is feasible.

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## Introduction

Actions against global warming have allowed the research and development of new fuels originated from renewable sources such as forest and agricultural biomass fuels for use in direct combustion systems. However, this valorisation technique involves some environmental, health and social concerns. As part of a research project aiming to characterize the emissions from the combustion of agricultural biomass fuels (Brassard et al., 2012), it appeared that such practice could lead to odour emissions liable to cause a future problem of cohabitation. In fact, besides to have an interesting energetic value, agricultural biomass fuels should satisfy concerns in order to replace successfully fossil fuels. The aim of the present study was to evaluate the potential of some biomass fuels to create odorant discomforts during their storage and their combustion. The specific objectives of the present project were (1) to develop a reproducible method for sampling and measuring the odorant emissions from biomass fuels storage, and (2) to evaluate the odour emissions from the storage and the combustion from different agricultural biomass fuels.

## Materials and Methods

Three agricultural biomass fuels were evaluated: fast growing willow, switchgrass and dried solid fraction of pig manure (SFPM). Moreover, commercial wood pellets (a mixture of black spruce and jack pine) were used as reference. All four biomasses were on pellet form. Odorant emission tests both from the storage and from the combustion of the biomass fuels were performed in a completely random arrangement including three repetitions.

### *Sampling odorant emissions from the biomass fuels storage*

Since odour control in commercial buildings for storage is provided by the ventilation system (Pelletier et al., 2004), a small-scale assembly simulating a ventilated closed storage of biomass fuel was set up in order to sample odorant emissions (figure 1a). The small-scale warehouse is composed of a 50 L sealed bag made in Nalophane® where the biomass was introduced. The Nalophane®, often used in olfactometry analyses (Godbout et al., 2010 and Martel et al., 2010), is an odourless material which guarantees non-odour adsorption. Moreover, in order to simulate the ventilation of a warehouse, a valve was installed at each end of the bag and 5 LPM airflow was forced to circulate through the bag. The 5 LPM airflow was based according to the ventilation rate recommended by ASHRAE (2001) for a commercial warehouse (0.25 L $s^{-1}$ $m^{-2}$).

A carbon filter was installed between the pump and the small-scale warehouse in order to prevent air contamination by fine particles into the samples. Afterwards, the air exhausting from the assembly was collected in a Nalophane® sampling bag (figure 1c) (patent pending). All Nalophane® bags were made at the IRDA Institute using materials complying with the EN 13725 standard (CEN, 2003).

### *Sampling odorant emissions from the biomass fuels combustion*

Non scientific information was found about an odour analysis method from the combustion of biomass fuels. For the present research, flue gas samples were collected directly from the chimney of a 17.58 kW nominal output biomass pellet stove (Enviro Omega, Vancouver, Canada). A probe inserted into the chimney and a sampling lung extracted the flue gas exhausting from the combustion appliance. Flue gas samples were collected in a 50 L Nalophane® bags. Each combustion test (Brassard et al., 2012) included a period for the stabilisation of the burning conditions (50 min) before the sampling period (around 10 min).

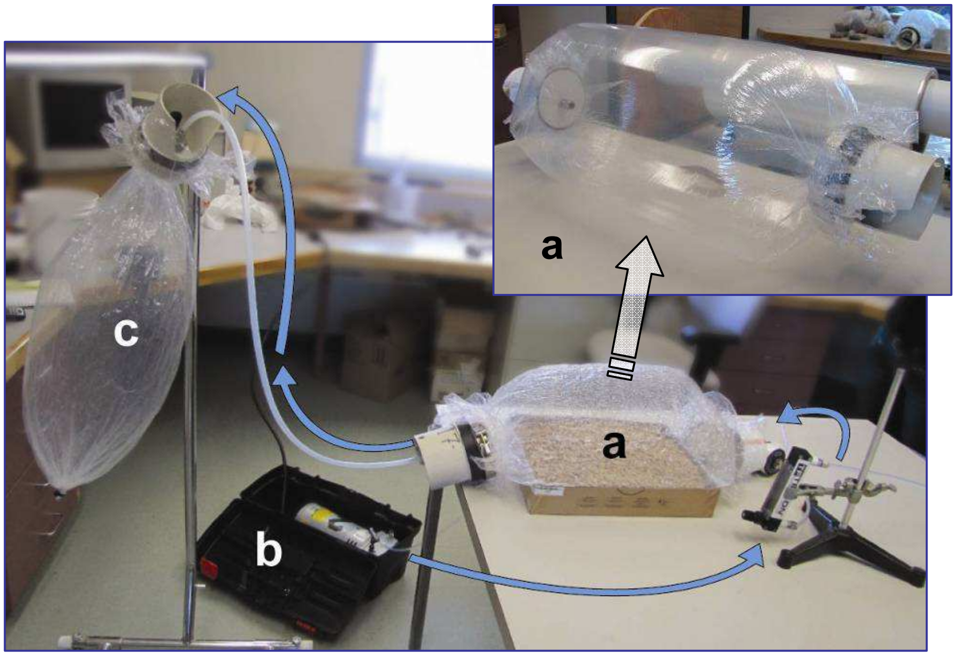


Figure 1. Setup for sampling odorant emissions from the biomass fuels storage; a. Small-scale assembly simulating a ventilated closed storage of biomass fuel; b. Pump for ventilating the simulated storage; c. Nalophane® bag for sampling the air exhausted from the simulated storage.

### *Odour measurement and emission calculation*

All sampling bags both from small-scale biomass storage and biomass combustion tests were analysed within 24 h after sampling by dynamic olfactometry (Odile olfactometrer, Odotech inc., Montréal, Québec, Canada) at the mobile laboratory of olfactometry at IRDA. This laboratory allows the dilution of the olfactory perception threshold by triangular choice for evaluating both the odour concentration and the olfactory perception threshold of an odorous gas sample. Moreover, the laboratory includes six sniffing posts where selected panellists evaluate the samples. For the selection and training, panellists evaluate previously the perception threshold of butanol at different concentrations.

Besides the odour concentration, hedonic tone (pleasant or unpleasant tone of a sample) was also evaluated by the panellists in a qualitative manner scoring on a numerical scale from -5 (very unpleasant) to 5 (very pleasant).

The odour emissions from the small-scale biomass storage and the biomass combustion were calculated using equation 1 and 2, respectively. A statistical analysis were carried out, in one hand, by a mixed linear model using the PROC MIXED procedure from SAS (Littell et al., 2006) in order to analyze the effects of the biomass fuels on the odour emissions. In the other hand, the Fisher exact test was used to evaluate the association between the hedonic tone and the biomass fuel.

$$E_S = \frac{[OU] \cdot Q_S}{CV \cdot M} \quad [1]; \qquad E_C = \frac{[OU] \cdot Q_{CH}}{CV \cdot CR} \quad [2]$$

Where: $E_S$: Odour emission at storage ($OU_E$ $MJ^{-1}$ $min^{-1}$); $E_C$: Odour emission from combustion ($OU_E$/MJ); [OU]: Odour concentration ($OU_E$ $m^{-3}$); $Q_S$: Ventilation rate at storage ($m^3$ $min^{-1}$); $Q_{CH}$: Flow of combustion gases in the chimney ($m^3$ $min^{-1}$); CV: Calorific value of the biomass fuel (MJ $kg^{-1}$); M: Mass of biomass in the small-scale storage (kg), and CR: Combustion rate (kg $min^{-1}$).

## Results

The odour concentration and the odour emission exhausting from the wood storage were higher (1 209 $OU_E$ $m^{-3}$ and 0.085 $UO_E$ $MJ^{-1}$ $min^{-1}$, respectively) than from agricultural biomasses (from 279 to 531 $OU_E$ $m^{-3}$ and from 0.026 to 0.065 $OU_E$ $MJ^{-1}$ $min^{-1}$, respectively for the odour concentrations and the odour emissions) (table 1). The fast growing willow had the lowest odour emission (0.026 $UO_E$ $MJ^{-1}$ $min^{-1}$) and had a tendency to be significantly different (P=0.04). However, globally, there is no significant effect of the type of biomass on the odour emissions.

Table 1. Odour concentrations, odour emissions and hedonic tone from the biomass fuel storage.

| Biomass fuel | Average odour concentration ($OU_E$ $m^{-3}$) | Odour emission ($UO_E$ $MJ^{-1}$ $min^{-1}$) | | | Hedonic tone |
|---|---|---|---|---|---|
| | | Lower bound | Upper bound | Average | |
| Wood | 1 209 | 0.039 | 0.185 | 0.085 a | -0.07 a |
| SFPM | 478 | 0.020 | 0.093 | 0.043 a | -0.13 a |
| Swichtgrass | 531 | 0.030 | 0.143 | 0.065 a | 0.27 a |
| F.G. Willow | 279 | 0.012 | 0.057 | 0.026 a* | 0.03 a |

*Tendency to be significantly different; signification level α = 0.05;

Hedonic tones were similar for all biomass fuel near zero. In fact, the samples from the storage of fast growing willow and switchgrass obtained scores ranging from -3 to 3, while for samples from wood and FSPM obtained scores between -2 and 2. There is no significant association between the type of biomass and hedonic tone (table 1), which suggests that the panellists are not particularly upset by a particular type of biomass fuel.

Regarding odour nuisance analysis for emissions from the combustion of the biomass fuels, as expected, odour concentrations are higher than from the biomass fuel storage (table 2). However, as in emissions from storage, emissions from the wood combustion tests are no statistically differences from the agricultural biomasses. In fact, SFPM emitted the highest odour emission and fast growing willow the lowest (2 937 and 1 225 $UO_E$ $MJ^{-1}$ $min^{-1}$, respectively), while wood emitted 1 390 $UO_E$ $MJ^{-1}$ $min^{-1}$.

Table 2. Odour concentrations, odour emissions and hedonic tone from the biomass fuel combustion.

| Biomass fuel | Average odour concentration ($OU_E$ $m^{-3}$) | Odour emission ($UO_E$ $MJ^{-1}$ $min^{-1}$) | | | Hedonic tone |
|---|---|---|---|---|---|
| | | Lower bound | Upper bound | Average | |
| Wood | 1 492 | 295 | 6 558 | 1 390 a | -1,05 a |
| SFPM | 2 024 | 826 | 10 447 | 2 937 a | -2,1 a* |
| Swichtgrass | 956 | 349 | 4 447 | 1 245 a | -0,83 a |
| F.G. Willow | 1 097 | 78 | 982 | 1 225 a | -1,17 a |

*Tendency to be significantly different; signification level α = 0.05;

Hedonic tones from biomass combustion were more unpleasant than from biomass storage. Actually, no panellist scored a sample higher than 2 (but not less than -4) resulting all negative averages. The statistical analysis allowed to point out a probability from the hedonic tone of the SFPM near the threshold of significance to be different from wood ($P$ = 0.0548). Nevertheless, no significant differences resulted between agricultural biomass fuels and wood.

## Discussion

This study aimed to test the hypothesis that agricultural biomass fuels, during storage and during direct combustion, produce odorant emissions different from the wood causing discomfort. Indeed, agricultural biomass could origin a problem of cohabitation by unpleasant odours in some stages of their production chain.

The results of this study confirmed that there are no statistically significant differences between the odours emitted by either the combustion or the storage of wood and SFPM, switchgrass or fast growing willow. However, according to the results, the solid fraction of pig manure has a tendency to create odour emissions with a concentration and a negative hedonic tone more important than other biomass fuels, particularly during combustion.

In summary, the storage, handling and combustion of evaluated agricultural biomass fuels not cause an olfactory trouble greater than wood. Thus, from a viewpoint of cohabitation, the valorisation of these biomass fuels for energy production is feasible.

## Conclusion

Reproducible methods for sampling and measuring the odorant emissions from the storage and the combustion of biomass fuels were developed. According to the results obtained at this study, there are no statistically significant differences between the odour emissions either from combustion or from storage of wood and solid fraction of pig manure, switchgrass or fast growing willow. In this vein, storage, handling and processing of agricultural biomass combustion evaluated should not cause olfactory troubles larger than burning wood. Thus, in terms of cohabitation, the valorization of biomass as fuel is possible.

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