



Analysis of dioxin-like compounds formed in the combustion of tomato plant

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ABSTRACT

In an initial effort to minimize some of the uncertainty regarding the open burning of biomass, emission factors of carbon oxides, light hydrocarbons, PAHs, PCDD/Fs and dioxin-like PCBs were determined in the combustion of tomato plant in a residential stove and in two runs at 500 °C and 850 °C in a laboratory scale reactor. In all the runs nearly the same PAHs were identified, being naphthalene the main obtained. Combustion of tomato plant at 500 °C in the laboratory scale reactor produced the highest emission factors for all compounds analyzed. Tomato plant was analyzed for PCDD/F and dioxin-like PCB content in order to establish the level of pollutants in the sample itself. Ash obtained in the combustion carried out in the residential stove was analyzed for the dioxin-like compound content and compared with a sample of ash collected from the open burning of tomato plant.

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1. Introduction

Tomatoes are one of the most widely produced vegetables on the planet. According to Food and Agriculture Organization of the United Nations Statistical Database (FAOSTAT, 2005), 125 million tons of tomatoes were produced in the world in 2005, being Spain one of the 10 largest producing countries in the world.

After harvest campaigns, tomato plants are normally decomposed and burnt on the field. Open burning, due to its non-ideal combustion conditions, typically produces soot, particulate matter, carbon monoxide, light hydrocarbons, volatile organic compounds and semivolatile compounds including several persistent bioaccumulative and toxic pollutants like polychlorinated dibenzo-*p*-dioxins, polychlorinated dibenzofurans (PCDD/Fs) or polychlorinated biphenyls (PCBs).

Many countries have undertaken inventories of sources of PCDD/Fs to better identify these sources and to quantify the emitted amounts of PCDD/Fs. While industrial sources reduce their emissions in response to environmental regulations, non-industrial sources such as open burning are becoming dominant in the emissions inventory (Lemieux et al., 2004). It must be noted that data related to pollutants produced in open burning sources are very limited, probably due to the difficulty of sampling (mainly air sampling) of this kind of uncontrolled processes. Moreover, PCDD/F emissions vary greatly from source to source and exhibit significant variations within source categories and combustion condi-

tions, so it is very important to have acceptable test data for PCDD/F and other toxic compound emissions from open burning so that these contributions of sources to the overall PCDD/F emissions inventory can be better quantified.

An effective way to develop emission factors for open burning sources is through laboratory simulations using two kinds of systems: open burn simulation facilities in which higher amounts of material can be burnt and laboratory scale reactors. Ikeguchi and Tanaka (2000) burnt straw and rice straw in an open burn simulation facility and obtained 20.2 ng I-TEQ kg⁻¹ burnt and 67.4 ng I-TEQ kg⁻¹ burnt, respectively. Jenkins et al. (1996a,b) studied the emission factors for PAHs obtained in a series of laboratory tests on emissions from burning cereal crop residues. Gullet and Touati (2003) burnt wheat and rice straw stubble in a field burn simulation facility and obtained approximately 0.5 ng I-TEQ kg⁻¹ burnt for both sources. No data have been found for dioxin-like compound emission factors in open burning of tomato plants.

In agricultural residue open burning, the emissions are also not spread evenly throughout the year; rather, they are typically episodic in time or season and localized/regionalized. Shun-I et al. (2008) found that during the rice straw open burning season the total PCDD/F I-TEQ concentration in the ambient air of two areas in southern Taiwan was approximately 4 and 17 times higher than that without biomass open burning.

In this paper an effort to minimize some of the uncertainty regarding the open burning of tomato plant was made. Emission factors of several compounds like: CO, CO₂, light hydrocarbons, PAHs, PCDD/Fs and dioxin-like PCBs were determined in the combustion of tomato plant in a residential stove and in two runs at

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different temperatures in a laboratory scale reactor. The residential stove was used in order to obtain a combustion chamber with poor oxygen–fuel mixture, similar to that obtained in an open-burning fire, but with the possibility to reproduce the operating conditions in the greenhouses.

2. Experimental

2.1. Raw material

The sample employed in this study was tomato plant obtained from the Alicante area (Spain). Some characteristics of the material studied are presented in [Tables 1 and 2](#). Ultimate analysis of the sample was obtained with a CHNS/O analyzer (Perkin–Elmer 2400, Perkin–Elmer, UK) and the ash residue was obtained by calcination at 850 °C. The moisture content was determined by the weight loss at 105 °C for 12 h. [Table 2](#) shows the results obtained using an automatic sequential spectrometer of X-ray fluorescence (TW 1480, Philips Co, Ltd.). Ethanol-solubilized, hemicellulose, cellulose and lignin contents were determined for this material according to [Rowell et al. \(1996\)](#) and TAPPI test methods: T12, T222 and T203 ([Technical Association for the Pulp and Paper Industries, 1978a,b,c](#)).

In a previous paper ([Font et al., 2008](#)) a kinetic analysis of the pyrolysis and combustion of tomato plant was carried out by thermogravimetry. [Figs. 1A and 1B](#) show the weight fraction and its derivative from dynamic runs carried out at 10 °C min^{−1}. In pyrolysis plots ([Fig. 1A](#)) it can be observed that there is an initial small peak around 100 °C, corresponding to the moisture, a wide band centred at 275 °C and another band in the last part of the run between 400 °C and 500 °C. For the combustion run ([Fig. 1B](#)), there is the same initial peak of the moisture, the wide band centred at 275 °C and finally a peak corresponding to the combustion of the

Table 1
Characteristics of the material used.

Moisture (wt.%)	16.6
<i>Composition on dry basis</i>	
C (wt.%)	38.3
H (wt.%)	5.2
N (wt.%)	2.7
S (wt.%)	1.1
Ash content (wt.%)	15.8
O% by difference (wt.%)	36.9
Ethanol extracts	4.9
Hemicellulose	33.0
Cellulose	34.4
Lignin	11.9

Table 2
Analysis of tomato plant by X-ray fluorescence (semiquantitative analysis).

Element	Tomato plant (wt.%)
Ca	32.6
K	15.6
Cl	9.0
Mg	2.9
P	2.1
Si	1.9
Cu	0.8
Al	0.7
Sr	0.4
Fe	0.4
Mn	0.2
Br	0.06
Zn	0.06
Zr	0.06

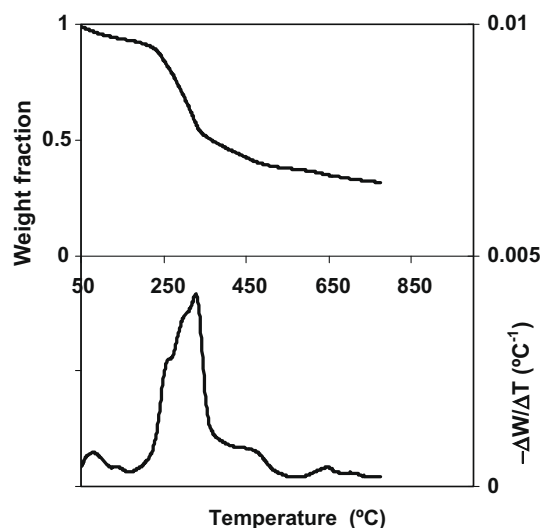


Fig. 1A. Weight fraction and its derivative from a pyrolysis run at 10 °C min^{−1}.

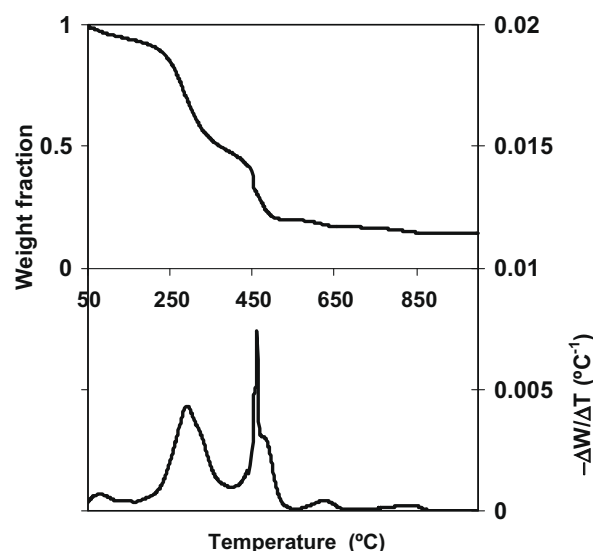


Fig. 1B. Weight fraction and its derivative from a combustion run at 10 °C min^{−1}.

residue previously formed at 400–500 °C. Note that the combustion is nearly complete at 500 °C.

In order to establish the level of pollutants in the sample itself and compare with those obtained in the combustion processes, the analysis of PCDD/F and dioxin-like PCB content was carried out for tomato plant.

3. Experimental procedure

3.1. Laboratory reactor

A batch laboratory scale horizontal tubular reactor was used for the continuous simulations of tomato plant combustion at 500 °C and 850 °C. A detailed description of the equipment can be found elsewhere ([Moltó et al., 2005](#)). For each experiment and once the furnace had reached the nominal temperature, around 150 mg of sample were introduced into the reactor at a constant speed (1 mm s^{−1}). The air was introduced co-current to the sample, with constant gas flow at around 300 mL min^{−1}. With this gas flow rate,

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