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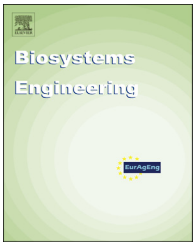

Research Paper

Source of airborne sunflower dust generated during combine harvester operation

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The sunflower harvest season presents challenges for many farmers when an abundance of airborne dust is carried by surrounding winds and allowed to relocate on equipment surfaces. Combine fires are a serious problem resulting from the ignition of biomass dust that settle and accumulate on the combine harvester. Farmers' anecdotal evidence indicates that harvesting sunflowers can produce more airborne dust than other commodity crops. The source of this airborne sunflower dust was investigated using various methods to analyse different parts of the sunflower: whole heads, outer stalk, and inner stalk pith. These samples were compared to a collected amount of bulk sunflower dust field sample taken directly from a horizontal surface on a combine harvester during the 2011 harvest season. All testing methods; proximate and ultimate analyses, biomass dust particle density analysis, Fourier transform infrared spectroscopy, and scanning electron microscopy; suggest the sunflower bulk field sample is comprised of mostly inner stalk pith rather than dust particles from the outer stalk and whole sunflower heads. By confirming the source of the airborne sunflower dust field sample, the arrangement of combine harvester equipment could be modified to reduce the amount of sunflower dust generated during operation.

1. Introduction

Biomass resources have become an increasingly important topic concerning advanced renewable energy research (Markowski-Lindsay et al., 2012; Sultana & Kumar, 2011; Zhu & Yao, 2011). Future biofuel production is expected to utilise inedible biomass feedstocks estimated to be approximately 1.6 billion tons annually (U.S.DOE, 2011). Specialty oilseed crops including sunflowers could supply vegetable oils with triglycerides composed of high quality oleic acid for biodiesel or renewable jet fuel production (Georgogianni, Kontominas, Pomonis, Avlonitis, & Gergis, 2008; Maher & Bressler, 2007; Pereyra-Irujo et al., 2009). Sunflower production issues including combine harvester fires could potentially limit the feedstock supply chain for biorefineries producing renewable biofuels (Polin, Gu, Humburg, & Dalsted, 2013).

According to the project's collaborating farmers, more airborne sunflower dust is typically generated while operating the combine harvester than other crops (Humburg, Dalsted, & Polin, 2011). This may be due to sunflowers' inherent plant structure and fracturing during the combine's threshing

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process. In addition, recent advancements to increase the combine's ability to process more plants at faster rates has led to more rigorous threshing processes and could generate more biomass dust than past years. According to the United States Department of Agriculture's (USDA) Economic Research Service (ERS), the overall U.S. sunflower harvest yield in metric tonnes per hectare has generally risen over the past 32 years (Fig. 1) (USDA/ERS, 2013). Increased production of sunflower plants to produce higher yields of seeds could also contribute to generating more airborne dust when processed by the combine harvester. The project's scope was to investigate the properties for different parts of sunflower and compare them to an actual field sample to identify the source of the airborne sunflower dust.

2. Materials and methods

2.1. *Agricultural machinery and equipment settings*

The collaborating farmer used a Case International Harvester (Case IH) model 8120 combine harvester during the 2011 sunflower harvest season; this particular combine is an axial flow machine with a longitudinal rotor and separator. Although the rotor speeds were not recording during the tests, the operator has much experience harvesting sunflowers and adjusted the machine to minimise threshing and cleaning losses. The combine utilised an “all crop” header that captured stalks between two rubber belts while a cutter disk sliced the stalk below. The operator adjusted the header height low enough to minimise any losses from short or bent over sunflowers; this allowed for the header to capture all of the standing sunflowers but needed to cut an ample portion of the sunflower stalks. This method is common among farmers in order to maximise their yield of sunflower seed.

The combine's speed was adjusted according to crop conditions to maximise throughput while conforming to the engine's rated power limits. The combine harvester's diesel engine utilised a conventional exhaust system with a turbocharger and preceded any advanced exhaust gas post-treatment systems for NO_x and soot removal. These post-treatment systems are expected to be more common in machines compliant with recent Tier 4 emissions standards (Johnson, 2008) set by the United States Environmental Protection Agency (U.S. EPA).

2.2. *Biomass dust sample preparation*

The collaborating farmers pointed out horizontal surfaces on the combine harvester where sunflower dust predominately builds up and must be cleaned off regularly; the sunflower dust samples were taken from a single combine harvester that processed several fields containing sunflowers near Onida, SD for further laboratory analysis. The sunflower bulk field sample was the summation of several dust samples collected on a particular day during the 2011 harvest season in which the collaborating farmer documented three small smouldering fires that needed to be extinguished before resuming the sunflower harvest. The dust particle size distribution of the sunflower bulk field sample can be seen in Fig. 2. Fraction 1, the largest particle size range >710 μm, accounted for 22% of the total bulk field sample and was comprised of mostly sunflower hulls. The second fraction, an intermediate particle size range from 710 to 150 μm, also represented 22% of the total bulk field sample. The third fraction, representing the smallest dust particles, accounted for the majority of the total bulk field sample at 56%; this particle size range represents airborne dust that can be easily carried by surrounding winds.

About twenty whole sunflower plants were also randomly collected during the harvest at the same fields as the bulk dust sample and later separated by hand into different parts: whole heads, outer stalk, and inner stalk (pith). The separated sunflower parts were individually milled with a small lab grinder to obtain milled biomass samples; these samples were then

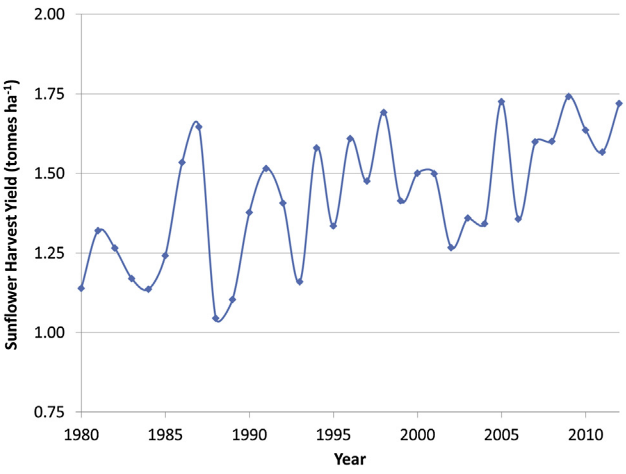

Fig. 1 – Overall U.S. sunflower production by harvest yield (tonnes ha^{-1}) from 1980 to 2012. Source data: (USDA/ERS, 2013)

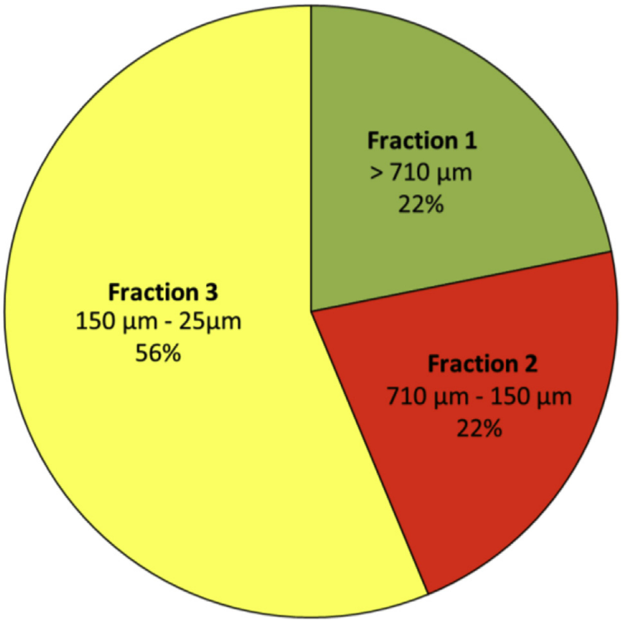

Fig. 2 – Dust particle size distribution by mass percentage of sunflower bulk field sample.