Potential for on-farm sustainable, ethanol production using a MicroFueler™

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Abstract

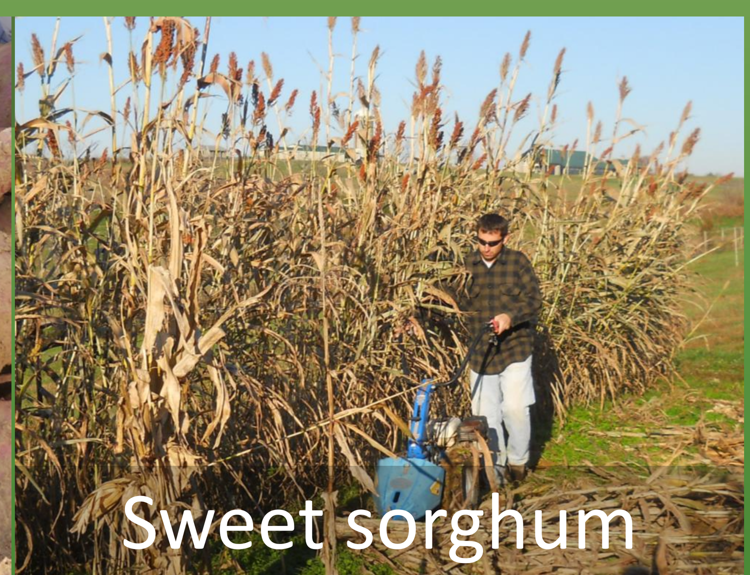
Small and organic farms are often dependent on fossil fuels for production. On farm biofuel production has the potential for alleviating some of the costs associated with small and organic farming. At Kentucky State University a small scale fuel alcohol plant called MicroFueler™ has been purchased. The machine, which became operational in September of 2011, can ferment, distill, and purify sugar solutions of feedstock crops and will dispense fuel grade ethanol. Feedstock crops being considered are corn, sweet sorghum, and sweet potato along with fruit waste such as Pawpaw. Sweet sorghum and sweet potato were chosen because of the sugars and starches naturally available in those crops for maximum fermentation potential, their ability to grow well in much of the southeastern US, and low off farm input requirements. Land, labor and energy use efficiency is being recorded with each feedstock crop tested in the machine.

Introduction

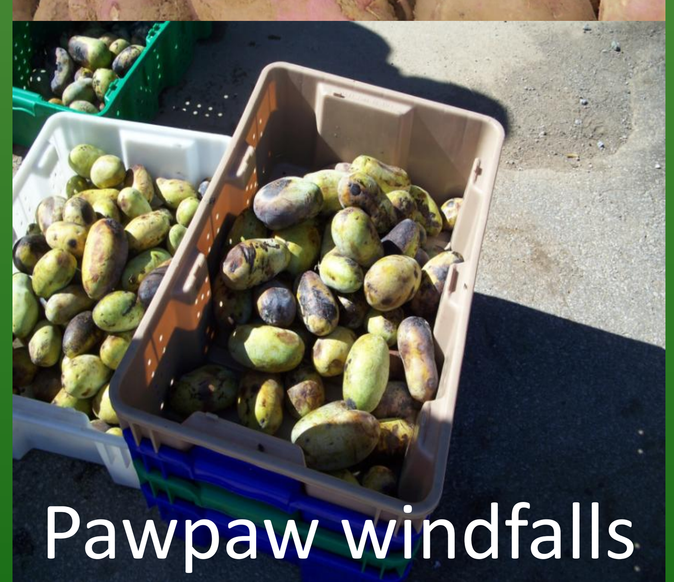
The MicroFueler™ is a small-scale fermentation, distillation and pumping apparatus designed to convert starchy, sugary, or alcoholic wastes into hydrous ethanol fuel. The machine is intended to decentralize fuel production by creating a user-friendly means for households, farms, and small businesses to convert waste to fuel.

The Kentucky State University farm generates sugary and starchy waste through production of sweet sorghum, sweet potato, and pawpaw. Tests are being conducted to assess the potential ethanol fuel yield, and the labor and energy input required for on-farm fuel production from such wastes using the Microfueler.

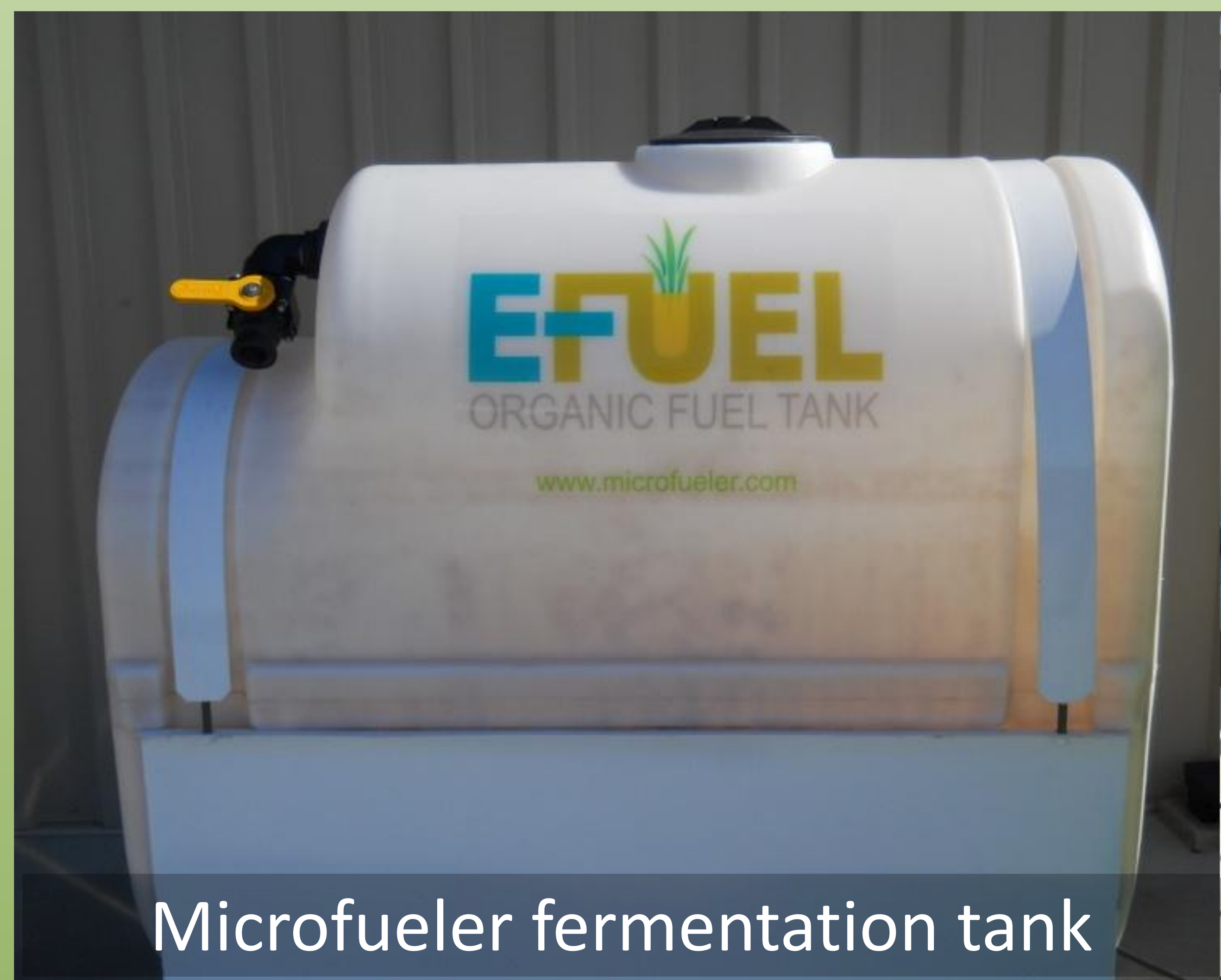
Sweet potato culls



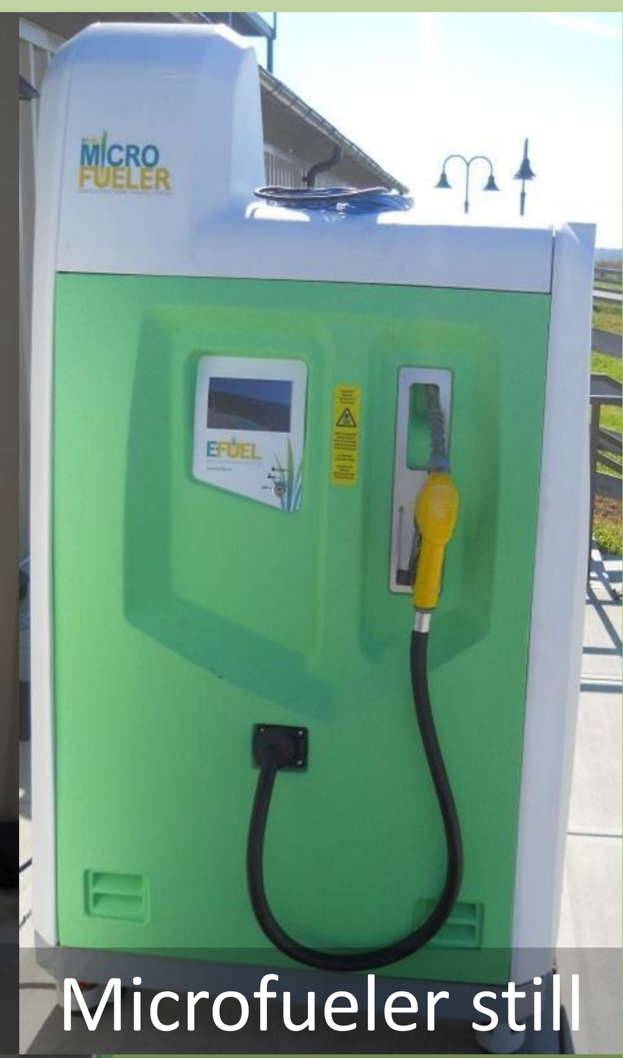
Sweet sorghum



Pawpaw windfalls



Microfueler fermentation tank



Microfueler still

Materials and Methods

Sweet potato (*Ipomaea batatas* cv. 'Beauregard') was harvested using a potato chain digger (D10T, Small Farm Equipment, WY). The yield was divided into marketable and unmarketable grades then weighed. Tuber samples were finely ground and mixed with water to produce a 2:1 water:tuber slurry for fermentation.

Sweet sorghum (*Sorghum bicolor* cv. 'M81E' and 'Dale') was harvested by sickle bar mower. Seed heads were removed and stalks were weighed before juice was extracted from stalks using a 3-roller cane mill (Chattanooga #23, Chattanooga Plow Co., TN). Juice was suitable for direct fermentation without further processing.

Pawpaw (*Asimina triloba*) windfalls were collected by hand. Pulp was separated from seeds and skin with a seed extractor (Bouldin & Lawson Seed Cleaner, TN). Water was added during the extraction process to produce a 1:3 water:pulp slurry for fermentation. The soluble solid content of each sample of fermentable material was measured in °Brix using a refractometer (Leica Brix50, LabSource, IL). Potential ethanol yield was estimated as 51% of the soluble solid weight (%ABV = °Brix × 0.51).

Table 1. Estimates of fermentable material, water balance, and 95% hydrous ethanol fuel yield from one acre of sweet sorghum, sweet potato, or pawpaw waste processed through a Microfueler.

	Fermentable material (lb/ac)	Water added (gal/ac)	Batches (/ac)	°Brix	Ethanol yield (%)	Ethanol yield (lb/ac)	Water removed (%)	95% Ethanol yield (gal/batch)	95% Ethanol yield (gal/ac)
Sweet sorghum	9,980	-	4.8	18.3	9.33	931	88	31	149
Sweet potato	16,261	1,300	13	3.19	1.63	265	98	3.2	42
Pawpaw	2,100	60	1.25	10.4	5.30	111	93	14	18

Results and Discussion

Sweet sorghum showed the greatest potential for ethanol production from crop wastes among the crops tested (Table 1). Sweet sorghum was the only crop that provided directly fermentable material without addition of water during pre-processing. The fermentable material from sweet sorghum had the highest soluble solid content and potential ethanol yield. Less water has to be removed by distillation to produce 95% ethanol fuel from fermented sweet sorghum waste, relative to the other crops tested.

Sweet potato provided more fermentable material from an acre of land than the other crops, but demanded an energy and labor-intensive grinding phase, and addition of more water than the other crops tested (Table 1). The fermentable material produced from sweet potato had the lowest soluble solid content, yielding the lowest proportion of ethanol among the crops tested. Consequently, more water had to be removed by distillation to yield 95% ethanol fuel. The addition of water during pre-processing and its subsequent removal through distillation reduces process sustainability for at least three reasons:

1. Fresh water supply is limited;
2. Water removal through distillation is the most energy-intensive stage in ethanol production; and
3. More batches have to be run through the Microfueler to process dilute ethanol solutions, slowing the production process.

The pre-processing method used for sweet potato needs to be improved to make more sugar available using less water. Theoretical sugar and ethanol yield from sweet potato is much higher than achieved in this study (Mays et al. 1990, Mathewson 2006).

Pawpaw had the least potential for ethanol production from an acre of waste, but demanded less water addition and removal than sweet potato, making for a more energy and labor efficient conversion to fuel than sweet potato (Table 1). The Microfueler enables small-scale ethanol fuel production from agricultural wastes, but process sustainability depends on the waste products used, and a variety of process inputs, including land, labor, energy, and water. Efficient use of the Microfueler will require careful feedstock selection and optimization of pre-processing techniques.

References

1) Mathewson, 2006, Mother Earth Alcohol Fuel - The Manual for the Home and Farm Production of Alcohol Fuel, Ten Speed Press, © Copyright 1980 J.A. Diaz Publications.
2) Mays, D.A., W. Buchanan, B.N. Bradford, and P.M. Giordano. 1990. Fuel production potential of several agricultural crops. p.260-263. J. Janick and J.E. Simon (eds.), Advances in new crops. Timber Press.