EVALUATION OF CORN RESIDUES AS SUSTAINABLE BIOFUEL PRODUCTION

A.Azarpanah1, A.hajgozar2,
1-M.SC, faculty of Agriculture Arsenjan Azad university
Arash_Azarpanah@yahoo.com
2-Assistant Professor, Faculty of Entomology, shiraz Azad university

Abstract

As the worlds source of fossil fuels diminishes, another source of energy must replace fossil fuels. Concerns about global climate change, air quality , and volatility in the fossil fuel market the have brought about renewed interest in alternative fuels. Interest has been partially focused on the biomass sector as a source of fuel for renewable energy production. This article evaluates biofuel , one alternative form of energy by showing what biofuel is, how it works, and benefits and drawbacks it pertains. We hypothesized that corn residues biofuel be an effective alternative energy. Our conclusion does not support our claim, but in terms of worldwide usage.

Key words: *Zea mays L.*, biofuel , sustainable , residues , biomass, agriculture

Introduction

Crop residues have potential to be utilized for bioenergy production. Annually approximately 204 million dry metric tons of corn residue are retuned to the ground as waste by product in corn grain production (Perlack,R.D.,et al.2005). While corn stover the above ground corn plant excluding corn kernels, has much potential in use as a biomass feedstock(Graham ,R. L., et al.2007), there are concerns associated with its removal from the ground. Crop residue removal contributes to soil organic matter and nutrient depletion (Follett 2001; Wilhelm, W.W., et al.2004). Soil organic matter levels are related to many productive soil characteristics and are associated crop production potential (Reiocosky and Forcella,1988). Soil organic matter levels also affect soil water infiltration, water holding capacity, and aeration (Wilhelm ,W.W., et al.2004).

Crop residues are also important as top cover on agricultural land. Residues can act as buffers to falling rain and wind sheer that dislodge soil particles and cause erosion. Sun radiation, heat flux , and moisture evaporation are also affected by crop residue levels (Wilhelm ,W.W., et al.2004). The removal of crop residue be balanced against the environmental impact (soil erosion), maintenance of nutrient and soil organic matter levels, and preservation of productivity levels (Wilhelm ,W.W., et al.2004). These concerns associated with corn stover collection can be mitigated with partial stover collection. Biofuel is a buzzword employed to describe ”homegrown gasoline and diesel substitutes made from crop likes corn, soybeans, and sugarcane” (Bourne, 2007, P.41). It is touted as the panacea for the impending world –

wide fuel shortage. Unlike fossil fuel , which takes thousands of years to form, biofuel is man made , can be produced in the space of few weeks, and is potentially sustainable (Bourne , 2007).

Biofuel also promises to help the world cut down on carbon dioxide emissions. Burning a fossil fuel alternative , such as ethanol, release less carbon dioxide than fossil fuels (Bourne , 2007), though it does produce other greenhouse gases. Despite these positive attributes , biofuel has serious problems that must be solved before it can become a sustainable source of energy. Corn residues ethanol , the biofuel of choice in developed countries, are the worst crop to use because it takes "at least as much fossil fuel to obtain ethanol , as we may gain by burning it"(Anti et al ., 2005,p.324). If developed countries are serious about finding a sustainable source of biofuel , the idea of using corn residues to manufacture it must be discarded.

Corn takes more resources to cultivate than any other crop, and causes the most pollution (Anti et al ., 2005). Corn requires nitrogen- rich fertilizer in order to grow, and ammonia is the primary ingredient in such fertilizers. Manufacturing this fertilizer is hazardous , as well as detrimental to the environment, because "practically all ammonia is produced from methane. All carbon in the feedstock methane is converted to carbon dioxide and , as a result , two pounds of carbon dioxide are produced for every pound of ammonia (Anti et al ., 2005 , p.324). To convert corn residues in to alcohol, it has to be boiled at least three times to distill the alcohol and remove excess water. The energy levels required to do so are immense , and are powered by fossil fuels. Thus , even if corn residues ethanol produced less carbon dioxide when burned, The process of growing the corn and converting it in to fuel would more than make up for it.

Growing corn also requires about 35 gallons of water per bushel , which causes massive amounts of fertilizer and herbicide runoff (Anti et al ., 2005). The environmental impacts of contaminated wastewater and runoff occurs in agricultural places where the water is undrinkable due to the pollution, and "vast quantities of farm land are degraded, aquifers are depleted and contaminated rivers are polluted with fertilizer and pesticide run-off"(Anti et al .,2005,p.326). Another roadblock is the way ethanol is burned. Because standard automotive engines cant burn straight ethanol, drivers would have to buy a new engine to replace fossil fuels with ethanol, which isn't feasible (Bourne , 2007 , p.47) .

Supporters of corn residues ethanol assume that corn production builds up the economies of small rural towns. This isn't true .while the price of corn increases as demand increases , "corn farmers are receiving a maximum of only an added two cents per bushel for their corn or less than $2.80 per acer because of the corn ethanol production system"(Patzek & Pimentel, 2005, P.67). Most of the profits go to a few large corporations , just as they do in the oil industry. Whether biofuel can benefit farmers and small communities depends on "ownership of production facilities and the mix and marketability of useful co-products"(Kurki et al .,2006,p.1).

Material and methods

Energy Content

Corn residues used in bioenergy conversion must have adequate energy content. Energy content of corn residues can be given as an energy density measurement – energy per unit volume or weight. The volumetric energy density of an energy corn residues is significant when considering the volume of biomass needed to be harvested , transported , stored , and utilized in an energy production process. The higher the energy density , the less volume of biomass needed to produce a given amount of energy. While corn residues are not as energy dense as the fossil fuels that society is familiar with , they have a similar energy density to other biomass corn residues and less energy dense coals , both of which are successfully utilized as energy corn residues around the world. For comparison , the volumetric and mass energy densities of several corn residues are given here on dry basis.

Fuel	Corn residues	Corn stover	Switchgrass	Wood pellets	Bituminous Coal	oil
Energy content(MJ/Kg)	18.25-19.18	17	18	19	25.5	43.5
Energy content (MJ/m3)	4960-5210	2550	2500	12400	17,200-23,300	38,600

Table1. Source: clark , T.T. and Lathrop , E.C; Foley , K.M.; Powder and Bulk; Mclaughlin , S.B.,et al

It should be emphasized that the energy content of corn residues is given here in MJ/kg dry matter. Corn residues are not harvested , stored , or utilized in a moisture free condition. Therefore , the actual energy densities of corn residues , as with all forms of biomass , should be adjusted to compensate for the moisture content. For instance , at 20% moisture , a kg of cob residues would have a higher heating value 14.16 – 15.3 MJ. It should also be stated that the wood pellet in the above table have higher mass and volumetric energy content due to pelletization . This process, while increasing the density of the product, requires additional energy and equipment. The net result is increased cost of production and a reduction of the products net energy. Corn residues are sufficiently dense and therefore do not require densification.

Composition and Conversion

The chemical properties and physical characteristics of corn residues make for a feedstock suitable for several methods of energy generations. A group of studies (Clark ,T.F. and Lathrop E.C., 1953; Foley ,K., 1978) found that corn residues contain 32.3-45.6% cellulose, 39.8% hemicelluloses – mostly composed of pentosan and 6.7-13.9% lignin. Cellulose is a polysaccharide of glucose units that serve as the main structural component of cobs cell walls. Hemicellulose is a less complex polysaccharide that can more easily be broken down to simpler monosaccharides , simpler sugars. Lignin is a complex , non- carbohydrate , structural component which binds to cellulose and stiffens plant cell walls. Current and experimental process are available to convert the energy contained in the corn residues molecular structure. Thermochemical conversion technologies such as combustion and gasification can utilize the molecular structure of the cellulose, hemicellulose , and lignin present in corn residues to produce heat energy and/ or synthesis gas. In direct combustion , corn residues are completely combusted in an oxygen rich environment to produce heat energy. Direct combustion heating process should either be fueled exclusively with corn residues or co-fueled with coal. The benefits of using corn residues as a partial coal substitute include a potentially cleaner emissions stream and the reduction of undesirable emissions and waste ash(Gani , A . and Naruse , I., 2007).

The process of gasification uses high temperatures and an oxygen deficient environment to create a lower energy producer gas that can be used similarly to natural gas. Gasification allows for a more controlled partial combustion process and reductions in undesired emissions when compared to direct combustion. Experimental cellulosic ethanol production – a type of biochemical conversion – is being researched to developed a process of converting the cellulose and hemicellulose portions of plant matter into ethanol. The cellulose and hemicellulose in cobs are hydrolyzed , broken down into simple sugars , and the fermented into alcohol. These processes can be impeded by variations; for this reason consistent , uncontaminated corn cobs appear to be a desirable feedstock. The use of cobs in cellulosic ethanol production creates an identical alternative to grain produced ethanol and reduces dependence on corn grain.

Sustainable production

Bioenergy feedstock should be sustainably produced in order to act as a long – term energy source while minimizing negative impacts. Corn residues collection for the production of bioenergy is feasible within limits.(Wilhelm, W.W., et al ., 2004) to verify the sustainability of cob collection , the ramifications of corn cob removal need to be thoroughly explored. Crop residues play an important role in the maintenance of soil productivity. Residues provide a buffer to wind shear and raindrop impact that leads to soil erosion. Residues also aids in the maintenance of soil organic matter, soil organic carbon, and nutrient levels – all desirable characteristics of productive soil. Sustainable removal rates of agriculture residues , including corn cobs, are highly location dependent.

The climate , geography , and management of land are all factors in the calculation of the amount of biomass able to removed sustainably. Climatic parameters (annual rainfall, rainfall rates , and wind frequency and velocity), as well as geographic features (terrain and soil types) , and human influences (tillage practices, crop rotations , and crop yields) all contribute to requiring the guidelines of residue removal be viewed on an individual site basis. Sites with steep grades , dry climates , and /or highly erodible soils produce much less and in some cases no removable organic matter due to their increased susceptibility to erosion. Studies on wind and soil erosion have resulted in the construction of the revised wind erosion equation (RUSLE) (Nelson , R.G.,et al .,2004), two models used to predict the amount of removable residue when maintaining acceptable soil erosion rates that will not lead to prolonged soil deterioration, soil erodibility , ground slope , crop yield and several management factors such as crop rotation and tillage practices) and create guidelines for keeping soil erosion at maintainable levels , but do not take into account the role crop residue in maintenance of productive soil. Crop residue strongly influences soil characteristics. Soil surface residue affects penetration of solar radiation, soil energy flux, retention of soil moisture. When reincorporated into the soil , residue aids in the maintenance of soil nutrients , soil organic matter, and soil organic carbon. These factors make crop residue retention essential in varying degrees. The removal of a potion of residue from wet and cold climate soils may aid crop production due to higher spring time soil temperatures and the reduction of excess moisture.

However , in dry and hot climates , completes residue retention may be required for the preservation of soil moisture and reduction of soil erosion. When considering the role of crop residue in maintenance of soil productivity, corn cob collection for collection for bioenergy generation offers advantages. Collection of corn cobs 15-20% content of corn stover – allows for the remaining stover to be returned to the ground for top cover, soil organic matter replenishment , and nutrient replacement. Although much is known about the role of crop residue in retention of soil productivity , additional research is needed to determine the long – term effect of corn cob removal and construct guidelines for sustainable corn cob removal. The low nutrient content of corn cobs add to the potential sustainable use as a feedstock. The low nutrient content of corn cobs reduce the amount of nutrients removed with cobs at harvest which later need to be replaced to maintain soil nutrient levels.

Moisture and storage

The moisture content of corn residues can pose challenges in storage and use for energy conversion. Corn cobs are generally harvested with moisture content in the range of 25-50% which depends on the corn cultivar characteristics and harvest conditions (recent weather and date harvested). The high side of the range poses potential issues with storage and immediate use for energy production. Cobs with 10% to 30% moisture content are ideal for energy production; however , the range can vary depending on the production process. Cob moisture content has been found to be a critical factor in long term storage.

A study done by R.D.Smith (Smith , R.D.et al .,1985) examined the outside storage of corn cobs. Corn cobs were stacked in piles with varying initial moisture values of 28.0 – 38.5% . The piles were stored eight to nine months (winter to summer) and either ventilated with ambient air or left unventilated. Despite being outdoors and subjected to precipitation , the piles interiors all decreased in average moisture content. The ventilated piles had the lowest interior moisture percentages at 9.1% , 15.1%, and 18.4% , while the unventilated piles had higher values of 23.6%, 25.4% and 25.5%.

Dry matter loss of the piles was associated with high moisture content which allowed for microbial activity and decomposition of corn cobs. The outer layer matter loss was unavoidable due to precipitation and weather conditions that caused high piles moisture content. Ambient air ventilation proved to be advantages for reducing cob spoilage. Ventilation allowed for quicker reduction of interior moisture and in turn reduced the cob dry matter loss. The importance of ventilation was enforced by Dunning who stated that pile ventilation was important for the reduction of high corn cob moisture due to the lack of moisture changes in non- ventilated piles. (Dunning et al., 1984) Although these studies showed that ventilation improved cob storage , further research should be done to determine if the reduction in cob spoilage offers the cost of electricity and equipment needed for pile ventilation. Storage area is highly dependent on the piling method.

A single circular pile optimize the mass stored per unit area. A single circular pile optimizes that mass stored per unit area. However , restrictions due to available equipment , Stacking methods, and ventilation may require alternative pile configuration and increase the necessary storage area. Furthermore , figures are representational and do not take into account necessary pile spacing for fire control. Spontaneous combustion is a concern when dealing with large piles of high moisture material which are required for an energy plants operation.

Conclusion

There is no single solution that will solve countries future energy needs. Replacing the large amounts of fossil fuel based energy with renewable alternative will require the use of numerous technologies , methods, and natural resources. Energy production methods should be best matched with a regions available natural resources. Energy crops such as swithgrass and miscanthus are not grown in large volume in countries and will require acceptance and development before their potential is fully realized. Corn residues are a viable energy feedstock and hold much promise for use in local and regional energy production. Corn residues together with other bioenergy feedstocks and renewable energies, will provide the energy to be less dependent on fossil fuels and to reduce their harmful effects.

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