Can we fly and eat too?

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The Biofuels for Aviation Summit was called to assess the availability of biofuels for US military and commercial aviation in 2012 and 2017. US airplanes consume approximately 26 billion gallons of jet fuel each year -- approximately 8% of US petroleum consumption and about one-third of global jet fuel consumption (EIA 2008).

In recent years the US has increasingly turned to its farms to generate fuel. In 2005 the US overtook Brazil as the world's largest producer of bioethanol. In 2008 the country produced 9 billion gallons of ethanol at 172 industrial-scale refineries. All but ten of these use corn as a feedstock.

Although billed as a renewable fuel, corn ethanol is perhaps a quarter to a third renewable. About three quarters of the energy available from combustion of a gallon of bioethanol is currently needed to produce the corn (~25%) and process it into ethanol (~50%) (Marris 2006). Most of this energy currently comes from non-renewable fuels, such as natural gas and coal. It's production also involves intensive an unsustainable use of renewable renewable resources, including land and water.

An average new ethanol refinery has a production capacity of 80 million gallons per year (Renewable Fuels Association 2009), requiring 30 million bushels (194,000 acres) of corn each year. The scale of these refineries demands large corn monocultures and long distance feedstock hauling. As more land is dedicated to growing corn for ethanol, crop rotations that have helped reduce soil erosion, fertilizer use, and pesticide applications are being abandoned: The top research priority identified by Kentucky grain growers in 2007 was addressing soil quality and disease problems associated with sequential corn plantings (Kentucky Ag Advisory Council 2007).

Even at this large production scale, bioethanol replaces a very small proportion of the fossil fuel used in the USA. The bioethanol produced in 2008 displaced <4% of US gasoline use and <1% of its fossil fuel use (Renewable Fuels Association, Energy Information Administration). The bioethanol currently produced in the US is a useful replacement for Methyl Tertiary Butyl Ether (MBTE), a suspected carcinogen used to make higher octane fuels, but it does little to reduce greenhouse gas emissions or promote energy production, energy independence or food security. Iowa State University economists have concluded that the primary effect of the US corn to ethanol program is to increase prices of corn and farmland (Rubin et al 2008).

Jet fuel is more similar to diesel than gasoline, so an analysis of the potential to displace jet fuel with biofuel should consider past experience with biodiesel. Biodiesel and jet fuel can both be made from fatty acids. Consequently, feedstocks high in oil are used for biodiesel production, while feedstocks high in starch or sugar are more appropriate for ethanol production. Corn is a source of both oil and starch, so can be a feedstock for either biodiesel or bioethanol. Oil-rich crops, such as soybean or canola, are more commonly used for biodiesel feedstock in the USA.

Sugars, starches, and oils provide the bulk of calories in most human diets, and are the raw material for first generation biofuel production. Since many of our traditional food crops have been bred for carbohydrate and oil production these crops were among the first choices for biofuel feedstocks. The U.S. ethanol industry uses corn as its main feedstock; the U.S. and South American biodiesel industries use soybean oil as their main feedstock; biodiesel in Europe mainly comes from rapeseed oil; Brazilian ethanol is produced from sugarcane; and biodiesel in Southeast Asia is made primarily from palm oil.

Entirely replacing US transport fuel with biodiesel would require about 140 billion gallons (Chisti 2007). Meeting this demand using corn, soybean, or canola feedstocks, respectively, would require 17, 6.5, or 2.4 times the entire cropping area of the USA. We cannot be self-sufficient in biodiesel production from traditional food crops and continue to feed ourselves. Not even half our transportation fuel needs can be met with biodiesel derived from food crops.

Aviation accounts for just 8% of US petroleum use and 19% of transport fuel use (Energy Information Administration 2009). Even so, replacing the entire cropping area of the US with corn or soybean would not produce enough feedstock to replace current aviation fuel use with biofuels (Chisti 2007). Canola is more efficient: Dedicating 46% of US cropland to canola production would produce sufficient feedstock to meet the current fuel demand of the aviation industry (Chisti 2007). The remainder could feed Americans sufficiently if:

1) We dramatically curtail ethanol production from corn,
2) We dramatically reduce food exports, and
3) We dramatically reduce our consumption of animal products.

We can fly and eat too, but cheeseburgers won't be on the menu if our aviation fuel is made from food crops.

Recognition that food production will be compromised if we attempt to replace a substantial portion of our fuel use with biofuel made from food crops has led to calls for second and third generation biofuels, made from non-food crops. Non-food feedstocks can still affect food supplies by displacing food crops. Dedicated biomass crops such as switchgrass or miscanthus reduce food supplies if they are planted on agricultural land, just as they reduce biodiversity if they are planted on wild lands. Because biofuels require biomass, and because biomass requires land, there will always be trade-offs between biofuel production, food supplies, and biodiversity (Babcock 2008).

A widely-cited estimate of the amount of biomass that could be harvested from US farms and forests claims that "relatively modest changes in land use" would allow the harvest of 1.3 billion tons of feedstock annually by 2030 (Perlack et al 2005). These changes include:

1) A 50% increase in all small grain yields by 2030, requiring a much faster rate of increase than has been achieved over the past 40 years;
2) Conversion of all cropland to no-till, requiring conversion of 70% of cropland within the next two decades, in addition to the 30% of cropland already converted after four decades of development and promotion of no-till systems;
3) Conversion of 55 million acres of cropland – more than the entire area dedicated to wheat production in the US – to perennial biofuel crops; and
4) Recovery of 75% of the crop residues that help maintain soil health.

The likelihood of any of these happening over the next two decades is slim, and there is almost no chance that they will all happen together. If they do, sufficient biomass could be harvested to replace 20% of the transportation fuel used in the US (Perlack et al 2005), enough to replace the fossil fuel used for aviation. Complete replacement of aviation fuel with biofuel may be feasible if efforts to displace other transportation fuels with liquid biofuels are scaled back. If all existing biofuel refineries could be re-tooled to make jet fuel instead of ethanol (they can't), current refining capacity and feedstock harvest might be sufficient to replace a third of the nation's jet fuel consumption with biofuel.

Conversion of lignocellulosic feedstock crops to fuel will require rapid adoption of new technology. The most likely scenario in the near term is to use the Fischer-Tropsch process to synthesize aviation fuel from gasified biomass. Fischer-Tropsch technology is mature, but has been criticized for its high greenhouse gas emissions: Currently operating Fischer Tropsch plants emit 10 times more CO_2 per barrel than conventional petroleum refineries (Andrews and Logan 2008).

Algae have attracted considerable interest for their ability to produce high oil yields from small areas. Algal production, harvest, and conversion technology remains in its infancy, and algal biofuel will not contribute substantially to fossil fuel displacement in the near term. Early experience with algae shows that the production systems are expensive (~100 times forest biomass in open systems, ~1000 times in closed systems), in part because of the energy and resources needed to construct and maintain ponds or photobioreactors, which involve mechanical circulation, cooling, and gas-exchange systems. Algal harvest is also energy-intensive, involving flocculation, centrifugation, drying and lipid extraction before lipids can be converted to biodiesel using established technology. Production of biofuel from algae deserves further research attention, but considerable system innovation is needed for algal biofuel to approach renewable status. Even if algal production does not compete directly with food crops for land, biomass used as a renewable energy source for system maintenance will.

Phasing out fossil fuel use is necessary to achieve sustainability. A small proportion of current US fuel consumption can be replaced with biofuels, but policies intended to replace current fuel consumption with biofuels in the long term could compromise environmental stability and our nation's ability to feed itself. A nation that has 5% of the world's population but uses a third of the world's jet fuel has ample opportunities to reduce fuel consumption through conservation and efficiency. Reducing fuel consumption must be the top priority to reduce ecological and food system stress associated with biofuel production.

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