Determining the rate of used cooking oil output by the restaurant industry in the Salt Lake Valley, UT

Jonathan Miller

Abstract The amount of used restaurant oils diverted to biodiesel production in the United States is increasing due to growing consumer interest, the emergence of biodiesel cooperatives, and increased commercial capacity (NBB 2006). Biodiesel, a renewable fuel used as an alternative or additive to conventional diesel, offers several benefits: biodiesel burns cleaner than conventional diesel, it can be produced from multiple feedstocks, and the introduction of production facilities has been shown to result in a net increase in jobs and revenue for a given community (Van Dyne and Weber 1996). To determine an upper bound for the potential impact restaurant oils may have on the biodiesel market, a survey of 163 restaurants was conducted in the Salt Lake Valley. The primary purpose of the survey was to determine the rate of used oil disposal and the type of cuisine served at each restaurant, although some supplementary data was collected as well, such as the number of customers served. Extrapolating the amount of oil produced to the approximately 1640 restaurants that exist in Salt Lake County suggests that restaurants dispose of roughly 500,000 gallons of spent oils per year. This volume is enough oil to satisfy approximately 1/250 of the diesel demands of Salt Lake County and suggests that spent restaurants oils are at most a niche feedstock for biodiesel production.

Introduction

Biodiesel is a renewable fuel receiving an increasing amount of attention and production in the face of constrained petroleum supplies. In 2005 U.S. biodiesel production reached 75 million gallons (up from 0.5 million in 1999), with approximately 10% of the fuel produced from spent cooking oils (Schenpf 2005). Biodiesel, which consists of mono-alkyl fatty acid esters (with the most common constituent being linoleic ($C_{17}H_{31}CO_2CH_3$)), is made from animals fats and vegetable oils including, but not limited to, soybean, corn, rapeseed (canola), olive, cotton seed, and mustard seed oils (Felizardo et al. 2006). While the majority of biodiesel is produced from virgin oils, the use of spent oils as a feedstock has significant room for growth. However, the limit of this feedstock is controlled by the amount of oils restaurants use, resulting in an upper-bound much lower that of virgin oils. Determining the upper-bound for biodiesel production using restaurant oils in an urban environment is the topic of research.

Producing biodiesel is a simple process which can be efficiently performed on scales ranging from a few gallons per batch for personal use to millions of gallons per year in commercial production facilities (NBB 2006). In order to transform vegetable oils into a fuel suitable for use in a combustion engine, the glycerin contained in the oil must be removed. Separating glycerin from the oil is accomplished through a process known as transesterification, which involves heating the oil, adding a solution of lye and methanol, cooling the oil, and removing the glycerin layer. The simplicity of this process allows biodiesel production to be incorporated into a community at almost any scale, ultimately bounded by the amount of available oil.

Biodiesel is primarily used as an alternative to conventional diesel fuel and can be used as the primary fuel or as an additive to increase lubricity in low-sulfur diesel fuel. Conventional diesel engines can accept biodiesel, or a diesel-biodiesel blend in any ratio, without modification or a reduction in performance (Yeou-Feng and Yeh 2001). Compared to conventional diesel, the use of biodiesel results in a significant reduction of unburned hydrocarbons (-90%), carbon monoxide (-50%), and particulate matter (-30%), while the emissions of sulfur oxides and sulfates are virtually eliminated[*] (Lue and Yeh 2001). Increased concentrations of nitrogen oxides are known to aggravate asthma conditions, contribute to ozone, and contribute to acidic

[*] The only criteria air pollutants whose emissions are increased when using biodiesel are nitrogen oxides, rising by 13% compared to conventional diesel (Lue and Yeh 2001). Increased concentrations of nitrogen oxides are known to aggravate asthma conditions, contribute to ozone, and contribute to acidic conditions; however, these effects are not unique to nitrogen oxides and the effects of the modest increase in NO_x emissions are far negated by the substantial reduction in unburned hydrocarbons, particulate matter, and sulfur emissions (EPA 2006).

conditions; however, these effects are not unique to nitrogen oxides and the effects of the modest increase in NO_x emissions are far negated by the substantial reduction in unburned hydrocarbons, particulate matter, and sulfur emissions (EPA 2006).] The reduction in unburned hydrocarbons, which are precursors to ozone, results in a 50% decrease in the ozone forming potential of the exhaust emissions (Durbin and Norbeck 2002). A decrease in ground-level carbon monoxide, particulate matter, and ozone is desirable for the health of any populace, especially those in urban settings where traffic is heavy and exposure to automobile emissions is frequent.

Since biodiesel is produced from oilseed crops, the bulk of the fuel is part of a closed-carbon system, meaning the carbon content of the fuel was recently removed from the atmosphere (in the form of carbon dioxide) by the crops themselves. However, biodiesel is not part of an ideal closed-carbon system, as this claim would neglect the fossil fuel infrastructure being used to produce the biodiesel, as well as the addition of methanol. Virtually all carbon in fossil fuels, on the other hand, has not existed in the atmosphere in human history. The carbon released from fossil fuels, therefore, has the potential to warm the atmosphere, relative to what is considered a normal climate. In an ideal closed-carbon system, a fuel’s contribution to global warming is nil. However, since there is fossil fuel input to transport and refine the oils, the net decrease in carbon dioxide is not 100%, but still a considerable 78% when compared to traditional diesel (Nabi and Shahadat 2006).

Furthermore, biodiesel has been found to have a positive effect on local economies in a number of case studies. The emergence of local biodiesel production and sales has been shown to result in a net increase in jobs, wages, and tax base for a given community (Van Dyne and Weber 1996). Additionally, value is added to oilseed crops and new markets for agribusiness are created (Ramos and Wilhelm 2005). The construction of biodiesel production facilities, the operation of the facilities, and the distribution and retailing of the biodiesel fuel creates jobs for local markets (Bekers 1995). The increase in jobs due to the production of biodiesel is only partially offset by slight decreases in jobs in petroleum-based fuel supply firms and retailers (Van Dyne and Weber 1996). Besides the pollution reduction and economic incentives, biodiesel also offers increased stability and sustainability on a national level by reducing U.S. dependence on foreign oil (Jeong et al. 2004).

The bulk of biodiesel in the U.S. is produced at one of 53 production plants throughout the nation, with soybean oil used as the primary feedstock (NBB 2006). However, dozens of biodiesel cooperatives have emerged in cities and states across the U.S. whose primary source of oil for biodiesel production is recycled waste oil from local restaurants (for many, restaurants oil is their sole source, particularly cooperatives that operate in urban settings) (Leung 2001). In the absence of biodiesel programs, used restaurant cooking oil must be taken to authorized collection facilities or agencies. The restaurant management may transport the used oil themselves, yet it is far more common for restaurant owners to pay an independent firm to remove the oils. This process of ‘waste’ removal is an additional cost to restaurant owners (Estill 2005). Most biodiesel cooperatives collect restaurant oils with no charge to either party and produce valuable biodiesel fuel in local outfits. As of yet, there have been no studies conducted to directly determine the amount of spent oils the restaurant industry outputs. Restaurant oils currently contribute approximately 1% (7 million gallons per year) of the total feedstock that is invested in biodiesel production; however, this fraction will likely decrease due to the high rate of growth in the use of virgin oils. Nevertheless, in order for the full potential of restaurant oils to be realized, accurate estimates regarding oil availability must be provided. A concrete number for the output of oils is an important tool for setting production goals, designing business plans, and quantifying the potential benefits to the local economy and environment.

Studies related to biodiesel have focused on the technical aspects of the fuel (such as the combustion characteristics, production techniques, and emissions) or economic aspects of biodiesel production on macro and micro scales. The research conducted in Salt Lake County, UT, complements the findings of existing literature by quantifying the volume of spent oils available for biodiesel production. The potential impacts of used oils cannot be evaluated without an estimate for the rate of oil disposal, as offered in this study.

Methods

To determine the upper bound for biodiesel production using waste oils, an estimate for the total output of the restaurant industry in a given area must be provided. In this case, the estimate was computed by extrapolating the average oil output per restaurant (determined by surveying 163 restaurants) to include the total number of restaurants in the study site. The extrapolation process was performed both on the entire data set and categorically (pooled by cuisine type).

When producing biodiesel from cooking oils, there is a negligible change in volume due to the addition of methanol (approximately 10% by volume), which roughly equals the volume of glycerine and non-dissolved solids removed (Eijsbouts et al. 2003). As such, the conversion factor for the volume of cooking oil to the volume of potential biodiesel production is assumed to be one (typical of biodiesel analyses). Additionally, all used cooking oils may be converted to biodiesel (Ghadge 2005). While oils containing elevated levels of water, particles, and fats may require a more intensive pretreatment process, the final value for the oil output rate is intended to be an upper bound, so no correction will be made for the variance in restaurant oil.

Data collection To establish the output rate of spent oils, a survey of restaurants was conducted. I used the Salt Lake Valley, Utah as a case study, an area bounded by the border of Salt Lake County (fig. 1). The Salt Lake Valley was chosen as the study site for two reasons. First, Salt Lake City has an average number of restaurants per 1000 people (1.56 versus a national average of 1.52 for cities with a population of 50,000 or greater) (Wiltsee, 1998). Second, the study site has a population greater than one million, providing an appreciable amount of diverse restaurants to be studied in a manageable area.

Fig. 1: The study site includes all of Salt Lake County

To generate a representative sample that could be extrapolated to the entire population, the restaurants were categorized to account for the large variability of oil output among restaurants. An average sized restaurant or cafeteria disposes of approximately 30 gallons of used cooking oil per month; however, the range varies greatly and is primarily dependent on the type of cuisine and number of customers served (Stoll and Gupta 1997). For example, the owner/operator of two Iceberg Drive Inns in the Salt Lake Valley estimates that both of his restaurants produce 45 gallons of used cooking oil per month, while two of his restaurants' neighbors, a pizzeria and a deli, output <1 gallon of used cooking oil per month (Bryan Jensen, personal contact, 2006). To account for these variations, I categorized restaurants into ten cuisine types: American, Chinese, deli, fast food, Italian, Japanese, Mexican, other Asian, pizza, and other. The categories were developed as a logical extension of the number and types of restaurants listed in the local yellow pages. Using categories based on cuisine is appealing because a large number of restaurants can be categorized into food types with little research and relative ease.

A second variable in the rate of oil output is the number of customers served. To analyze correlation between the patronage rates and oil output, the survey included a question regarding the number of customers served (fig. 2, question 4). While there appears to be correlation between the number of customers and oil output by a restaurant, this data was not used in the extrapolation, as there are no records available describing the number of customers served in restaurants.

Before beginning the survey, 34 restaurants were chosen at random for each of the food categories, giving a potential sample size of 340 restaurants. This value was chosen because it is approximately twice the desired number of responses, which proved to be sufficient. Two survey methods, interviews and paper surveys, were used in conjunction. The interview was the primary survey method and accounted for two-thirds of the responses. For restaurants where an interview could not be obtained, the paper survey was left for the manager or owner (fig. 2). In addition to the on-foot method, approximately 80 surveys were mailed directly to restaurants. Both survey methods address the same questions, though interviews were sometimes expanded when the managers expressed interest or asked questions. The most vital questions in the survey regard the rate of oil disposal and the type of food served. Supplementary questions, such as the number of customers served, were also collected. The survey method was chosen because it directly questions those most familiar with the oil output of their respective restaurant. Owners, managers, and other restaurant operators commonly have knowledge of the amount and fate of spent oils output by their restaurant. No other studies have attempted to calculate the oil output in a region using this method.

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Restaurant name (optional) ______________________________

1) What type of food does the restaurant serve?

- □ American
- □ Italian
- □ Mexican
- □ Chinese
- □ Japanese
- □ Other Asian
- □ Pizza
- □ Fast food
- □ Other

2) How much used cooking oil is disposed of each month?

- □ <1 gallons
- □ 1-5 gallons
- □ 5-15 gallons
- □ 15-25 gallons
- □ 25-35 gallons
- □ 35-45 gallons
- □ 45-55 gallons
- □ ≥55 gallons (approx.______)
- □ Other ________

3) How does the restaurant dispose of its used cooking oil?

- □ Take oils to a recycling facility
- □ Pay an independent firm to pick up the oils
- □ Donate oils to partners for biodiesel production
- □ Other ______________________________

4) Approximately how many customers does the restaurant serve weekly?

______________ □ don't know

5) Would the restaurant consider donating its oil to a local biodiesel cooperative?

- □ yes
- □ no
- □ don't know

6) Is the restaurant part of a chain?

- □ yes
- □ no

8) If so, how many of this chain are located in Salt Lake Valley

______________ □ don't know

Thank you for your kind participation in this survey. Please mail this page in the provided, pre-stamped envelope. You may also fax this page to 801-942-7047 or e-mail your answers to jonmiller@berkeley.edu. Include comments and inquiries (with contact information) on the back of this page or on a separate sheet.

Fig. 2: Sample of the paper survey distributed to restaurants.

Statistical Analysis Following the data collection, a descriptive statistical analysis (mean, median, standard deviation, standard error, skew, and quartiles) was performed on each category. To calculate the total output rate for the study site, the mean for each category was multiplied by the total number of restaurants in the respective category. The results were summed and Gaussian error propagation was performed on each step. Linear extrapolation is the simplest method to determine the output rate and was used in this analysis.

In addition to determining the total output rate, regression lines and r^2 values were calculated for the relationship between customers served and oil output. These values were calculated both categorically and on the data set as a whole.

Results

The estimated total output of waste oil from the approximately 1640 restaurants in the Salt Lake Valley is 500,000 gallons per year. This value is based on responses received from 163 restaurants, with between 13 and 20 responses for each of the 10 cuisine categories (the total number of restaurants surveyed was 263, resulting in a response rate of 62%). The average oil output for each food category ranged from <1 gallon per month for delis to 48 gallons per month for fast food. Fast food is the dominant contributor to total oil output, disposing of more than 110,000 gallons per year. This volume accounts for approximately 22% of the total oils disposed, whereas fast food restaurants account for only 13% of the total number of restaurants.

The average for the entire survey of restaurants is 26 gallons per month, with a standard error of 2. The distribution of the whole data set is not smooth due to a large spike near zero oil output (fig. 3). However, when delis and pizzerias are removed from the data set, the distribution resembles a common bell curve. When delis and pizzerias are excluded, the average output is 31 gallons per month, with standard error of 2. When this portion of the data set is extrapolated to

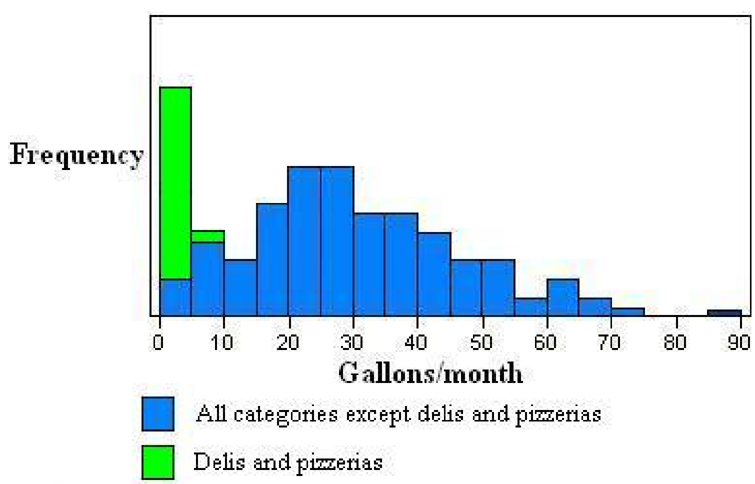

Fig. 3: Distribution of data set (n=163)

include all the remaining restaurants, it results in a value with a smaller error, 450,000 ± 25,000 gallons per year.

Less than half of the restaurants surveyed (n=71) also provided data on the number of customers served. Statistically significant trends exist between the number of customers served and the amount of oil output. A scatter plot of the paired data (fig. 4) reveals a trend in which customers served and oil output are positively correlated; performing a linear regression on this set returns an r^2 value of 0.15, where t <0.05. Similar to the distribution analysis, when delis and pizzerias are removed, the trend becomes more consistent (fig. 5). A linear regression on this subset returns a significantly higher r^2, 0.38, and a reduced p-value. The low r^2 values and apparent noise suggest that the oil output per customer varies significantly among restaurants.

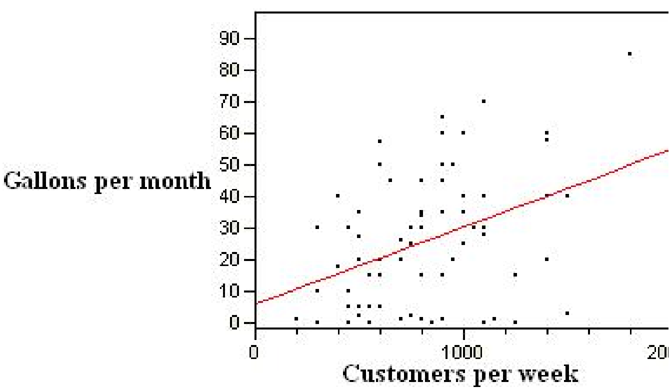

Fig. 4: Scatter plot of customers served by oil output for entire data set (r^2=0.15)

Fig. 5: Scatter plot of customers served by oil output, excluding delis and pizzerias (r^2=0.38)

The average household with one or more vehicles consumes 1,194 gallons per year in the mountain west region and the average household has 1.72 drivers (EIA 2005). Therefore, if a system were to be designed where all of the oil in the valley was collected and used to create biodiesel, the fuel needs of 423 households (728 drivers) would be met. This estimation does not account for the amount of fuel used to collect the oil, but since the oil is already being collected, the result can be interpreted as 728 additional drivers served from the status quo. However, the loss of some restaurant oils as the feedstock of animal feeds, soaps, and cosmetics may increase fuel use elsewhere.

Table 1: Summary of the data set including total estimated oil output

Oil output Restaurant type	Average (gal/month) ± s.e.	Number surveyed (n)	Min(gal/month)	Max(gal/month)	Total restaurants	Total Output (1000 gal/yr) ± s.e.
Deli	0.4 ± 0.1	15	0	1	155	0.8 ± 0.3
Pizza	6 ± 2	15	0	20	184	15 ± 4
Japanese	15 ± 3	14	0	40	96	18 ± 3
Other	17 ± 3	17	0	35	109	24 ± 4
Italian	20 ± 3	13	5	35	131	30 ± 4
Other Asian	20 ± 3	14	5	35	165	44 ± 5
Mexican	35 ± 3	18	15	58	170	77 ± 7
Chinese	37 ± 4	18	10	63	168	83 ± 8
American	41 ± 3	20	15	65	244	100 ± 10
Fast food	48 ± 5	19	15	85	219	110 ± 12
All restaurants	26 ± 2	163	0	85	1641	430 ± 30
Total Output*						500 ± 50

*The "total output" value is the sum of the individual categories, which were calculated by extrapolating the average oil output for each category across the number of restaurants of that type. The "all restaurants" value was calculated by taking the average of the entire data set and extrapolating to include all the restaurants in the study site.

Discussion

The contribution waste oils may have on the overall diesel market is small, suggestive of a niche feedstock. In this particular case study, the estimated output of spent oils for a year, 500,000 gallons, is slightly more than one third of the diesel fuel sold in the state of Utah *per day*. Thus, the contribution of used oils into the diesel market is slightly less than a thousandth of the total diesel supplied. The estimate of diesel fuel sold (1,428 thousand gallons per day) in the entire state was used because the EIA does not offer county-wide statistics; however, if the same method was used to include the entire state, the contribution would not likely surpass more than a few thousandths of the total diesel fuel supplied (EIA, 2005).

The amount of oils output from different types of restaurants varied greatly, ranging from <1 gallon to 48 gallons per month. This range is the result of different cooking techniques employed by the 10 cuisines. For example, none of the delis surveyed uses a fryer. In contrast, nearly all fast food and Chinese food restaurants use deep fryers regularly. The average oil output for all restaurant categories is 26 ± 2 gallons per month. If this average is linearly extrapolated across 1641 restaurants, the resulting total is 430,000 ± 30,000 gallons per year. However, restaurants producing between 33 and 39 gallons per month comprise 50% of the total number of restaurants, which is responsible for the higher total of 500,000 ± 50,000 gallons per year. The discrepancy between these two methods (extrapolating the group as a whole or categorically) is more than 10%. This difference suggests that determining the distribution of restaurant types may be a useful method to determine total oil output of oil; however, in this particular study, the standard errors are slightly too large to claim that the difference between the methods is statistically significant.

These results differ significantly from a study conducted by George Wiltsee in 1998 titled “Waste grease resources in 30 metropolitan areas.” This study predicts an oil output for Salt Lake City that is nearly three times as high as my survey suggests. However, Wiltsee’s methods are lacking, as they do not distinguish between restaurant types. To determine the average output of oil per restaurant, Wiltsee contacted grease collectors and inquired about their customers. Therein lays the problem, as grease collectors’ customers are grease producers. Many restaurants have no contract with grease collectors, as they either have a negligible amount of waste oils or pool their waste oils with neighboring restaurants. The amount of oil these restaurants produce is neglected, and they are merely lumped with the larger contributors. This is exemplified in deli restaurants, which account for 10% of the total restaurants, but contribute only 0.5% of the total oil. The composition of restaurants in a region appears to be an important factor when determining the waste oil resources of a given city.

Another variable in the oil output of restaurants is the number of customers served. The size of the establishment does have an effect on the amount of oil used, but this should not be the only variable used to estimate the amount of oil a given region outputs. The oil output of some cuisine categories, such as delis and pizzerias, is not sensitive to the number of customers served (see regression analysis, fig. 4 and 5). Based on these observations, the number of customers served is a useful metric, but should only be used when data is available on the type of food served at the given restaurant.

Of the restaurants visited, a majority of the managers and owners (where present) were accommodating and many showed interest in the project, inquiring to varying degrees. When a response was not obtained, it was typically because those familiar with the oil collection were absent or they preferred to refer the question to another authority. Approximately 75% of the restaurants where I received no response referred me to either an individual or corporation. Of the referrals I contacted, a response rate of approximately 50% was achieved.

Although a sizeable sample was obtained (approximately 10% of the total restaurants in the study site were surveyed), there are a number of issues that contribute uncertainty in the data. For example, the oil output of restaurants varies from month to month, so restaurant managers cannot give a precise answer. Rather, most restaurants offered a 5 gallon range of output. Additionally, the reliability of the responses themselves must be questioned. During the survey, a majority of the interviewees answered with confidence; however, others were less sure and approximated as best they could. These effects are difficult to quantify, but must be considered when interpreting the final values. An added uncertainty of ± 5 gallons per month for each value in the data set may result in an increase (or decrease) of as much as 100,000 gallons per year, however unlikely. Nevertheless, the potential for used oils is limited. To put the result in perspective, a reduction of 500,000 gallons of fuel per year in Salt Lake County could be accomplished by reducing the number of miles driven per driver by approximately 2 miles per month, or increasing the fuel mileage of the fleet of vehicles by less than 0.1 miles per gallon.

Although the restaurant industry cannot generate a significant portion of the diesel market, biodiesel refined from agricultural feedstocks will continue to increase and may contribute a significant portion of the nation’s diesel needs. Estimates from the National Biodiesel Board predict that biodiesel will contribute more than 1% of the total diesel market by the end of the decade (NBB, 2005). Restaurant oils will contribute to this trend, but, as the above data suggests, it will near its upper bound after a small rise relative to the overall diesel market. Nevertheless, used restaurant oils play a unique role in the biofuel market that stretches beyond the quantity of oil provided. The ability to produce liquid fuels that operate in conventional engines from used vegetable oils has increased awareness of biofuels and given home-brewers the opportunity to produce their own fuel at a reduced cost to themselves and the environment.

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