# Awareness, Use, and Perceptions of Biodiesel by Belgian and American College Students

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## Abstract

*Biodiesel is a renewable liquid transportation fuel with potential to extend petroleum supplies and reduce tailpipe emissions of particulate matter, unburned hydrocarbons, and carbon monoxide (CO) and reduce life-cycle carbon dioxide ($CO_2$) emissions relative to petroleum diesel. However, little is known about how various groups, either internationally or domestically, view biodiesel. This study examined Belgian and American college students' awareness, use, and perceptions of biodiesel. A higher percentage of Belgian students versus American students reported driving diesel automobiles (60% and 17%, respectively) and being aware of biodiesel (100% and 86%, respectively). However, only 4% of either Belgian or American students had purchased biodiesel. Belgian students were undecided and American students slightly agreed there were renewable and environmental benefits of biodiesel use. Both Belgian and American students were undecided about biodiesel quality, with Belgian students being more uncertain. Belgian and American students were also undecided if there were negative externalities associated with biodiesel. Both groups tended to agree that continued long-term reliance on fossil fuels is not sustainable; however, Belgian students agreed more strongly than American students. While there were significant differences between Belgian and American students, both groups were largely undecided about biodiesel quality and the food and economic consequences of biodiesel production and use; differences were primarily in the degree of uncertainty. Both groups (especially Belgian students) were concerned about continued reliance on fossil fuels. Given the low level of use and the high degree of uncertainty, efforts should be made to educate Belgian and American college students about biodiesel.*

**Keywords:** Biodiesel, Perceptions, Survey, Belgium, United States

## Introduction

Worldwide biodiesel production increased from 17.8 billion liters in 2009 to 21.4 billion liters in 2012, a four-year increase of 20.2%. In 2011, the United States ranked first in biofuel (ethanol and biodiesel) production by country, with a total of 57.4 billion liters produced (REN21, 2012). Of the total, 3.2 billion liters were biodiesel. Belgium was the 11th highest biofuel-producing country, totaling 0.8 billion liters. Biodiesel use increase has occurred because of energy mandates put into place in both countries, to reduce fossil fuel dependency and improve Green House Gas (GHG) emissions.

This renewed interest of liquid biofuels among the public, government, and industry was largely caused because of diminishing petroleum supplies, increasing energy demands, the geographical concentration of known petroleum reserves, and concerns about the environment (Koonin, 2006; Rojey & Monot, 2010). The U.S. Energy Independence and Security Act of 2007 mandated that 136 billion liters of renewable biofuels be in use by 2022 (Schnepf & Yucobucci, 2010). Likewise, in 2009, the European Union (EU) adopted the Renewable Energy Directive setting a target of 10% biofuels for all transportation fuels by 2020 (Böhringer, Rutherford, & Tol, 2009). U.S. biofuels policy has been mandate-driven and there is minimal pressure to change that position while the European Union (EU) is verging toward more reliance on mandates (Ziolkowska, Meyers, Meyer, & Binfield, 2010).

Commercially available liquid biofuels are considered to be first generation biofuels, because they are produced primarily from food crops (cereals, sugar crops, and oil seeds) using mature technologies (Sims, Mabee, Saddler, & Taylor, 2010). Although there is strong political and agricultural industry support for first generation biofuels, not all critics have been convinced of the net benefits of increased production and use. Some question the performance (Skipper, Van de Velde, Popp, Vickery, Van Huylenbroeck, & Verbeke, 2009), environmental consequences (Lehrer, 2010), economic impacts (Pimentel, 2009), and food availability and cost effects of first generation biofuels (Naik, Goud, Rout, & Dalai, 2010). While there is a great deal of scientific interest and on-going research concerning second generation biofuels (produced from non-food feedstocks, such as lingo-cellulose and algae), commercialization is estimated to be a decade or more in the future (Sims et al., 2010).

Ulmer et al. (2004) examined Oklahoma consumers' attitudes toward ethanol-blended gasoline. A majority (59.2%) of respondents indicated that reduced U.S. dependence on foreign oil was the greatest benefit of ethanol-blended gasoline. No significant relationship was found between consumers' willingness to purchase an ethanol blend and the demographic variables of gender, education, income, age, or urban versus rural residence. These results partially conflict with previous research indicating that females (Zelezny, Chua, & Aldrich, 2000) and younger adults (Gronhoj & Thogersen, 2009) have more pro-environmental attitudes than males and older adults. A study to assess consumers' perceptions related to biofuel use in transportation, conducted in the northwestern part of Romania, noted that participants believed biofuel was cleaner and caused less pollution to the environment (Mariasiu, 2013). Of the 1036 respondents, 55.6% agreed they would be willing to pay more for biofuels to ensure less pollution and a cleaner environment. Research comparing Belgian and American consumers noted similarities and differences

between the two groups (Popp, Van de Velde, Vickery, Van Huylenbroeck, Verbeke, & Dixon, 2009). Consumers in both countries ranked fuel economy and purchase price as highly important factors in deciding whether to purchase a gasoline, diesel, or biofuel automobile.. High income Americans were less concerned with fuel economy. American consumers, having both higher fuel taxes and average annual miles driven, were more concerned than Belgian consumers over fuel prices.

A recent study assessing Greek university students' perceptions of energy and the environment noted that students are "overwhelmingly positively disposed towards the environment" (Charisiou & Goula, 2012, p. 9). Students believed protecting the environment should take precedence over economic consideration and 82% believed bioenergy was an acceptable method to reduce global warming. Halder (2011) studied the importance of bioenergy knowledge, perceptions, and attitudes among young citizens. The study found three influential dimensions of bioenergy perceptions and attitudes: (a) practical, (b) motivation, and (c) critical. The study identified critical perceptions of bioenergy among the younger generation and noted distinct differences between American and Belgium students; namely Belgium students did not have positive perceptions toward bioenergy, but were interested in learning more, and American students knew little of bioenergy but were excited to use it.

Previous comparative research on the acceptance of genetically-modified organisms (GMOs) in the food supply provided evidence that American and Belgian students may differ in their perceptions and acceptance of other innovations such as biodiesel due to cultural factors (Gaskell, Bauer, Durant, & Allum, 1999; Wohlers, 2010). Differences in perceptions may also be influenced by increased urbanization and decreased agricultural land in Belgium. While these trends are also occurring in the U.S., concerns may be more muted due to the lower population density and greater availability of arable crop land in the U.S. as compared to Belgium (Central Intelligence Agency, 2013; Tempels, Verbeek, Pisman, & Allaert, 2012).

Understanding consumers' perceptions, attitudes, and knowledge about energy and environmental technologies and programs can provide a framework for educational strategy and policy development (Segon, Stoer, Domac, & Yang, 2004). Public opinion surveys about renewable energy sources have become increasingly important. These surveys have been used to assess awareness, attitudes, and knowledge, and have provided a springboard to overcoming social barriers toward renewable energy sources (Segon et al., 2014).

Knowledge of current levels of GHG emissions and the prediction of a 50% increase in population on Earth by 2050 has reached consumers worldwide. Today, consumers are increasingly more aware of their purchasing behaviors with regards to the environment (Van de Velde et al., 2009). Biofuels give consumers an opportunity to purchase a transportation fuel that reduces harmful emissions to the environment; however, some consumers question other potential consequences of the use of biofuels. A consumer survey that assessed American and Belgian citizens' perceptions determined that respondents with heightened awareness towards the environment felt that renewable fuels could potentially result in higher food costs (Skipper et al., 2009). However, both American and Belgian consumers preferred low food prices over low fuel prices. The research noted that environmental concerns were largely the same between respondent groups.

Acker (2008) noted the importance of educating students, consumers, and policymakers about renewable energy, including biofuels. The research further noted that education was one of three primary needs necessary to expand the renewable energy market. Specifically, Acker recommended educational programs target industry personnel, school groups, and the general public. Additionally, Wingenbach, Boyd, and Lindner (2003) noted the importance of understanding students' knowledge and attitudes about international agricultural issues to prepare them for the workforce. College students will play an important role in the development and use of biodiesel as citizens, consumers, teachers, business leaders, voters, policy makers, and scientific and technical experts (Acker, 2008; Cortese, 2003). Yet, little is known about how these students view biodiesel production and use (Zyadin et al., 2012). Thus, the purpose of this study was to determine and compare Belgian and American college students' use, awareness, and perceptions of biodiesel in an effort to determine educational needs for the future.

## Research Objectives

This study was used to:
1) Determine and compare the awareness, use, and perceptions of biodiesel among retail fuel consumers in America and Belgium; and
2) Determine if there were significant relationships between awareness, use and perceptions of biodiesel and selected consumer demographic characteristics among American and Belgian fuel consumers.

## Research Methods

The population for this study was comprised of students enrolled in an introductory agricultural economics course at the U.S. University (University of Arkansas) and an introductory chemistry course at the Belgian University (University of Ghent) during fall 2011. The survey was administered in each class during the fall semester of the 2011-2012 academic year. Prior to administering the survey, a brief statement was read to students describing the purpose of the study and assuring students their participation was voluntary and responses would be anonymous. At the U.S. University, 90 of 105 (85.7%) students enrolled were present and provided usable responses; at the Belgian University 119 of 120 (99.2%) were present and provided usable responses. The anonymous nature of responses precluded follow-up of absent or non-responding students.

The survey instrument was developed by the researchers based on a review of the literature related to consumer awareness, use, and perceptions of biofuels (Halder et al., 2011; Kinsey, Peterson, & Haines, 2003; Skipper et al., 2009). The completed instrument contained three sections. Section one had three items to determine if the respondent owned or drove a diesel-fueled vehicle, had ever heard of biodiesel, or had ever purchased biodiesel. (The second item was used as a screening question; respondents indicating they had never heard of biodiesel were directed to proceed directly to the demographic items.) Section two contained 34 items on a 1 to 5 Likert-type scale (1 = *strongly disagree* and 5 = *strongly agree*) designed to determine respondent perceptions about biodiesel. To prevent response set, 11 of these 34 items were negatively worded. Section three contained three demographic items related to gender, age, and type of area where the student was raised [farm, rural - nonfarm,

town ($\leq$ 10,000 population), or city (>10,000 population)].

The test-retest procedure was used to determine instrument reliability (Gall, Gall, & Borg, 2006). The survey was administered twice, at a 14 day interval, to seven American undergraduate students not included in the main study. The coefficients of stability were 1.0, 0.81, and 0.99, for sections one, two, and three, respectively. A panel of six individuals with expertise in survey methods ($n = 3$), biofuels research ($n = 1$), biodiesel marketing ($n = 1$), and Belgian university teaching ($n = 1$) reviewed the instrument and judged it to possess face and content validity.

Data were analyzed using descriptive and inferential statistics. Principal components analysis was used to identify the number and nature of the underlying factors responsible for covariance in the 34 items designed to measure perceptions of biodiesel (section two). Following principal components analysis, negatively worded items were reverse-coded and factor scores were constructed for each identified factor, factor reliabilities were assessed, and the resulting factor scores were used as criterion variables in subsequent multiple regression analyses (Hair, Anderson, Tatham, & Black, 1998; Hatcher, 1994). The 0.05 alpha level was selected *a priori* for all tests of statistical significance.

**Findings**

The typical Belgian student ($N = 119$) was male (65%), grew up in a town (38.5%) or city (26.5%), was majoring in engineering (87%), and was 19.0 ($SD = 0.72$) years old. The typical American student was also male (58.6%), grew up on a farm (35%) or in a rural area (21%), was majoring in agriculture (80%), and was 19.9 ($SD = 3.3$) years old.

A majority of Belgian students, but less than one in five American students, reported owning or driving a diesel automobile (see Table 1). Awareness of biodiesel was high for both Belgian and American students, but, at 100%, was significantly higher for Belgian students. Only about 4% of either Belgian or American students had ever purchased biodiesel. Among those owning or driving a diesel vehicle, 7% of Belgian and 27% of American students reported they had previously purchased biodiesel.

Table 1

*Vehicle Fuel Type and Awareness and Use of Biodiesel for Belgian and American College Students*

| Statement | Belgian %($f$) | American %($f$) | $\chi^2$ |
|---|---|---|---|
| I own or drive a diesel automobile | 60.3(70) | 16.8(15) | 39.25[****] |
| I was aware of biodiesel prior to this survey | 100.0(117) | 85.6(77) | 18.03[****] |
| I have purchased biodiesel or a biodiesel blend | 4.3(5) | 4.4(4) | 0.01 |

*Note.* [****]$p<.0001$.

Data from the 34 biodiesel perception items were subjected to exploratory factor analysis, using the FACTOR procedure in SAS Version 9.3 (SAS Institute, 2013), to identify latent factors. The principal factor method was used to extract the factors,

followed by a promax (oblique) rotation. Based on the scree plot of eigenvalues, the proportion of variance explained, and the interpretability of the factors (Hatcher, 1994), four factors: (a) Renewable and Environmental Benefits, (b) Negative Externalities, (c) Low Quality Fuel, and (d) Lack of Concern; were identified and named (see Table 2). These four factors explained 100% of the variance in the original 34 items.

Table 2

*Factors, Loadings, and Scale Reliabilities for Student Responses to the Biodiesel Survey*

| Item | Factor loading |
|---|---|
| Factor 1: Renewable and Environmental Benefits | |
| ($\alpha = 0.77$) | |
| Biodiesel can significantly reduce dependence on foreign oil | 0.67 |
| Biodiesel produces fewer harmful exhaust emissions than petroleum diesel | 0.67 |
| By buying biodiesel I can contribute to a cleaner environment | 0.64 |
| It is better to use biodiesel since it is made from renewable resources | 0.62 |
| The Belgian [U.S.] government should support biodiesel research | 0.52 |
| Increased use of biodiesel will decrease global warming | 0.49 |
| I am willing to go out of my way to purchase biodiesel | 0.45 |
| Factor 2: Negative Externalities | |
| ($\alpha = 0.71$) | |
| Increased use of biodiesel will cause a shortage of food | 0.73 |
| Increased use of biodiesel will cause an increase in the cost of food | 0.67 |
| Increasing biodiesel production will decrease food production | 0.62 |
| Most new jobs resulting from increased biodiesel use will be low-paying jobs | 0.46 |
| Increased use of biodiesel will increase farmers' income | -0.46 |
| Factor 3: Low Quality Fuel | |
| ($\alpha = 0.74$) | |
| Using biodiesel results in increased engine repair and maintenance costs | 0.71 |
| Diesel engines will not run properly on biodiesel | 0.66 |
| I would never use biodiesel in a diesel engine | 0.63 |
| If I had a diesel car or truck, I would use biodiesel | -0.55 |
| Biodiesel is better for my engine than petroleum diesel | -0.52 |
| Factor 4: Lack of Concern | |
| ($\alpha = 0.66$) | |
| Emissions from automobiles have no effect on average global temperatures | 0.77 |
| I believe that average global temperature is increasing | -0.67 |
| There are sufficient oil resources to meet Belgian [U.S.] petroleum needs for the foreseeable future | 0.47 |

Items with negative factor loadings were reverse-coded and individual factor scores were calculated by summing all responses within a factor and dividing this sum by the number of items (Hatcher, 1994), resulting in factor scores that retained the original 1 to 5 scaling. The real limits for the scaled responses were defined as 1.00 to 1.49 =

*strongly disagree*; 1.50 to 2.49 = *disagree*; 2.50 to 3.49 = *undecided*; 3.50 to 4.49 = *agree*; and 4.50 to 5.00 = *strongly agree.*

Based on the nature of the factors, care must be used in interpreting factor scores. Higher factor scores for the Renewable and Environmental Benefits factor represent more positive perceptions of the benefits of biodiesel use; conversely, higher factor scores for the Negative Externalities, Low Quality Fuel, and Lack of Concern factors represent more negative perceptions of biodiesel.

Based on mean scores (see Table 3), Belgian students were categorized as undecided about the Renewable and Environmental Benefits, the Negative Externalities, and the Low Fuel Quality biodiesel factors. Belgian students disagreed with the Lack of Concern factor, indicating they had concerns about the supply and environmental aspects of continued reliance on fossil fuels. The mean scores for American students indicated they agreed with the Renewable and Environmental Benefits factor, disagreed with the Lack of Concern factor, and were undecided about the Negative Externalities and Low Fuel Quality Factors.

There was no statistically significant difference between Belgian and American students on perceptions of the Renewable and Environmental factor, with the mean for Belgian students near the upper limit of the undecided category and the mean for American students near the lower limit of the agree category. Both Belgian and American students were undecided about the Negative Externalities and Low Quality Fuel factors and disagreed with the Lack of Concern factor. However, there were statistically significant differences between Belgian and American students on the Negative Externalities (lower mean for American students), Low Fuel Quality (lower mean for American students), and Lack of Concern (lower mean for Belgian students) factors. The difference between means for the Negative Externalities factor was relatively small ($\Delta = 0.18$); however, the differences for the Low Quality Fuel and Lack of Concern factors were larger ($\Delta = 0.53$ for each). Using Cohen's (1988) effect size descriptors, the difference between the means for Belgian and American students was small (Cohen's $d = 0.30$) for the Negative Externalities factor, and large for the Low Quality Fuel (Cohen's $d = 0.76$) and Lack of Concern (Cohen's $d = 0.80$) factors.

Table 3

*Comparison of Belgian and* American *College Students' Perceptions of Biodiesel Factors*

|  | Belgian | | American | | |
| --- | --- | --- | --- | --- | --- |
| Factor | *M* | *SD* | *M* | *SD* | *t* |
| Renewable and environmental benefits | 3.48 | 0.50 | 3.57 | 0.64 | 1.09 |
| Negative externalities | 2.96 | 0.57 | 2.78 | 0.59 | 2.05[*] |
| Low quality fuel | 3.10 | 0.52 | 2.57 | 0.58 | 6.51[****] |
| Lack of concern | 1.87 | 0.56 | 2.40 | 0.81 | 4.97[****] |

*Note.* [****]$p<0.0001$, [***]$p<0.001$, [**]$p<0.01$, [*]$p<0.05$.

Among Belgian students there were significant negative correlations between student age and level of agreement with the Low Quality Fuel ($r = -0.26$) and Lack of

Concern ($r = -0.24$) factors; older students tended to perceive biodiesel as higher in quality and were more likely to have concerns about continued reliance on fossil fuels. There was also a significant negative relationship ($r = -0.20$) between the size of community in which the student was raised (dichotomized as farm/rural or town/city) and their level of agreement with the Negative Externalities factor; students from towns or cities tended to be less concerned about potential negative effects of biodiesel production and use. However, no demographic characteristics explained more than 7% of the variance in Belgian students' perceptions of any biodiesel factor. There were no significant relationships between gender and any of the four biodiesel factors.

Among American students there was a significant positive relationship ($r = 0.25$) between gender and level of agreement with the Negative Externalities factor, with females tending to have stronger concerns about potential negative consequences of biodiesel use. There was also a significant negative relationship ($r = -0.27$) between the size of community in which the student was raised (dichotomized as farm/rural or town/city) and level of agreement with the Lack of Concern factor; students from towns or cities tended to have higher concerns about continued reliance on fossil fuels. Both demographic characteristics explained less than 8% of the variance in the level of agreement with either biodiesel factor.

### Conclusions and Implications

Belgian students were more than three times as likely to own or drive a diesel vehicle and, at 100%, were more likely to be aware of biodiesel than were American students. Despite this greater use of diesel vehicles and greater awareness of biodiesel, Belgian students were no more likely to have previously used biodiesel than were American students (4.3% and 4.4%.

respectively). This finding was interesting because Belgium has had a B4 blending mandate since 2009; do students not consider "blends" to be biodiesel? Additional research should be conducted to answer this question. This research also noted that among only those driving diesel vehicles, American students were actually more likely to have purchased biodiesel than Belgian students.

The results of principal components factor analysis indicated 100% of the variance in responses to the 34 items measuring perceptions of biodiesel could be explained by four factors: (a) Renewable and Environmental Benefits, (b) Negative Externalities, (c) Low Quality Fuel, and (d) Lack of Concern. Belgian and American students were undecided about the Negative Externalities and Low Quality Fuel factors and disagreed with the Lack of Concern factor. The mean scores for the Renewable and Environmental Benefits factor placed Belgian students near the upper real limit of the undecided category and American students at the lower real limit of the agree category.

When comparing mean scores, there were significant differences between Belgian and American students on three of the four factors. Belgian students rated the Negative Externalities and Low Quality Fuel factors higher (less positively) than did American students. Conversely, American students rated the Lack of Concern factor significantly higher (indicating less concern) than did Belgian students. However, given that the real limits for the levels of agreement with each factor did not differ by group, one must conclude these are differences along narrow continuums. There was no significant difference between Belgian and American student means on the Renewable and Environmental Benefits factor. Both Belgian and American students had relatively "soft" perceptions of

biodiesel. Overall, Belgian students tended to be more negative toward the performance, food, and economic effects of biodiesel use. Both Belgian and American students had somewhat positive perceptions of the environmental effects of biodiesel. The finding that students maintain positive attitudes towards biodiesel and environmental concern supports previous research by Charisiou and Goula (2012) and Halder (2011). Further investigation should determine Belgian students' relatively negative perceptions of biodiesel performance.

Among Belgians, older students and those from towns or cities tended to be more positive about selected aspects of biodiesel production and use. Among American students females tended to be more concerned than males about the potential negative aspects of biodiesel use and students from towns and cities tended to have more concerns about continued reliance on fossil fuels. Demographic characteristics were not particularly robust predictors of perceptions of biodiesel for either Belgian or American students. This was also true for research completed by Ulmer et al. (2004).

Belgian and American students were largely uncertain about important aspects of biodiesel production and use. Thus, increased efforts are needed in both countries to better educate students about a variety of technical, economic, and societal issues related to biodiesel. Because of the vital role these students will play as consumers, citizens, opinion leaders, voters, and, in some cases, technical experts, increased educational efforts are essential. Additionally, research is needed to understand the basis for students' positive attitude towards environmental aspects of biodiesel. These attitudes may reflect generalized "positive bias" toward perceived "green technologies".

Understanding consumers' awareness, use, and perceptions of biodiesel is the first step in creating educational strategies to increase consumer acceptance. With fuel concerns and new global mandates, international agricultural and extension educators are in a unique position to educate consumers globally about biofuel production and use. This research should serve as in initial investigation into the needs for biofuel education internationally. Efforts should be made in the U.S. and the EU to educate consumers about biofuel production, use, and benefits. This research should serve as a catalyst for these efforts.

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