UNDERSTANDING BIOBASED CARBON CONTENT

Society of the Plastics Industry Bioplastics Council

February 2012

www.bioplasticscouncil.org

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INTRODUCTION

WHAT IS THE BIOBASED CONTENT OF A RESIN?

Biobased or renewable content of a product is the amount of biobased *carbon* in the material or product as fraction weight (mass) or percent weight (mass) of the total organic carbon in the material or product.

$$\text{\% BIO or BIOBASED CONTENT} \\ \text{\% Renewable Content} = \frac{\text{BIO (Organic) CARBON}}{\text{TOTAL (Organic) CARBON}} * 100$$

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ASTM has set a method standard (i.e., not a pass/fail criteria) to calculate the level of biobased or renewable material included in a resin (i.e., ASTM D6866 – Standard Test Methods for Determining the Biobased Content of Solid, Liquid, and Gaseous Samples Using Radiocarbon Analysis).

WHAT IS ASTM D6866?

The application of ASTM D6866 to derive "biobased content" is built on the same concepts as radiocarbon dating, but without use of the age equations. It is done by deriving a ratio of the amount of radiocarbon (14C) in an unknown sample to that of a modern reference standard. The ratio is reported as a percentage with the units "pMC" (percent modern carbon). If the material being analyzed is a mixture of present day radiocarbon and fossil carbon (i.e., containing no radiocarbon), then the pMC value obtained correlates directly to the amount of biomass material present in the sample.

ASTM D6866

HOW AND WHY ASTM D6866 WAS INTRODUCED

ASTM D6866 was not created as an environmental impact assessment tool and is independent from the application and the geographic area of the material tested. The purpose of the standard is just to set up a ratio consisting of the percentage of biobased content of natural range components in the tested material.

The ASTM D6866 text was published in 2004 under the title "Standard Test Methods for Determining the Biobased Content of Natural Range Materials Using Radiocarbon and Isotope Ratio Mass Spectrometry Analysis."[2]

[1] http://portal.ics.trieste.it/Portal/ActivityDocument.aspx?id=1630
[2] http://www.astm.org/Standards/D6866.htm

THE OVERALL OBJECTIVES

The only objective set by ASTM D6866 is to allow the practitioner to obtain data. Clearly practitioners have extrapolated the results into a series of conclusions that are not necessarily exact. The data extrapolation is not included in ASTM D6866. ASTM D6866 testing result can allow an intrinsic calculation only but should not be used as a Life Cycle Assessment (LCA) of a material. Appendix 1 provides an example of a "Report of Biobased Content Analysis Using ASTM D6866" as well as more detailed information about understanding the calculation.

ASTM D6866 AND THE U.S. DEPARTMENT OF AGRICULTURE BIOPREFERRED PROGRAM

The U.S. Department of Agriculture (USDA) BioPreferred program,[3] which is designed to promote the increased purchase and use of biobased products, refers to the ASTM D6866 test method to calculate the level of biobased content included in a material. It is data used by the program to grant the right to use the USDA BioPreferred labeling system (note: the USDA BioPreferred label assures the consumer that a product or package contains a verified amount of renewable biological ingredients.) The USDA sets minimum levels of biobased content level for a given product, calculated using the ASTM method. However, ASTM D6866 does not set any type of minimum biobased content level.

ALTERNATIVE APPROACHES TO REPORTING BIOBASED CONTENT

DETERMINING BIOBASED CONTENT BY WEIGHT PERCENTAGE

The weight approach has a different perspective. Operators inserting a certain percentage of biobased content inside an existing material may suggest that the percentage of renewable content is more relevant than the ASTM test result which will show a substantially lower number. For instance a 50% starch content inserted in a polyolefin may show only a 20 to 25% biobased content while the weight approach might show a higher result. Some companies, such as DuPont, publish both approaches to reporting biobased content. For example, for its Sorona product description[4] both the biobased carbon content (i.e., 28%) and the renewable content by weight (i.e., 37%) are listed.

CAUTION WHEN DETERMINING BIOBASED CONTENT BY WEIGHT PERCENTAGE

1. Reporting biobased content by weight percentage may be tempting because it follows directly from the "recipe" the producer uses. As an example, consider a blend of 30 weight percent cellulose and 70 weight percent fossil-based copolyester. One mistakenly may say that this blend has 30 weight percent biobased content. *However, such a claim would be*

[3] www.biopreferred.gov
[4] http://www2.dupont.com/Renewably_Sourced_Materials/en_US/sorona.html#

incorrect. This claim is inaccurate because weight percent includes not just the contribution to the weight from the carbon, but also from other elements in the materials – most especially oxygen. Arguably all of the oxygen is "bio-derived" (i.e., from plant respiration) and includes the oxygen that makes up about 30 weight percent of the copolyester. So this simple weight percentage approach leads to a great deal of ambiguity.

Biobased carbon content does not lead to such ambiguity[5], and unlike weight percentage, it can be directly measured and verified in the finished blend, product, etc. Biobased carbon content does not include the weight contribution from oxygen. Because the oxygen weight percentage typically is higher in bio-derived than in fossil-derived materials, the biobased carbon content percentage is quite often lower than the biomass content by weight percentage that follows from the "recipe."

Individuals may be tempted to choose an approach that gives a higher number because that could be perceived by the customer as "better." However, given the risks of greenwashing (including those noted in "Other Key Points to Consider" below), it is better for companies to report scientific, unambiguous information which can be verified using the ASTM D6866 standard.

2. Another caution when using biobased content by weight percentage is that some consumers may incorrectly believe that the higher the biobased content the more "natural" the material and the better it is for the environment. It is a consumer perception that does not have scientific support but marketers unfortunately have pushed the concept.

3. Using weight based percentages depends on what the overall purpose and the application are. If we consider the issues of environmental impact and greenhouse gases creation (GHG), one may ask if it is better to substitute an oil based material with a renewable content material such as starch. To give a proper answer an in-depth LCA needs to be established to understand the entire situation.

4. The application is extremely important and enters into end-of-life considerations as well. One may question the purpose of creating a biobased, compostable material if that material ends up in a landfill, and biodegrades slowly in the landfill releasing methane and CO2. Now if 10% of renewable material is introduced in large applications such as automotive or consumer products with the purpose of reducing oil dependency, then does it make sense?

OTHER KEY POINTS TO CONSIDER

1. ASTM is not taking any position on the questions raised above specific to biocarbon percentage versus weight percentage. It is just a method to calculate biobased content data. The interpretation of the data is not policed by the standard. It is not a standard specification (i.e., not pass/fail criteria).

[5] http://www.ides.com/articles/materials/2008/0225_Narayan.asp

2. ASTM D6866 does not establish an absolute minimum biobased carbon content required because of the vast array of applications. Other organizations such as the USDA BioPreferred program do establish minimum biobased carbon content to qualify products for preferred purchasing and/or to use the BioPreferred label. This minimum biobased carbon content varies by application and end-use.

3. Although the U.S. Federal Trade Commission's "Guides for the Use of Environmental Marketing Claims" do not specifically address biobased related claims, they do stress that "any party making an express or implied claim that presents an objective assertion about the environmental attribute of a product, package or service must, at the time the claim is made, possess and rely upon a reasonable basis substantiating the claim. A reasonable basis consists of competent and reliable evidence. In the context of environmental marketing claims, such substantiation will often require competent and reliable scientific evidence, defined as tests, analyses, research, studies or other evidence based on the expertise of professionals in the relevant area, conducted and evaluated in an objective manner by persons qualified to do so, using procedures generally accepted in the profession to yield accurate and reliable results." [6]

[6] http://ftc.gov/bcp/grnrule/guides980427.htm

APPENDIX 1: SAMPLE REPORT OF BIOBASED CONTENT ANALYSIS USING ASTM D6866

Explanation of Results – Biobased Analysis Using ASTM D6866

The application of ASTM D6866 to derive "biobased content" is built on the same concepts as radiocarbon dating, but without use of the age equations. It is done by deriving a ratio of the amount of radiocarbon (14C) in an unknown sample to that of a modern reference standard. The ratio is reported as a percentage with the units "pMC" (percent modern carbon). If the material being analyzed is a mixture of present day radiocarbon and fossil carbon (containing no radiocarbon), then the pMC value obtained correlates directly to the amount of biomass material present in the sample.

The modern reference standard used in radiocarbon dating is a NIST (i.e., National Institute of Standards and Technology) standard with a known radiocarbon content equivalent approximately to the year AD 1950. AD 1950 was chosen since it represented a time prior to thermo-nuclear weapons testing which introduced large amounts of excess radiocarbon into the atmosphere with each explosion (termed "bomb carbon"). This was a logical point in time to use as a reference for archaeologists and geologists. For an archaeologist or geologist using radiocarbon dates, AD 1950 equals "zero years old". It also represents 100 pMC. "Bomb carbon" in the atmosphere reached almost twice normal levels in 1963 at the peak of testing and prior to the treaty halting the testing. Its distribution within the atmosphere has been approximated since its appearance, showing values that are greater than 100 pMC for plants and animals living since AD 1950. It has gradually decreased over time with today's value being near 107.5 pMC. This means that a fresh biomass material such as corn would give a radiocarbon signature near 107.5 pMC. Combining fossil carbon with present day carbon into a material will result in a dilution of the present day pMC content. By presuming 107.5 pMC represents present day biomass materials and 0 pMC represents petroleum derivatives, the measured pMC value for that material will reflect the proportions of the two component types. A material derived 100% from present day soybeans would give a radiocarbon signature near 107.5 pMC. If that material was diluted with 50% petroleum derivatives, it would give a radiocarbon signature near 54 pMC.

A biomass content result is derived by assigning 100% equal to 107.5 pMC and 0% equal to 0 pMC. In this regard, a sample measuring 99 pMC will give an equivalent biobased content result of 93%.

This value is referred to as the “MEAN BIOBASED RESULT” and assumes all the components within the analyzed material were either present day living or fossil in origin. The results provided in this report involved materials provided without any source information. This situation is highly probable in a real life situation. The “MEAN VALUE” quoted in this report encompasses an absolute range of 6% (plus and minus 3% on either side of the MEAN BIOBASED RESULT) to account for variations in end-component radiocarbon signatures (a conservative approximation). It is presumed that all materials are present day or fossil in origin and that the desired result is the amount of biobased component "present" in the material, not the

amount of biobased material "used" in the manufacturing process. The most conservative interpretation of the reported percentages is as maximum values.

Summary of Results: Biobased Determination using ASTM D6866
Date Received: June 22, 2011
Date Reported: July 30, 2011

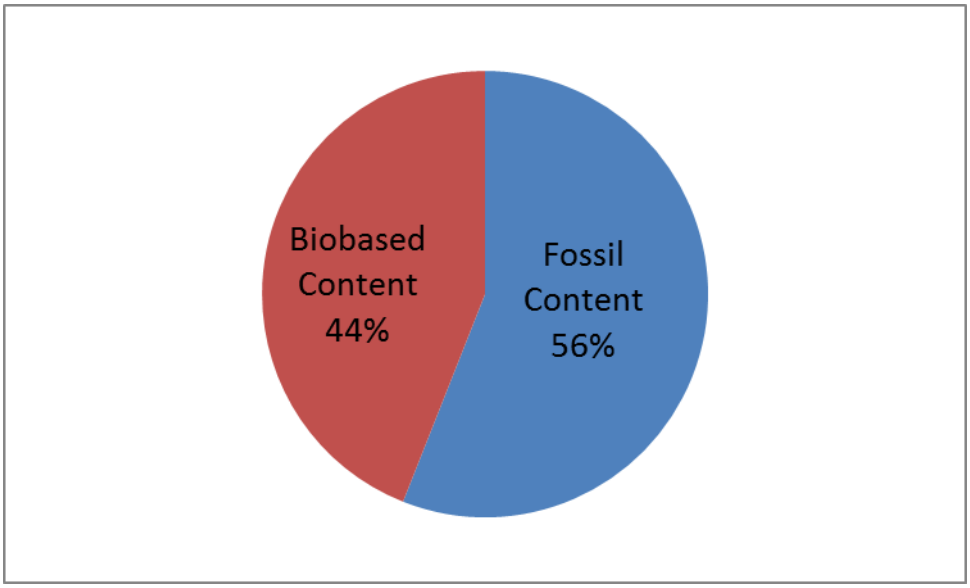
Laboratory Number	Material	ASTM D6866 Method	Mean Biobased Result*
228021	Blown Film	Method B	44%
228022	Blow Molding Resin	Method B	70%
228023	Extrusion Coated Resin	Method B	72%
228024	Injection Molding Resin	Method B	86%
228025	Thermoforming Resin	Method B	92%

* ASTM-D6866 cites precision on The Mean Biobased Result as +/- 3% (absolute). This is the most conservative estimate of error in the measurement of complex biobased containing solids and liquids based on empirical results. Real precision for readily combustible and homogenous materials (e.g. gasoline) and especially samples received as CO2 (e.g. flue gas or CEMS exhaust) can be as low as +/- 0.5-2%. The result only applies to the analyzed material. Fluctuations in carbon content within a batch of product, gasoline or flue gas must be determined separately (e.g. averaged measurements of multiple solids or liquids, and single measurement of the combination of gas aliquots collected over time). The accuracy of the result as it applies to the analyzed product, fuel, or flue gas relies upon all the carbon in the analyzed material originating from either recently respired atmospheric carbon dioxide (within the last decade) or fossil carbon (more than 50,000 years old). "Percent biobased" specifically relates % renewable (or fossil) carbon to total carbon, not to total mass or molecular weight. Mean Biobased estimates greater than 100% are assigned a value of 100% for simplification.

Report of Biobased Content Analysis Using ASTM D6866

Laboratory Number: 228021
Material Analyzed: Blown Film
Date Received: June 22, 2011
Date Reported: July 30, 2011

Mean Biobased Result: 44%*
Proportions Biobased vs. Fossil Based indicated by ^{14}C content



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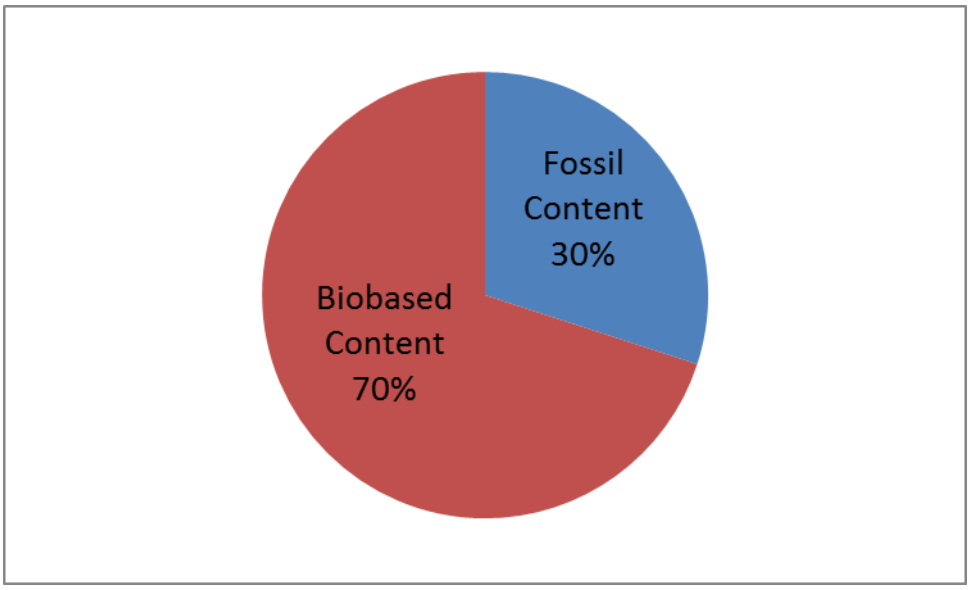
Report of Biobased Content Analysis Using ASTM D6866

Laboratory Number: 228022
Material Analyzed: Blow Molding Resin
Date Received: June 22, 2011
Date Reported: July 30, 2011

Mean Biobased Result: 70%*
Proportions Biobased vs. Fossil Based indicated by ^{14}C content

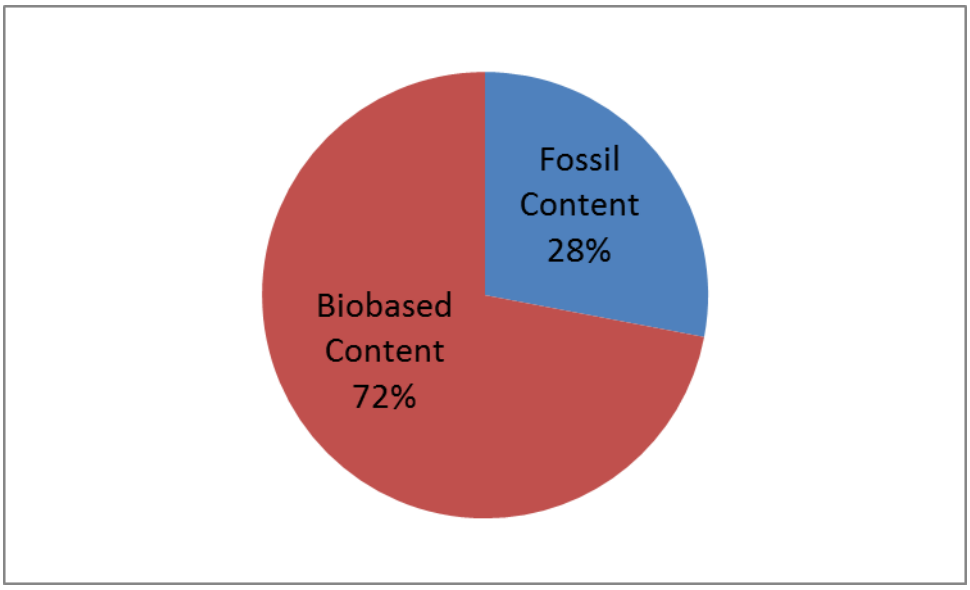


* ASTM-D6866 cites precision on The Mean Biobased Result as +/- 3% (absolute). This is the most conservative estimate of error in the measurement of complex biobased containing solids and liquids based on empirical results. Real precision for readily combustible and homogenous materials (e.g. gasoline) and especially samples received as CO2 (e.g. flue gas or CEMS exhaust) can be as low as +/- 0.5-2%. The result only applies to the analyzed material. Fluctuations in carbon content within a batch of product, gasoline or flue gas must be determined separately (e.g. averaged measurements of multiple solids or liquids, and single measurement of the combination of gas aliquots collected over time). The accuracy of the result as it applies to the analyzed product, fuel, or flue gas relies upon all the carbon in the analyzed material originating from either recently respired atmospheric carbon dioxide (within the last decade) or fossil carbon (more than 50,000 years old). "Percent biobased" specifically relates % renewable (or fossil) carbon to total carbon, not to total mass or molecular weight. Mean Biobased estimates greater than 100% are assigned a value of 100% for simplification.

Report of Biobased Content Analysis Using ASTM D6866

Laboratory Number: 228023
Material Analyzed: Extrusion Coated Resin
Date Received: June 22, 2011
Date Reported: July 30, 2011

Mean Biobased Result: 72%*
Proportions Biobased vs. Fossil Based indicated by ^{14}C content

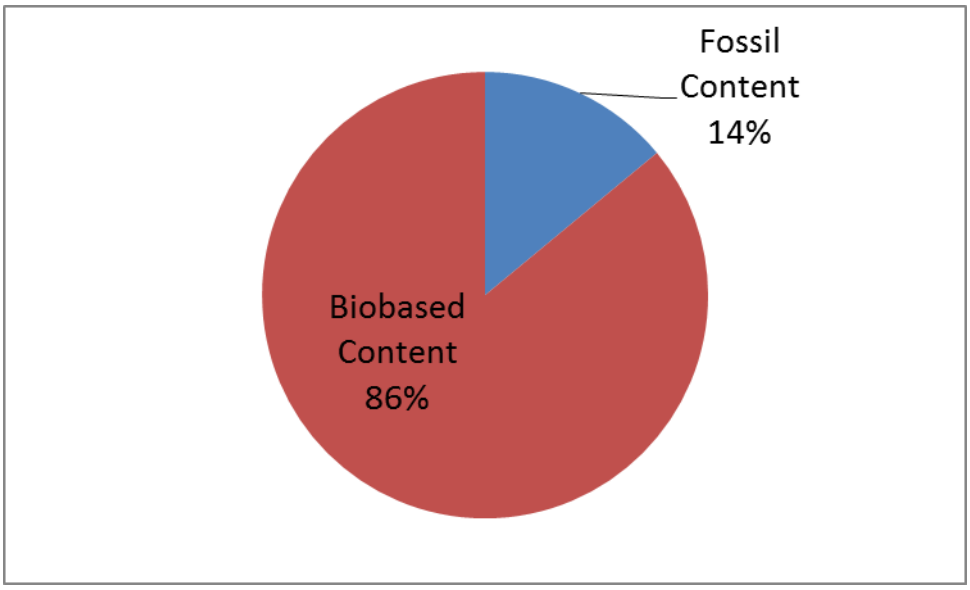


* ASTM-D6866 cites precision on The Mean Biobased Result as +/- 3% (absolute). This is the most conservative estimate of error in the measurement of complex biobased containing solids and liquids based on empirical results. Real precision for readily combustible and homogenous materials (e.g. gasoline) and especially samples received as CO2 (e.g. flue gas or CEMS exhaust) can be as low as +/- 0.5-2%. The result only applies to the analyzed material. Fluctuations in carbon content within a batch of product, gasoline or flue gas must be determined separately (e.g. averaged measurements of multiple solids or liquids, and single measurement of the combination of gas aliquots collected over time). The accuracy of the result as it applies to the analyzed product, fuel, or flue gas relies upon all the carbon in the analyzed material originating from either recently respired atmospheric carbon dioxide (within the last decade) or fossil carbon (more than 50,000 years old). "Percent biobased" specifically relates % renewable (or fossil) carbon to total carbon, not to total mass or molecular weight. Mean Biobased estimates greater than 100% are assigned a value of 100% for simplification.

Report of Biobased Content Analysis Using ASTM D6866

Laboratory Number: 228024
Material Analyzed: Injection Molding Resin
Date Received: June 22, 2011
Date Reported: July 30, 2011

Mean Biobased Result: 86%*
Proportions Biobased vs. Fossil Based indicated by ^{14}C content

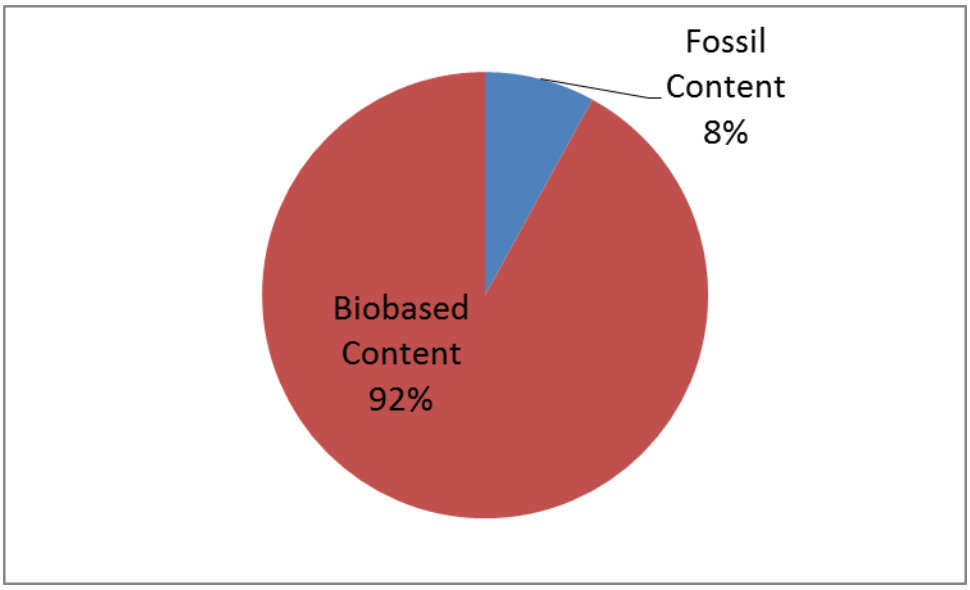


* ASTM-D6866 cites precision on The Mean Biobased Result as +/- 3% (absolute). This is the most conservative estimate of error in the measurement of complex biobased containing solids and liquids based on empirical results. Real precision for readily combustible and homogenous materials (e.g. gasoline) and especially samples received as CO2 (e.g. flue gas or CEMS exhaust) can be as low as +/- 0.5-2%. The result only applies to the analyzed material. Fluctuations in carbon content within a batch of product, gasoline or flue gas must be determined separately (e.g. averaged measurements of multiple solids or liquids, and single measurement of the combination of gas aliquots collected over time). The accuracy of the result as it applies to the analyzed product, fuel, or flue gas relies upon all the carbon in the analyzed material originating from either recently respired atmospheric carbon dioxide (within the last decade) or fossil carbon (more than 50,000 years old). "Percent biobased" specifically relates % renewable (or fossil) carbon to total carbon, not to total mass or molecular weight. Mean Biobased estimates greater than 100% are assigned a value of 100% for simplification.

Report of Biobased Content Analysis Using ASTM D6866

Laboratory Number: 228025
Material Analyzed: Thermoforming Resin
Date Received: June 22, 2011
Date Reported: July 30, 2011

Mean Biobased Result: 92%*
Proportions Biobased vs. Fossil Based indicated by ^{14}C content



* ASTM-D6866 cites precision on The Mean Biobased Result as +/- 3% (absolute). This is the most conservative estimate of error in the measurement of complex biobased containing solids and liquids based on empirical results. Real precision for readily combustible and homogenous materials (e.g. gasoline) and especially samples received as CO2 (e.g. flue gas or CEMS exhaust) can be as low as +/- 0.5-2%. The result only applies to the analyzed material. Fluctuations in carbon content within a batch of product, gasoline or flue gas must be determined separately (e.g. averaged measurements of multiple solids or liquids, and single measurement of the combination of gas aliquots collected over time). The accuracy of the result as it applies to the analyzed product, fuel, or flue gas relies upon all the carbon in the analyzed material originating from either recently respired atmospheric carbon dioxide (within the last decade) or fossil carbon (more than 50,000 years old). "Percent biobased" specifically relates % renewable (or fossil) carbon to total carbon, not to total mass or molecular weight. Mean Biobased estimates greater than 100% are assigned a value of 100% for simplification.