BIOSUCCINIUM®
sustainable succinic acid

## ENABLING SUSTAINABLE MATERIALS

### INTRODUCTION

BIOSUCCINIUM® sustainable succinic acid is a 100% bio-based succinic acid that enables the production of polyester polyols and polyurethane products with lower environmental footprint. BIOSUCCINIUM® offers an alternative to traditional chemicals such as fossil-based succinic acid or adipic acid which are conventional raw materials. This document shows the properties of polyester polyols based on bio-based succinic acid with a wide variety of applications. The data has been generated based on actual (lab scale) production of these polyester polyols and is intended to showcase that (1) polyester polyols based on bio-based succinic acid can be manufactured and (2) lead to properties that are in the same range as conventional polyester polyols.

In those polyols where mixed diols or mixed diacids are used to synthesis co-polyesters, the mix ratios are expressed in % molar.

The renewable content is expressed as percentage renewable carbon content. In the formulations below, BIOSUCCINIUM®, 1,3-propanediol and sebacic acid are of renewable origin. Ethylene glycol, di-ethylene glycol, and 1,4 butanediol are of fossil origin.

| Di-acid | Diol (molar ratio) | Renewable content [%w] | Functionality | Mn [g/mol] | Viscosity [mPa.s] | Acid / OH value [mg KOH/g] | | Tm [°C] | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| Adipic acid | BDO | 0% | 2 | 1943 | 800 (70°C) | 0.75 | 57.0 | 58 | |
| BIOSUCCINIUM® | BDO | 50% | 2 | 1918 | Solid (75°C)<br>400 (125°C) | 0.11 | 58.5 | 108 | not soluble in THF |
| BIOSUCCINIUM® | BDO | 50% | 2 | 1623 | Solid (75°C)<br>274 (125°C) | 2.30 | - | 105 | not soluble in THF; synthesis incomplete |
| BIOSUCCINIUM® | BDO | 50% | 2 | 1009 | Solid (75°C) | 1.01 | 110.2 | 102 | not soluble in THF |
| Adipic acid | BDO+EG (50:50) | 0% | 2 | 2004 | 579 (75°C) | 1.30 | 54.7 | ~17 | |
| BIOSUCCINIUM® | BDO+EG (50:50) | 57% | 2 | 2004 | 1306 (75°C) | 1.10 | 54.9 | ~55 | |

Table 2: Formulation and properties of 1,4 BDO vs 1,3 PDO based polyester polyols

| Di-acid | Diol (molar ratio) | Renewable content [%w] | Functionality | Mn [g/mol] | Viscosity [mPa.s] | Acid / OH value [mg KOH/g] | | Tm [°C] | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| Adipic acid | BDO | 0% | 2 | 1943 | 800 (70°C)<br>136 (125°C) | 0.75 | 57.0 | 58 | |
| BIOSUCCINIUM® | BDO | 50% | 2 | 1918 | Solid (75°C)<br>400 (125°C) | 0.11 | 58.5 | 108 | not soluble in THF |
| BIOSUCCINIUM® | PDO | 100% | 2 | 1955 | 2680 (70°C) | 1.39 | 57.4 | 48 | 100% renewable |

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Table 3: Formulation and properties of mixed diol co-polyester polyols

| Di-acid | Diol (molar ratio) | Renewable content [%w] | Functionality | Mn [g/mol] | Viscosity [mPa.s] | Acid / OH value [mg KOH/g] | | Tm [°C] | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| Adipic acid | BDO | 0% | 2 | 1943 | 800 (70°C) | 0.75 | 57.0 | 58 | |
| BIOSUCCINIUM® | BDO | 50% | 2 | 1918 | Solid (75°C) 400 (125°C) | 0.11 | 58.5 | 108 | not soluble in THF |
| BIOSUCCINIUM® | BDO+EG (50:50) | 57% | 2 | 2048 | 3650 (70°C) | 1.19 | 53.6 | 56 | |
| BIOSUCCINIUM® | BDO+HDO (50:50) | 44% | 2 | 1995 | 2150 (70°C) | 0.55 | 55.7 | 50 | |
| BIOSUCCINIUM® | BDO+PDO (50:50) | 53% | 2 | 1985 | 2000 (70°C) | 1.13 | 55.4 | 56 | partly soluble in THF |

Table 4: Formulation and properties of succinic acid and adipic acid based co-polyester polyols

| Di-acid | Diol (molar ratio) | Renewable content [%w] | Functionality | Mn [g/mol] | Viscosity [mPa.s] | Acid / OH value [mg KOH/g] | | Tm [°C] | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| Adipic acid | BDO | 0% | 2 | 1943 | 800 (70°C) | 0.75 | 57.0 | 58 | |
| BIOSUCCINIUM®+ Adipic acid (20:80) | BDO | 8% | 2 | 1948 | 850 (70°C) | 0.51 | 57.1 | 34 | |
| BIOSUCCINIUM®+ Adipic acid (40:60) | BDO | 17% | 2 | 1901 | 1150 (70°C) | 1.31 | 57.7 | 22 | |
| BIOSUCCINIUM®+ Adipic acid (60:40) | BDO | 27% | 2 | 2078 | 1400 (70°C) | 0.4 | 53.6 | 66 | |
| BIOSUCCINIUM®+ Adipic acid (80:20) | BDO | 38% | 2 | 2057 | Solid (70°C) | 0.54 | 54.0 | 82 | |
| BIOSUCCINIUM® | BDO | 50% | 2 | 1918 | Solid (70°C) 400 (125°C) | 0.11 | 58.5 | 108 | not soluble in THF |

Table 5: Formulation and properties of succinic acid and sebacic acid based co-polyester polyols

| Di-acid | Diol (molar ratio) | Renewable content [%w] | Functionality | Mn [g/mol] | Viscosity [mPa.s] | Acid / OH value [mg KOH/g] | | Tm [°C] | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| Adipic acid | BDO | 0% | 2 | 1943 | 800 (70°C) | 0.75 | 57.0 | 58 | |
| Sebacic acid | BDO | 71% | 2 | 1967 | 1100 (70°C) | 0.85 | 56.2 | 63 | |
| BIOSUCCINIUM®+ Sebacic acid (50:50) | BDO | 64% | 2 | 1937 | 550 (70°C) | 0.81 | 57.1 | 42 | |
| BIOSUCCINIUM®+ Sebacic acid (67:33) | BDO | 60% | 2 | 1953 | 6500 (70°C) | 0.65 | 56.8 | 83 | |
| BIOSUCCINIUM® | BDO | 50% | 2 | 1918 | Solid (75°C) 400 (125°C) | 0.11 | 58.5 | 108 | not soluble in THF |

Table 6: Formulation and properties of EG/DEG co-polyester polyols for microcellular PU

| Di-acid | Diol (molar ratio) | Renewable content [%w] | Functionality | Mn [g/mol] | Viscosity [mPa.s] | Acid / OH value [mg KOH/g] | | Tm [°C] | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| Adipic acid | EG+DEG (60:40) | 0% | 2 | 1945 | 502 (75°C) | 1.1 | 56.6 | - | microcellular PU |
| BIOSUCCINIUM® | EG+DEG (60:40) | 59% | 2 | 2059 | 1405 (75°C) | 0.5 | 54 | - | microcellular PU |
| BIOSUCCINIUM®+ Sebacic acid (85:15) | EG+DEG (60:40) | 64% | 2 | 1958 | 1292 (75°C) | 0.3 | 57 | - | microcellular PU |

Table 7: Formulation and properties of polyols for foam, coatings or adhesives

| Di-acid | Diol | Renewable content [%w] | Functionality | Mn [g/mol] | Viscosity [mPa.s] | Acid / OH value [mg KOH/g] | | Tm [°C] | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| BIOSUCCINIUM® | conventional | t.b.d | 2-4 | 300-500 | 4350 (25°C) | 0.5 | 347 | - | Rigid Foam |
| BIOSUCCINIUM® | conventional | t.b.d | 2-4 | 300-500 | 3300 (25°C) | 0.5 | 238 | - | Rigid Foam |
| BIOSUCCINIUM® | conventional | t.b.d | 3-4 | 2000 | 4480 (60°C) | 1.12 | 61.5 | - | Coatings / Adhesives/ Flex Foam |
| BIOSUCCINIUM® | HDO | 40% | 2 | 2000 | 1000 (70°C) | 0.93 | 57.2 | 57 | Coatings / Adhesives |

## HOW TO ORDER BIOSUCCINIUM®

### Production

BIOSUCCINIUM® is available in commercial quantities from the first large scale commercial production plant, located in Cassano, Italy. Samples for evaluation are available, as well. The biotechnology process to produce BIOSUCCINIUM® was developed by Reverdia, a joint venture between DSM and Roquette. Since Reverdia's dissolution in April 2019, Roquette now manufactures and sells BIOSUCCINIUM® under licence from DSM. Please contact Roquette at www.roquette.com for more information.

### USDA CERTIFICATION

Roquette has earned the U.S. Department of Agriculture (USDA) Certified Biobased Product label. The product, BIOSUCCINIUM® succinic acid, is now able to display a unique USDA label that highlights its percentage of biobased content. It shows that BIOSUCCINIUM® contains 100% USDA certified biobased content.

USDA CERTIFIED BIOBASED PRODUCT PRODUCT 100%



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