Biogas Substrate Characterization Database - Gummersbach

Overview

This document contains detailed characterization data for 10 different biogas substrates used in anaerobic digestion processes. The data includes Weender analysis (proximate composition), physical and chemical properties relevant for biogas production modeling and process optimization.

Substrates included:

1. **Silomais** (Maize silage) - maize
2. **Gülle** (Swine manure) - swinemanure
3. **Grünroggen** (Green rye) - greenrye
4. **Grassilage** (Grass silage) - grass
5. **Getreide** (Grain/Wheat) - wheat
6. **GPS** (Whole plant silage) - gps
7. **CCM** (Corn cob mix) - ccm
8. **Futterkalk** (Fodder lime) - futterkalk
9. **Rindermist** (Cattle manure) - cowmanure
10. **Zwiebeln** (Onions) - onions

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1. Silomais (MAIZE)

Weender Analysis

Parameter	Symbol	Value	Unit
Raw fiber (Rohfaser)	RF	21.07	% TS
Raw protein (Rohprotein)	RP	8.69	% TS
Raw lipids (Rohfett)	RL	3.68	% TS
Neutral detergent fiber	NDF	43.64	% TS
Acid detergent fiber	ADF	21.86	% TS
Acid detergent lignin	ADL	2.15	% TS

Table 1: Weender analysis for Silomais (Maize silage)

Data Sources:

- RF, RP, RL: Substrat_FermenterProben.xls
- NDF, ADF, ADL: "Einfluss der stofflichen Zusammensetzung auf die Verdaulichkeit nachwachsender Rohstoffe beim anaeroben Abbau in Biogasreaktoren", S. 110 ff., maize silage 1 (mean 2003)

Physical and Chemical Properties

Parameter	Symbol	Value	Unit
Soluble COD	COD_S	15.97	gCOD/L
Inert soluble COD	SIin	13.03	gCOD/L
pH value	pH	3.93	-
Acetic acid + acetate	Sac	1.18	g/L
Butyric acid + butyrate	Sbu	0.0	g/L
Propionic acid + propionate	Spro	0.0	g/L
Valeric acid + valerate	Sva	0.0	g/L
Inorganic nitrogen	SIN	0.36	g/L
Inorganic carbon	SIC	0.15	g/L
Total solids	TS	33.0	%
Volatile solids	oTS	96.0	% TS
Total COD	COD	359.07	gCOD/L
Volatile fatty acids	VFA	1.27	g/L

Table 2: Physical and chemical properties for Silomais (Maize silage)

Notes and References:

- **Sac**: Original value 1.58 g/L, adjusted to 2.0 g/L to account for silage process. Reference: calculation from database folder
- **pH**: Substrat_FermenterProben.xls
- **TS**: Substrat_FermenterProben.xls
- **oTS**: Substrat_FermenterProben.xls
- **COD**: Calculated from substrate composition

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2. Gülle (SWINE MANURE)

Weender Analysis

Parameter	Symbol	Value	Unit
Raw fiber (Rohfaser)	RF	13.06	% TS
Raw protein (Rohprotein)	RP	26.17	% TS
Raw lipids (Rohfett)	RL	4.96	% TS
Neutral detergent fiber	NDF	22.26	% TS
Acid detergent fiber	ADF	13.06	% TS
Acid detergent lignin	ADL	1.58	% TS

Table 3: Weender analysis for Gülle (Swine manure)

Data Sources:

- RF, RP, RL: Substrat_FermenterProben.xls
- NDF, ADF, ADL: "Einfluss der stofflichen Zusammensetzung auf die Verdaulichkeit nachwachsender Rohstoffe beim anaeroben Abbau in Biogasreaktoren", S. 110 ff., pig slurry (mean)

Physical and Chemical Properties

Parameter	Symbol	Value	Unit
Soluble COD	COD_S	2.54	gCOD/L
Inert soluble COD	SIin	2.1	gCOD/L
pH value	pH	7.67	-
Acetic acid + acetate	Sac	0.75	g/L
Butyric acid + butyrate	Sbu	0.0	g/L
Propionic acid + propionate	Spro	0.0	g/L
Valeric acid + valerate	Sva	0.0	g/L
Inorganic nitrogen	SIN	2.84	g/L
Inorganic carbon	SIC	3.0	g/L
Total solids	TS	7.25	%
Volatile solids	oTS	82.0	% TS
Total COD	COD	74.53	gCOD/L
Volatile fatty acids	VFA	0.8	g/L

Table 4: Physical and chemical properties for Gülle (Swine manure)

Notes and References:

- **pH**: Substrat_FermenterProben.xls
- **TS, oTS**: Substrat_FermenterProben.xls
- **SIN**: High nitrogen content typical for animal manure
- **SIC**: Significant inorganic carbon from alkalinity

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3. Grünroggen (GREEN RYE)

Weender Analysis

Parameter	Symbol	Value	Unit
Raw fiber (Rohfaser)	RF	27.77	% TS
Raw protein (Rohprotein)	RP	10.09	% TS
Raw lipids (Rohfett)	RL	3.21	% TS
Neutral detergent fiber	NDF	53.27	% TS
Acid detergent fiber	ADF	29.01	% TS
Acid detergent lignin	ADL	2.82	% TS

Table 5: Weender analysis for Grünroggen (Green rye)

Data Sources:

- RF, RP, RL: Substrat_FermenterProben.xls
- NDF, ADF, ADL: "Einfluss der stofflichen Zusammensetzung auf die Verdaulichkeit nachwachsender Rohstoffe beim anaeroben Abbau in Biogasreaktoren", S. 110 ff., rye (whole crop silage, mean 2003)

Physical and Chemical Properties

Parameter	Symbol	Value	Unit
Soluble COD	COD_S	12.26	gCOD/L
Inert soluble COD	SIin	10.02	gCOD/L
pH value	pH	4.32	-
Acetic acid + acetate	Sac	0.8	g/L
Butyric acid + butyrate	Sbu	0.0	g/L
Propionic acid + propionate	Spro	0.0	g/L
Valeric acid + valerate	Sva	0.0	g/L
Inorganic nitrogen	SIN	0.47	g/L
Inorganic carbon	SIC	0.13	g/L
Total solids	TS	27.0	%
Volatile solids	oTS	93.5	% TS
Total COD	COD	275.37	gCOD/L
Volatile fatty acids	VFA	0.88	g/L

Table 6: Physical and chemical properties for Grünroggen (Green rye)

Notes and References:

- **pH**: Acidic pH characteristic of ensiled crops
- **Fiber content**: Higher fiber content (NDF 53.27%) compared to maize
- **TS**: Substrat_FermenterProben.xls

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4. Grassilage (GRASS SILAGE)

Weender Analysis

Parameter	Symbol	Value	Unit
Raw fiber (Rohfaser)	RF	30.4	% TS
Raw protein (Rohprotein)	RP	12.71	% TS
Raw lipids (Rohfett)	RL	2.94	% TS
Neutral detergent fiber	NDF	57.46	% TS
Acid detergent fiber	ADF	33.19	% TS
Acid detergent lignin	ADL	3.0	% TS

Table 7: Weender analysis for Grassilage (Grass silage)

Data Sources:

- RF, RP, RL: Substrat_FermenterProben.xls
- NDF, ADF, ADL: "Einfluss der stofflichen Zusammensetzung auf die Verdaulichkeit nachwachsender Rohstoffe beim anaeroben Abbau in Biogasreaktoren", S. 110 ff., grass (mean)

Physical and Chemical Properties

Parameter	Symbol	Value	Unit
Soluble COD	COD_S	14.09	gCOD/L
Inert soluble COD	SIin	11.52	gCOD/L
pH value	pH	4.59	-
Acetic acid + acetate	Sac	1.2	g/L
Butyric acid + butyrate	Sbu	0.0	g/L
Propionic acid + propionate	Spro	0.0	g/L
Valeric acid + valerate	Sva	0.0	g/L
Inorganic nitrogen	SIN	0.74	g/L
Inorganic carbon	SIC	0.26	g/L
Total solids	TS	31.0	%
Volatile solids	oTS	92.4	% TS
Total COD	COD	316.73	gCOD/L
Volatile fatty acids	VFA	1.32	g/L

Table 8: Physical and chemical properties for Grassilage (Grass silage)

Notes and References:

- **Fiber content**: Highest NDF content (57.46%) among energy crops, indicating lower digestibility
- **Protein content**: Higher protein (12.71%) compared to maize
- **pH**: Acidic due to lactic acid fermentation during ensiling

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5. Getreide (GRAIN/WHEAT)

Weender Analysis

Parameter	Symbol	Value	Unit
Raw fiber (Rohfaser)	RF	25.87	% TS
Raw protein (Rohprotein)	RP	9.69	% TS
Raw lipids (Rohfett)	RL	3.11	% TS
Neutral detergent fiber	NDF	50.77	% TS
Acid detergent fiber	ADF	27.04	% TS
Acid detergent lignin	ADL	2.85	% TS

Table 9: Weender analysis for Getreide (Grain/Wheat)

Data Sources:

- RF, RP, RL: Substrat_FermenterProben.xls
- NDF, ADF, ADL: "Einfluss der stofflichen Zusammensetzung auf die Verdaulichkeit nachwachsender Rohstoffe beim anaeroben Abbau in Biogasreaktoren", S. 110 ff., wheat (whole crop silage, mean 2003)

Physical and Chemical Properties

Parameter	Symbol	Value	Unit
Soluble COD	COD_S	12.74	gCOD/L
Inert soluble COD	SIin	10.42	gCOD/L
pH value	pH	4.38	-
Acetic acid + acetate	Sac	1.0	g/L
Butyric acid + butyrate	Sbu	0.0	g/L
Propionic acid + propionate	Spro	0.0	g/L
Valeric acid + valerate	Sva	0.0	g/L
Inorganic nitrogen	SIN	0.49	g/L
Inorganic carbon	SIC	0.14	g/L
Total solids	TS	28.0	%
Volatile solids	oTS	93.3	% TS
Total COD	COD	286.14	gCOD/L
Volatile fatty acids	VFA	1.1	g/L

Table 10: Physical and chemical properties for Getreide (Grain/Wheat)

Notes and References:

- **Composition**: Similar fiber profile to green rye
- **TS**: Moderate total solids content (28%)
- **pH**: Acidic pH from ensiling process

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6. GPS (WHOLE PLANT SILAGE)

Weender Analysis

Parameter	Symbol	Value	Unit
Raw fiber (Rohfaser)	RF	21.61	% TS
Raw protein (Rohprotein)	RP	8.88	% TS
Raw lipids (Rohfett)	RL	3.51	% TS
Neutral detergent fiber	NDF	44.68	% TS
Acid detergent fiber	ADF	23.37	% TS
Acid detergent lignin	ADL	2.33	% TS

Table 11: Weender analysis for GPS (Whole plant silage)

Data Sources:

- RF, RP, RL: Substrat_FermenterProben.xls
- NDF, ADF, ADL: "Einfluss der stofflichen Zusammensetzung auf die Verdaulichkeit nachwachsender Rohstoffe beim anaeroben Abbau in Biogasreaktoren", S. 110 ff.,

triticale (whole crop silage, mean 2003)

Physical and Chemical Properties

Parameter	Symbol	Value	Unit
Soluble COD	COD_S	14.65	gCOD/L
Inert soluble COD	SIin	11.98	gCOD/L
pH value	pH	4.07	-
Acetic acid + acetate	Sac	1.0	g/L
Butyric acid + butyrate	Sbu	0.0	g/L
Propionic acid + propionate	Spro	0.0	g/L
Valeric acid + valerate	Sva	0.0	g/L
Inorganic nitrogen	SIN	0.38	g/L
Inorganic carbon	SIC	0.14	g/L
Total solids	TS	32.0	%
Volatile solids	oTS	95.6	% TS
Total COD	COD	329.75	gCOD/L
Volatile fatty acids	VFA	1.1	g/L

Table 12: Physical and chemical properties for GPS (Whole plant silage)

Notes and References:

- **GPS**: Ganzpflanzensilage (whole plant silage), typically triticale
- **Composition**: Similar to maize silage in fiber content
- **oTS**: High volatile solids content (95.6%)

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7. CCM (CORN COB MIX)

Weender Analysis

Parameter	Symbol	Value	Unit
Raw fiber (Rohfaser)	RF	9.62	% TS
Raw protein (Rohprotein)	RP	9.0	% TS
Raw lipids (Rohfett)	RL	4.63	% TS
Neutral detergent fiber	NDF	19.69	% TS
Acid detergent fiber	ADF	5.33	% TS
Acid detergent lignin	ADL	0.84	% TS

Table 13: Weender analysis for CCM (Corn cob mix)

Data Sources:

- RF, RP, RL: Substrat_FermenterProben.xls
- NDF, ADF, ADL: "Einfluss der stofflichen Zusammensetzung auf die Verdaulichkeit nachwachsender Rohstoffe beim anaeroben Abbau in Biogasreaktoren", S. 110 ff., CCM (mean 2003)

Physical and Chemical Properties

Parameter	Symbol	Value	Unit
Soluble COD	COD_S	20.87	gCOD/L
Inert soluble COD	SIin	17.07	gCOD/L
pH value	pH	3.84	-
Acetic acid + acetate	Sac	3.0	g/L
Butyric acid + butyrate	Sbu	0.0	g/L
Propionic acid + propionate	Spro	0.0	g/L
Valeric acid + valerate	Sva	0.0	g/L
Inorganic nitrogen	SIN	0.41	g/L
Inorganic carbon	SIC	0.21	g/L
Total solids	TS	46.0	%
Volatile solids	oTS	98.0	% TS
Total COD	COD	469.92	gCOD/L
Volatile fatty acids	VFA	3.3	g/L

Table 14: Physical and chemical properties for CCM (Corn cob mix)

Notes and References:

- **Fiber content**: Lowest fiber content (NDF 19.69%), highest digestibility potential
- **TS**: Highest total solids content (46%) among substrates
- **Sac**: High acetic acid content (3.0 g/L) due to fermentation
- **oTS**: Excellent organic content (98%)
- **COD**: Highest COD concentration (469.92 gCOD/L)

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8. Futterkalk (FODDER LIME)

Weender Analysis

Parameter	Symbol	Value	Unit
Raw fiber (Rohfaser)	RF	0.0	% TS
Raw protein (Rohprotein)	RP	0.0	% TS
Raw lipids (Rohfett)	RL	0.0	% TS
Neutral detergent fiber	NDF	0.0	% TS
Acid detergent fiber	ADF	0.0	% TS
Acid detergent lignin	ADL	0.0	% TS

Table 15: Weender analysis for Futterkalk (Fodder lime)

Data Sources:

- All parameters: Inorganic additive, no organic components

Physical and Chemical Properties

Parameter	Symbol	Value	Unit
Soluble COD	COD_S	0.0	gCOD/L
Inert soluble COD	SIin	0.0	gCOD/L
pH value	pH	12.4	-
Acetic acid + acetate	Sac	0.0	g/L
Butyric acid + butyrate	Sbu	0.0	g/L
Propionic acid + propionate	Spro	0.0	g/L
Valeric acid + valerate	Sva	0.0	g/L
Inorganic nitrogen	SIN	0.0	g/L
Inorganic carbon	SIC	25.0	g/L
Total solids	TS	100.0	%
Volatile solids	oTS	0.0	% TS
Total COD	COD	0.0	gCOD/L
Volatile fatty acids	VFA	0.0	g/L

Table 16: Physical and chemical properties for Futterkalk (Fodder lime)

Notes and References:

- **Function**: pH buffer and alkalinity source for process stabilization
- **pH**: Highly alkaline (12.4), used for pH control
- **SIC**: High inorganic carbon content (25.0 g/L) provides alkalinity
- **Organic content**: Zero organic matter (oTS = 0%)
- **Application**: Added to prevent acidification and maintain process stability

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9. Rindermist (CATTLE MANURE)

Weender Analysis

Parameter	Symbol	Value	Unit
Raw fiber (Rohfaser)	RF	24.45	% TS
Raw protein (Rohprotein)	RP	15.93	% TS
Raw lipids (Rohfett)	RL	3.18	% TS
Neutral detergent fiber	NDF	44.37	% TS
Acid detergent fiber	ADF	28.43	% TS
Acid detergent lignin	ADL	7.03	% TS

Table 17: Weender analysis for Rindermist (Cattle manure)

Data Sources:

- RF, RP, RL: Substrat_FermenterProben.xls
- NDF, ADF, ADL: "Einfluss der stofflichen Zusammensetzung auf die Verdaulichkeit nachwachsender Rohstoffe beim anaeroben Abbau in Biogasreaktoren", S. 110 ff., cattle manure (solid, mean)

Physical and Chemical Properties

Parameter	Symbol	Value	Unit
Soluble COD	COD_S	3.52	gCOD/L
Inert soluble COD	SIin	2.88	gCOD/L
pH value	pH	8.1	-
Acetic acid + acetate	Sac	0.3	g/L
Butyric acid + butyrate	Sbu	0.0	g/L
Propionic acid + propionate	Spro	0.0	g/L
Valeric acid + valerate	Sva	0.0	g/L
Inorganic nitrogen	SIN	0.9	g/L
Inorganic carbon	SIC	1.2	g/L
Total solids	TS	17.0	%
Volatile solids	oTS	78.0	% TS
Total COD	COD	141.31	gCOD/L
Volatile fatty acids	VFA	0.33	g/L

Table 18: Physical and chemical properties for Rindermist (Cattle manure)

Notes and References:

- **Lignin content**: Highest ADL (7.03%), indicating presence of undigested plant material
- **pH**: Slightly alkaline (8.1), typical for cattle manure
- **Protein content**: High protein (15.93%) from undigested feed and microbial biomass
- **Nitrogen**: Moderate SIN content (0.9 g/L)

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10. Zwiebeln (ONIONS)

Weender Analysis

Parameter	Symbol	Value	Unit
Raw fiber (Rohfaser)	RF	9.06	% TS
Raw protein (Rohprotein)	RP	11.4	% TS
Raw lipids (Rohfett)	RL	2.2	% TS
Neutral detergent fiber	NDF	22.8	% TS
Acid detergent fiber	ADF	12.54	% TS
Acid detergent lignin	ADL	1.84	% TS

Table 19: Weender analysis for Zwiebeln (Onions)

Data Sources:

- RF, RP, RL: Assumed similar composition to vegetable waste
- NDF, ADF, ADL: Estimated from vegetable matter characteristics

Physical and Chemical Properties

Parameter	Symbol	Value	Unit
Soluble COD	COD_S	5.99	gCOD/L
Inert soluble COD	SIin	4.9	gCOD/L
pH value	pH	5.9	-
Acetic acid + acetate	Sac	0.3	g/L
Butyric acid + butyrate	Sbu	0.0	g/L
Propionic acid + propionate	Spro	0.0	g/L
Valeric acid + valerate	Sva	0.0	g/L
Inorganic nitrogen	SIN	0.24	g/L
Inorganic carbon	SIC	0.12	g/L
Total solids	TS	13.0	% TS
Volatile solids	oTS	92.0	% TS
Total COD	COD	134.62	gCOD/L
Volatile fatty acids	VFA	0.33	g/L

Table 20: Physical and chemical properties for Zwiebeln (Onions)

Notes and References:

- **Composition**: Low fiber content, relatively high protein for vegetable waste
- **TS**: Low total solids (13%) due to high water content
- **Digestibility**: Good digestibility potential based on low lignin content
- **Application**: Co-substrate in biogas production, good source of readily available organics

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Summary and Comparative Analysis

Substrate Classification

Energy Crops (High COD):

- CCM (469.92 gCOD/L) - Highest energy content
- Maize (359.07 gCOD/L) - Standard energy crop
- GPS (329.75 gCOD/L) - Good alternative to maize
- Grass (316.73 gCOD/L) - Moderate energy, high fiber

Animal Manures (High Nitrogen):

- Cattle manure (SIN: 0.9 g/L) - Solid fraction
- Swine manure (SIN: 2.84 g/L) - Liquid, highest nitrogen

Process Additives:

- Fodder lime - pH buffer and alkalinity source

Specialty Substrates:

- Onions - Vegetable waste, moderate energy content

Key Parameters for Co-digestion Design

Substrate	TS (%)	oTS (% TS)	C/N	pH
Maize	33.0	96.0	High	3.93
Swine manure	7.25	82.0	Low	7.67
Green rye	27.0	93.5	High	4.32
Grass	31.0	92.4	Medium	4.59
Wheat	28.0	93.3	High	4.38
GPS	32.0	95.6	High	4.07
CCM	46.0	98.0	High	3.84
Cattle manure	17.0	78.0	Low	8.1
Onions	13.0	92.0	Medium	5.9

Table 21: Key parameters for substrate selection and mixing ratios

Recommendations for Co-digestion

1. **Balance C/N ratio**: Combine energy crops (high C/N) with manures (low C/N) for optimal microbial growth
2. **pH management**: Use fodder lime to neutralize acidic energy crop silages
3. **TS optimization**: Mix high TS substrates (CCM, maize) with low TS manures for optimal reactor operation
4. **Trace elements**: Animal manures provide essential trace elements lacking in energy crops
5. **Process stability**: Monitor VFA accumulation, particularly with high-energy substrates like CCM

Data Quality and References

Primary data sources:

- Substrat_FermenterProben.xls - Laboratory measurements from fermentation facility
- "Einfluss der stofflichen Zusammensetzung auf die Verdaulichkeit nachwachsender Rohstoffe beim anaeroben Abbau in Biogasreaktoren" - Reference study for fiber fractions

Data reliability:

- Weender analysis: Direct laboratory measurements
- Physical properties: Combination of measurements and calculations
- Some parameters adjusted based on process calibration and experience

Limitations:

- Substrate composition varies with harvest time, storage conditions, and silage quality
- Parameters should be validated for specific batches in industrial applications
- Some calculated values (e.g., soluble COD fractions) are based on assumptions and should be verified

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Abbreviations and Terminology

Weender Analysis:

- **RF** - Rohfaser (raw fiber/crude fiber)
- **RP** - Rohprotein (raw protein/crude protein)
- **RL** - Rohfett (raw lipids/crude fat)
- **NDF** - Neutral Detergent Fiber (hemicellulose + cellulose + lignin)
- **ADF** - Acid Detergent Fiber (cellulose + lignin)
- **ADL** - Acid Detergent Lignin

Chemical Parameters:

- **COD** - Chemical Oxygen Demand
- **TS** - Total Solids
- **oTS** - Organic Total Solids (volatile solids)

- **VFA** - Volatile Fatty Acids
- **SIN** - Soluble Inorganic Nitrogen
- **SIC** - Soluble Inorganic Carbon

Substrate Abbreviations:

- **GPS** - Ganzpflanzensilage (whole plant silage)
- **CCM** - Corn Cob Mix (corn grain silage)