



We have
1001 reasons
to invest in sorghum

BIOENERGY PRODUCTION, WHICH VARIETY TO USE? - VARIETIES IDEOTYPES AND BRAZILIAN EXAMPLES

Dr. Rafael Augusto da Costa Parrella

Sorghum Breeder

October 8 and 9, 2025



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4th European Sorghum Congress Budapest

October 8th - 9th 2025



Rafael Parrella

Sorghum Breeder
EMBRAPA MILHO E SORGO

Embrapa's Innovation Network



We have
1001 reasons
to invest in sorghum

North

- ❖ Embrapa Acre
- ❖ Embrapa Amapa
- ❖ Embrapa Western Amazonia
- ❖ Embrapa Eastern Amazonia
- ❖ Embrapa Rondonia
- ❖ Embrapa Roraima
- Embrapa Fisheries and Aquaculture

Northeast

- ❖ Embrapa Mid-North
- ❖ Embrapa Tropical Semi-Arid
- ❖ Embrapa Coastal Tablelands
- Embrapa Goats
- Embrapa Cassava & Tropical Fruits
- Embrapa Cotton
- ❖ Embrapa Tropical Agroindustry
- ❖ Embrapa Foods and Territories
- Embrapa Cocais

Center-west

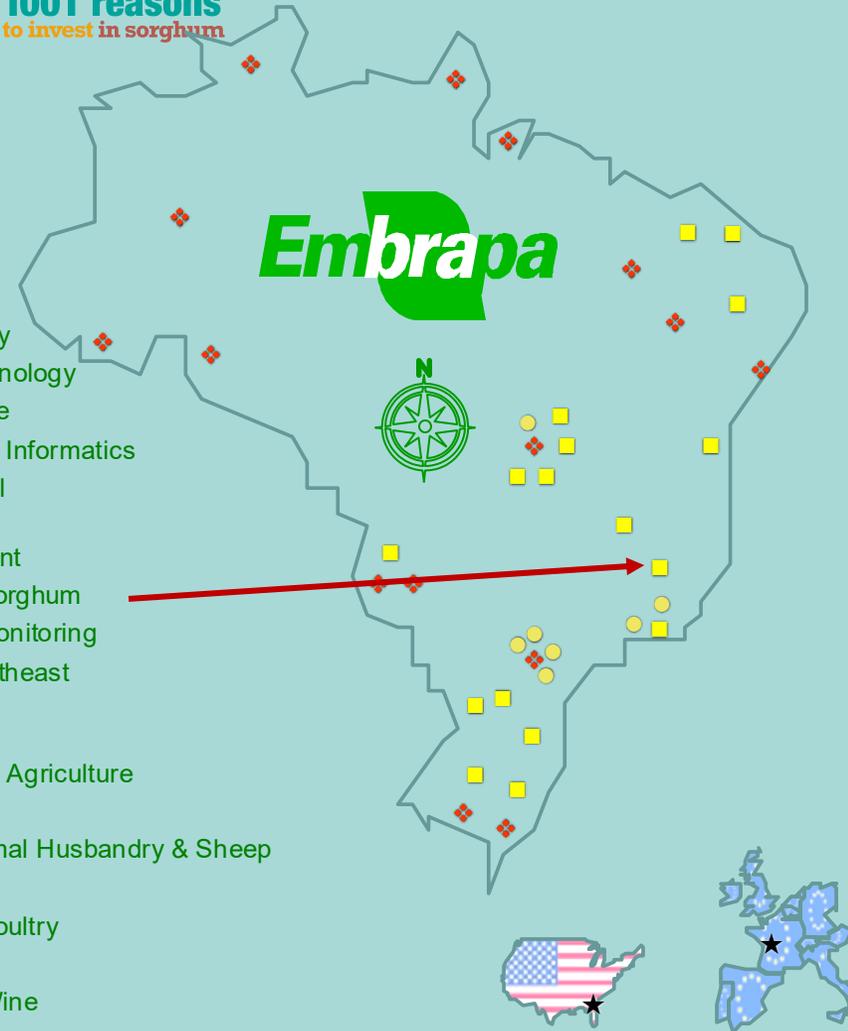
- ❖ Embrapa Western Region Agriculture
- Embrapa Rice & Beans
- Embrapa Coffee
- ❖ Embrapa Cerrados
- Embrapa Beef Cattle
- Embrapa Vegetables
- ❖ Embrapa Pantanal
- Embrapa Agroenergy
- Embrapa Genetic Resources & Biotechnology
- Embrapa Tecnological Information

Southeast

- Embrapa Agrobiology
- Embrapa Food Technology
- Embrapa Dairy Cattle
- Embrapa Agriculture Informatics
- Embrapa Agricultural Instrumentation
- Embrapa Environment
- Embrapa Maize & Sorghum
- ❖ Embrapa Satellite Monitoring
- Embrapa Cattle-Southeast
- Embrapa Soils

South

- ❖ Embrapa Temperate Agriculture
- Embrapa Forestry
- ❖ Embrapa South Animal Husbandry & Sheep
- Embrapa Soybean
- Embrapa Swine & Poultry
- Embrapa Wheat
- Embrapa Grape & Wine



Labex USA



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Topics



- ✓ Bioenergy in Brazil;
- ✓ Which sorghum variety to use and ideotypes;
- ✓ Sorghum products for bioenergy;
- ✓ Brazilian examples of bioenergy production (Cogeneration and Biogas);

SORGHUM MATERIALS AT EMBRAPA: INNOVATION ASSETS

100 reasons to invest in sorghum



Grain sorghum

BRS 330 in Rio Verde - GO

Grain for animal feed



Silage for animal feed



Sweet sorghum in sugarcane mill (cultivars and production systems)



Biomass sorghum for energy: cogeneration, second generation ethanol and biogas

Grain

- ✓ Grain yield
- ✓ Plant height
- ✓ Earliness
- ✓ No tanine
- ✓ No Lodging

Forage

- ✓ Green mass
- ✓ Digestibility (NDF, ADF)
- ✓ Protein
- ✓ High % of grain
- ✓ No Logging
- ✓ BMR
- ✓ Fotoperiod insensitivity
- ✓ Milk production

Bioenergy

- ✓ Green mass
- ✓ Juice yield
- ✓ High Sugar
- ✓ IPU
- ✓ Fiber
- ✓ Fotoperiod sensitivity

Broom

- ✓ Size
- ✓ Quality
- ✓ Yield
- ✓ Logging
- ✓ Fotoperiod Insensitive

All sorghum

- ✓ Drought tolerance
- ✓ Disease resistance
- ✓ Pests resistance
- ✓ Nematode resistance
- ✓ No Logging



Grazing



Broom

EMBRAPA'S PRIORITIES FOR ENERGY CROPS

Fossil carbon

Biogenic Carbon



Combustível fóssil

Energy Transition



Bioenergy in Brazil

2nd Survey of the sugarcane crop (August 2025/2026-Conab);

- ✓ Area: 8.849 million hectares (1.0 ↑)
- ✓ Sugarcane production: 668,820 thousand tons (1.2 ↑)
- ✓ Sugarcane Ethanol Production: 26.8 billion liters (1.3 ↑)
- ✓ Corn Ethanol Production: 8.9 billion liters (14.5% ↑)
- ✓ Biogas and Ethanol 2G
- ✓ RenovaBIO



Bioelectricity /
Steam / Vapor



Pellets

Sorghum Biofuel



Briquettes



1G and 2G Ethanol

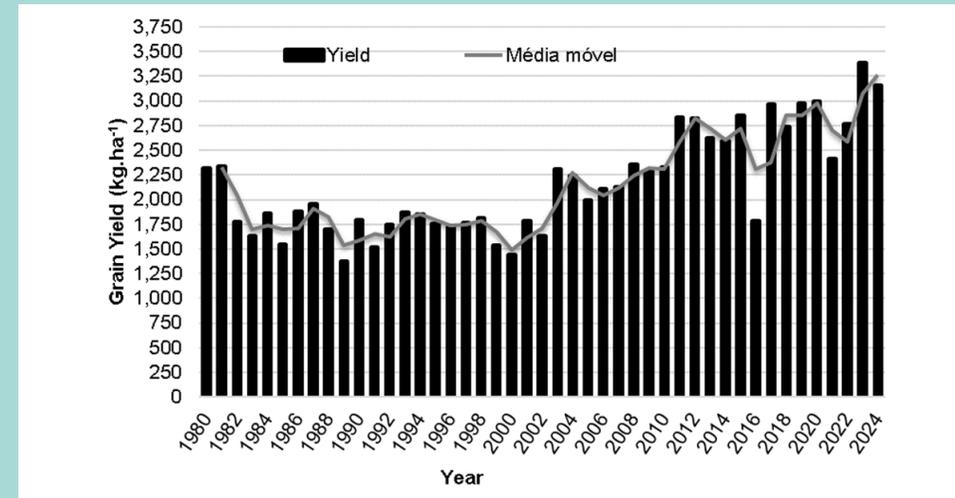
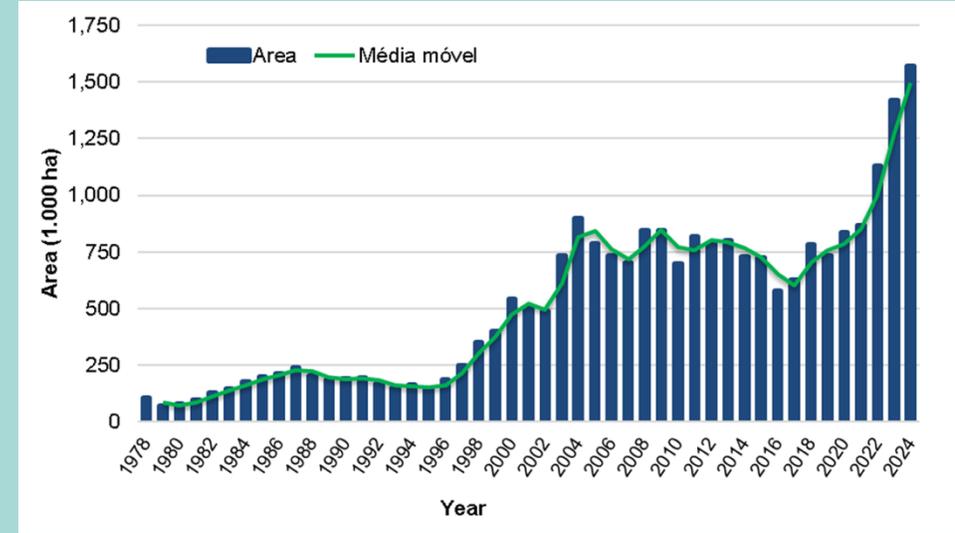
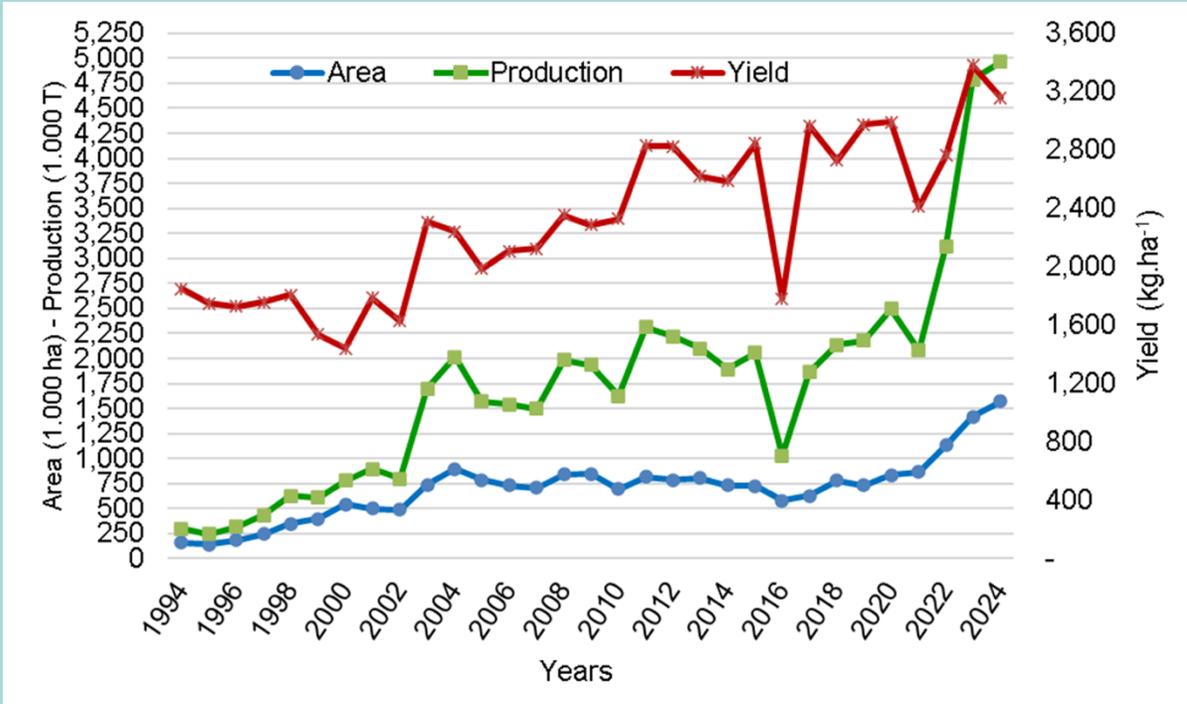


Biogas



Bio-oil

Historical series of grain sorghum in Brazil



2024 season crop
Area = 1.57 million hectares
Yield = 3,157 kg ha⁻¹
Production = 4.92 millions of tons

Source: CONAB, 2025.

Grain Sorghum for Ethanol Production

1 ton of grain sorghum



410 L of
ethanol

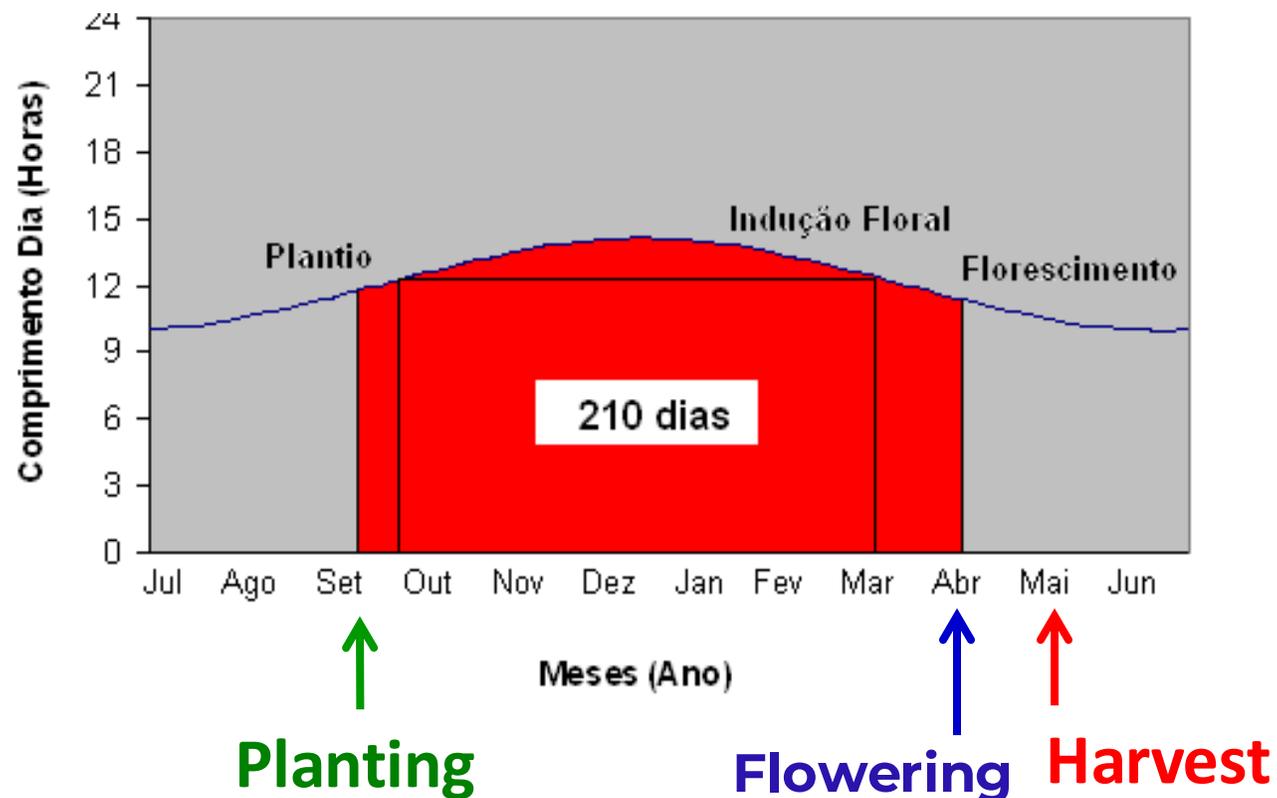
330 kg of
DDG



Sorghum Cycle "Sensitive* to Photoperiod"

PI - Photo Insensitive

PS - Photo Sensitive



Biomass Sorghum Production



Season/cycle (Days)	Fresh Biomass (t.ha ⁻¹)	Dry Biomass (t.ha ⁻¹)
1 ^a Season (Cycle 150-170)	80 - 120	24 - 36
2 ^a Season (Cycle 100-120)	40 - 50	12 - 15



INDUSTRIAL PARAMETERS FOR BIOENERGY SORGHUM

The interaction of:

- ✓ **Brix**
- ✓ **Total Sugars**
- ✓ **Fiber**
- ✓ **Juice Extraction**
- ✓ **Sugar Extraction**

extracted from sorghum stalks during the maturity phase at 7 or 14 day intervals for the varieties Rio and Wray grown in Brazil.

(CONSECANA, 2015)



HYDRAULIC PRESS



Sample Shredder and Homogenizer

The hydraulic press exerts a pressure of 250 kgf/cm² on the sample for one minute.

FIBER PERCENTAGE IN BIOMASS (WHOLE PLANT) OF DIFFERENTS SORGHUM GENOTYPES

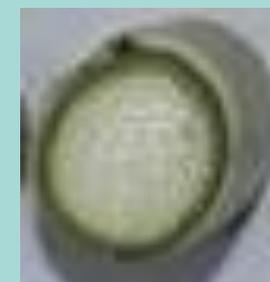


Genotype	FIBER (%)			
	130 DAP		160 DAP	
CMSXS5017	12	b	15	f
CMSXS5029	12	b	14	f
CMSXS5020	12	b	14	f
CMSXS5035	13	b	15	f
CMSXS5037	13	b	16	e
CMSXS5021	18	a	22	c
CMSXS5039	22	a	22	c
CMSXS5041	19	a	25	b
CMSXS5043	18	a	20	d
BRS716	21	a	27	a
Mínimo	11		12	
Máximo	22		27	



dd – Juice - stem

Sweet Sorghum



DD ou D_ – Pithy – dry stem

Biomass Sorghum

2024/2025 harvest, in Sete Lagoas, MG.

¹ Means followed by the same lowercase letter vertically are equal to each other by the Scott-Knott test (1974) at 5% probability.

Juice extraction (%) from different Sorghum Genotypes



Genotypes	130DAP						160DAP					
	Small mill			Hydraulic press			Small mill			Hydraulic press		
CMSXS5017	27.99	a	B	66.67	c	A	19.52	a	B	61.33	b	A
CMSXS5027	24.45	a	B	71.33	a	A	18.66	a	B	69.67	a	A
CMSXS5020	25.78	a	B	69.75	b	A	14.88	a	B	68.53	a	A
CMSXS5035	32.85	a	B	71.67	a	A	20.26	a	B	69.33	a	A
CMSXS5037	25.86	a	B	71.67	a	A	20.06	a	B	69.33	a	A
CMSXS5021	5.66	b	B	60.33	e	A	4.78	b	B	57.67	c	A
CMSXS5039	10.65	b	B	56.33	g	A	8.77	b	B	53.00	d	A
CMSXS5041	13.73	b	B	59.33	f	A	6.37	b	B	51.00	d	A
CMSXS7500	10.15	b	B	57.67	g	A	8.75	b	B	54.67	c	A
BRS716	5.12	b	B	59.33	f	A	5.79	b	B	51.33	d	A



dd – Juice - stem

Sweet Sorghum



DD ou D_ – Pithy – dry stem

Biomass Sorghum



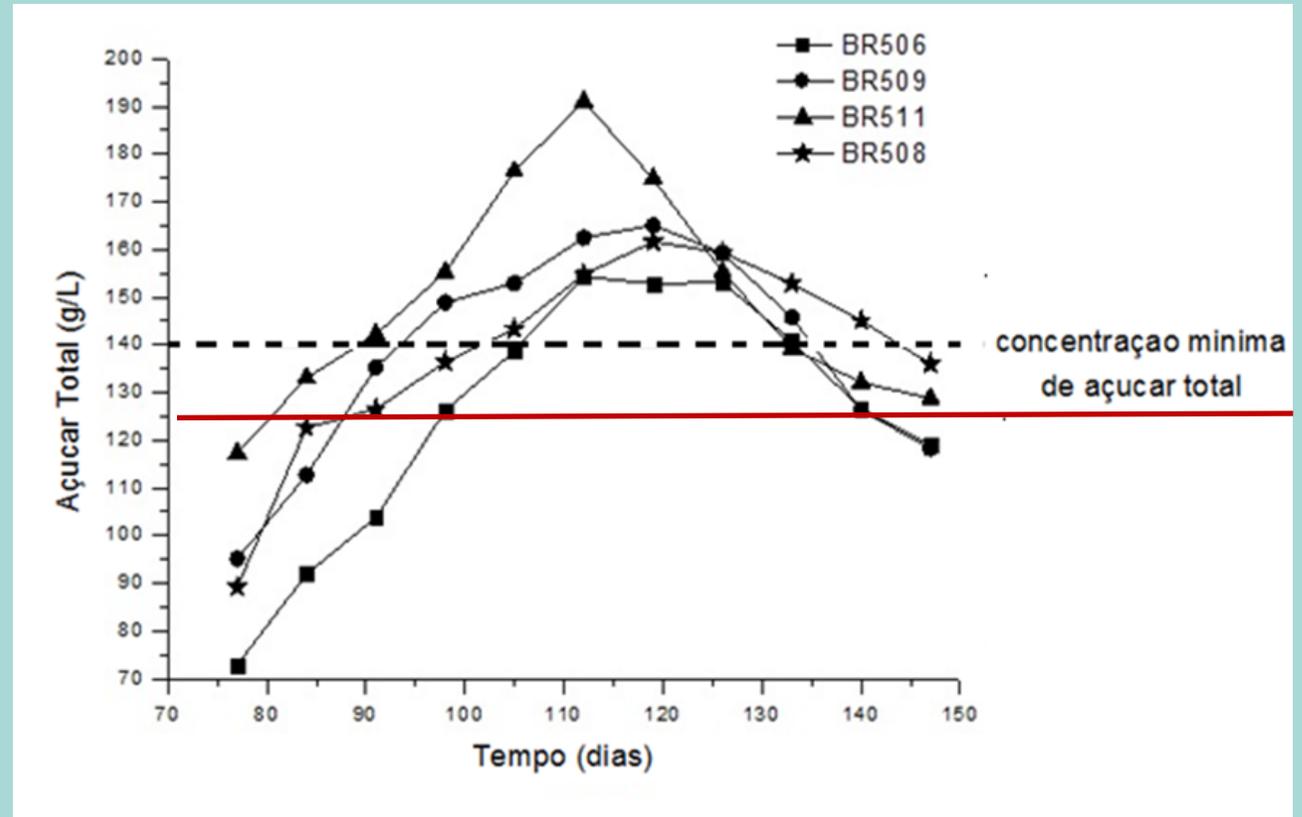
2024/2025 harvest, in Sete Lagoas, MG

¹ Means followed by the same lowercase letter vertically are equal to each other by the Scott-Knott test (1974) at 5% probability.

Period of Industrial Utilization (PIU)

Minimum Parameters for PIU

Total sugar (% juice): > 12,5%
Extracted sugars (hyd. press): >80 Kg t⁻¹
Period > 30 dias
(High Sucrose Desirable – Promotes longer PIU);
Necessary for Industrial Planning





Period of Industrial Utilization (PIU)

Sugar composition in the extracted juice;

TRS - Total recoverable sugars per ton of sorghum;

Theoretical Ethanol yield

Crop Season 2023/2024

Sete Lagoas-Mg

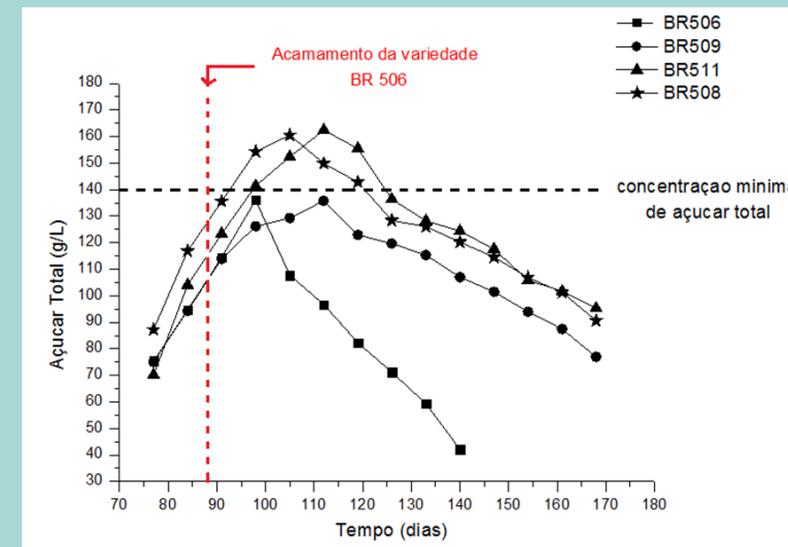
Genótipos	Times	Glucose (mg.mL ⁻¹)	Fructose (mg.mL ⁻¹)	Sucrose (mg.mL ⁻¹)	TSS ° Brix	TRS (mg.mL ⁻¹)	ETY* (L.t ⁻¹)
CMSXS5041	1 - 110 DAP	13,01	11,62	18,88	6,80	44,50	24,51
CMSXS5041	2 - 120 DAP	10,22	8,03	22,26	6,53	41,68	22,96
CMSXS5041	3 - 130 DAP	16,38	12,83	53,81	10,97	85,84	47,28
CMSXS5041	4 - 140 DAP	17,51	11,97	94,25	14,87	128,68	70,88
CMSXS5041	5 - 150 DAP	34,25	33,44	60,65	16,40	131,52	72,44
CMSXS5041	6 - 160 DAP	13,11	8,12	107,58	15,87	134,47	74,06
CMSXS5041	7 - 170 DAP	11,74	8,39	143,65	18,80	171,34	94,37
CMSXS5041	8 - 180 DAP	10,87	7,60	102,51	14,57	126,38	69,61
BRS716	1 - 110 DAP	13,72	11,78	6,89	5,40	32,75	18,04
BRS716	2 - 120 DAP	15,55	12,22	29,99	7,00	59,34	32,68
BRS716	3 - 130 DAP	15,24	12,26	28,10	8,10	57,07	31,43
BRS716	4 - 140 DAP	19,55	17,13	43,35	10,80	82,31	45,33
BRS716	5 - 150 DAP	32,34	31,55	26,67	12,57	91,96	50,65
BRS716	6 - 160 DAP	14,37	10,70	50,90	10,63	78,64	43,31
BRS716	7 - 170 DAP	15,00	10,45	70,78	12,77	99,96	55,06
BRS716	8 - 180 DAP	12,90	8,74	45,66	9,77	69,70	38,39

Challenges: Lodging Resistance

Lodging: Reduces sugar content and increases impurity content



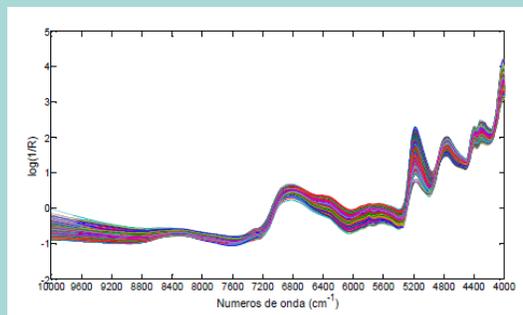
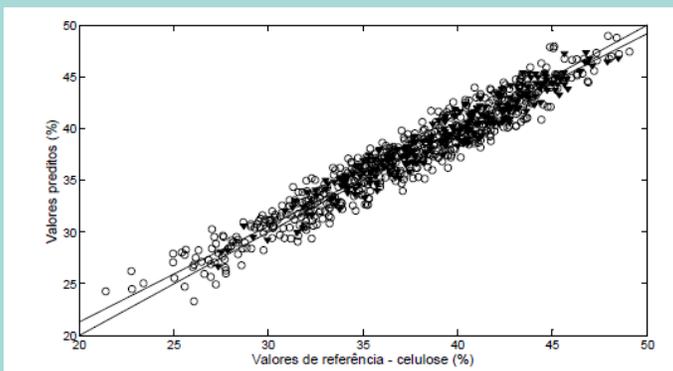
Susceptible to lodging



Resistent to lodging

Fernandes et al., 2014

NIR Analysis for characterization of sorghum genotypes for sugar, cellulose, hemicellulose, lignin and Biogas



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Near infrared spectroscopy determination of sucrose, glucose and fructose in sweet sorghum juice

Maria Lúcia F. Simeone ^{a,*}, Rafael A.C. Parrella ^a, Robert E. Schaffert ^a, Cynthia M.B. Damasceno ^a, Michelle C.B. Leal ^a, Celio Pasquini ^b

^a Embrapa Milho e Sorgo, MG 424, km 45, 35701-970 Sete Lagoas, MG, Brazil
^b University of Campinas, Chemistry Institute, C. P. 6154, 13083-970 Campinas, SP, Brazil

CrossMark

Biomass sorghum for 2G ethanol



Pre-treatment



Saccharification



Fermentation



SORGO BIOMASSA

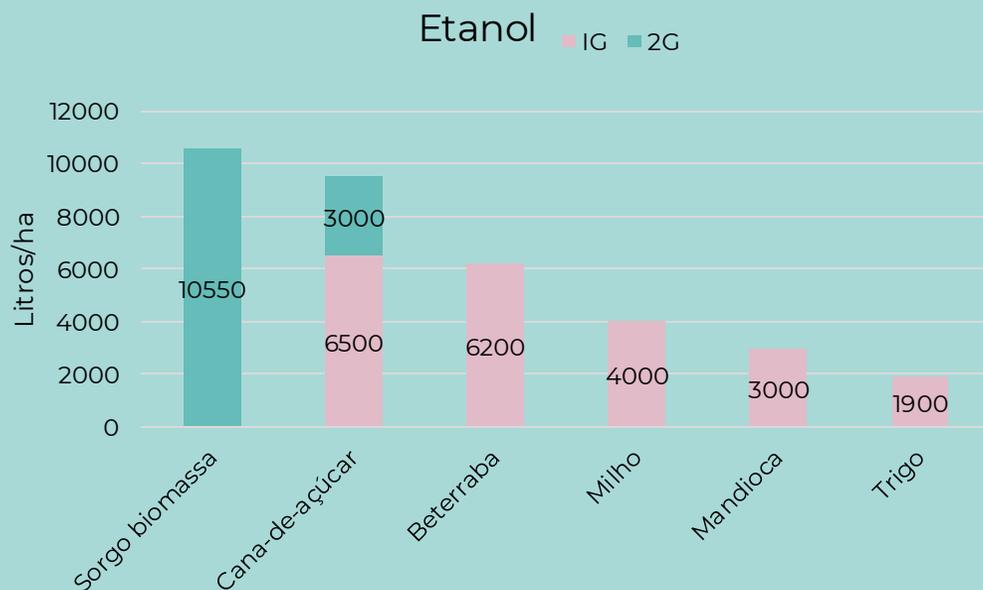


BRS 716

- Primeiro híbrido de sorgo biomassa registrado no Brasil



- Etanol 2G: 211 L/t (produtividade biomassa seca: 30 a 50 t/ha)



SORGO BIOMASSA



Ethanol yields by cellulosic genotype

Híbridos	L EtOH/ ha SFS ác.		L EtOH/ ha SFS ác.+bs		L EtOH/ ha SSF	
	Sete Lagoas	Couto M. Minas	Sete Lagoas	Couto M. Minas	Sete Lagoas	Couto M. Minas
201556(B)002	3821,21 Aa	4220,28 Aa	11567,86 Aa	9232,21 Bb	9288,38 Aa	8286,97 Bb
201556(B)003	3715,52 Aa	4196,27 Aa	6612,57 Ab	8080,50 Ab	7767,84 Ab	8511,44 Ab
CMSXS7027	2806,64 Bb	3577,77 Ab	6671,33 Bb	8459,30 Ab	7423,88 Ab	7369,04 Ac
CMSXS7016	3788,22 Ba	4520,18 Aa	7256,25 Bb	9316,34 Ab	9323,90 Ba	10330,07 Aa
BRS716	3976,62 Aa	4401,47 Aa	10587,97 Aa	11838,46 Aa	8166,88 Bb	10820,36 Aa



bmr Sorghum : 0.51 L/kg de biomassa
Biomass Sorghum: 0.35 L/kg de biomassa

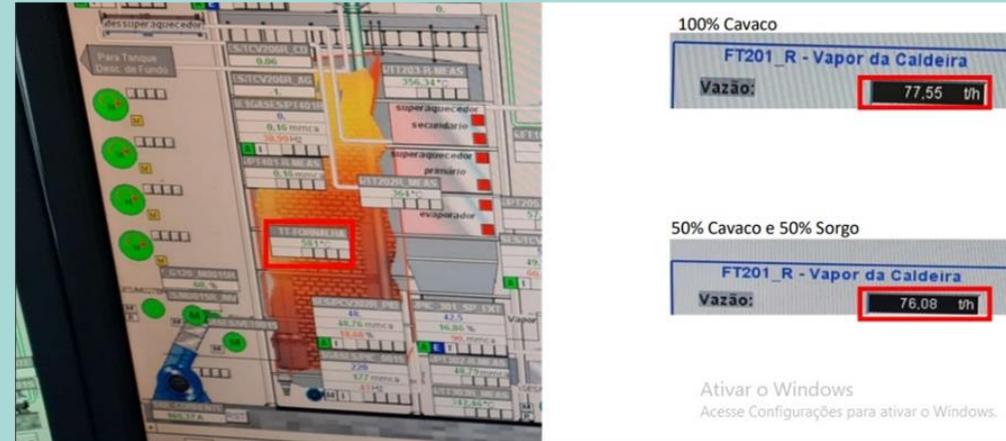
Almeida et al. (2019) Characterization of cell wall polysaccharides and cellulosic ethanol potential in genotypes of sorghum biomass. **International Journal of Development Research**, v. 09, p. 26810-26820, 2019a.

Almeida et al. (2019) Composition and growth of sorghum biomass genotypes for ethanol production. **Biomass & Bioenergy**, v. 122, p. 343-348, 2019b.

Partnership between EMBRAPA and COCAMAR to use biomass sorghums for direct boiler burning



Pictures: Rusti Federle (rusti.Federle@cocamar.com.br)



Implementation of a pilot area of 120 ha with biomass sorghum in the harvest season 2021/2022.

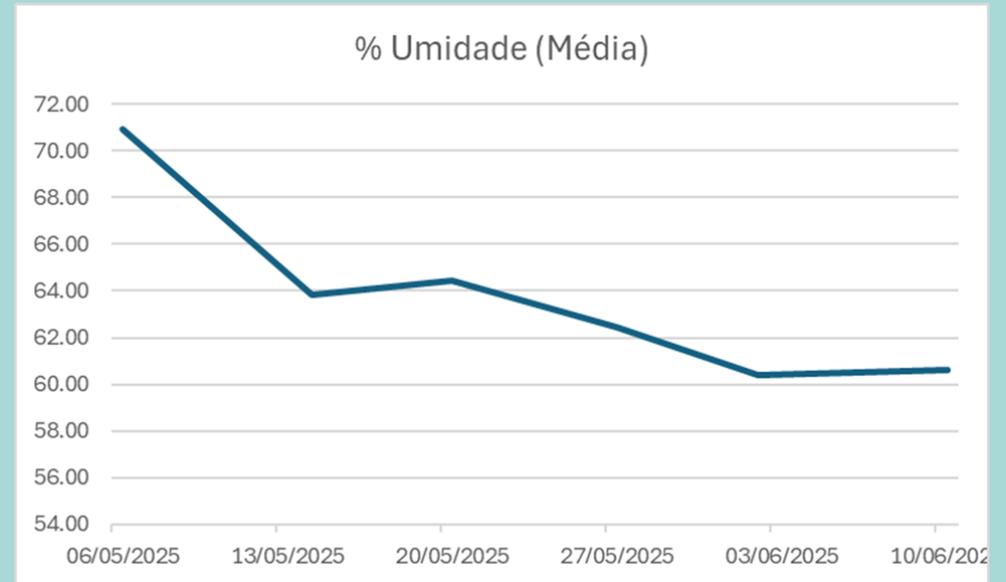
Estimate parameters for steam production (How many kg of sorghum to produce one t of steam?)

Adjustments in Harvest and Logistics



Partnership between EMBRAPA and COCAMAR to use biomass sorghums for direct boiler burning

Glyphosate herbicide was sprayed using drone after sorghum flowering.



Harvesting started 40 days after spraying.



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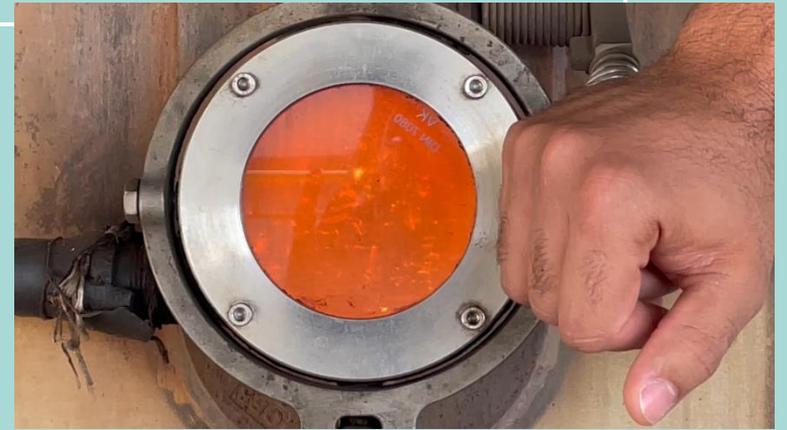


Loading and Transporting Sorghum for Power/Steam Co-generation





Sorghum for power/steam co-generation



Sorghum harvest for energy/steam co-generation

Results of biomass sorghum burning in a high pressure boiler for steam production at Cocamar. July 2022.

Test	Percentage of Sorghum %	Percentage of Chip %	Sorghum Moisture (%)	Chip Moisture (%)	Weighted Humidity (%)	Produced Steam (ton/day)	Specific Consumption (kg/ton of steam)	Boiler Performance
1	0	100	0	37	37	1000	345	Stable
2	49	51	58	41	49	742.5	372.9	Stable
5	59	41	50	39	46	733.83	385.6	Stable
8	71	29	58	39	52	630.24	416	Stable

Physicochemical and mechanical properties of BRS716 Biomass sorghum pellets

Property	Unit	Value	Property	Unit	Value
Diameter	mm	6.12	Fixed carbon	%	9.0
Length (mean)	mm	14.62	Volatile matter	%	79.6
Length (max)	mm	30.16	Ash	%	4.1
Length (min)	mm	3.53	Moisture	%	7.3
N° de pellets/100g	unity	224	Higher heating value	J/g	17,66
Apparent density	g.cm ⁻³	0.658	Lower heating value	J/g	15,26
Basic density	g.cm ⁻³	0.775	Energy density	GJ/m ³	10.04
Durability	%	98.37	Carbon	%	41.4
Fines < 3 mm	%	1.63	Hydrogen	%	4.7
Sulfur	%	0.06	Oxygen	%	0.7
Potassium	%	1.2	Chlorine	%	0.3
Nitrogen	%	0.7			

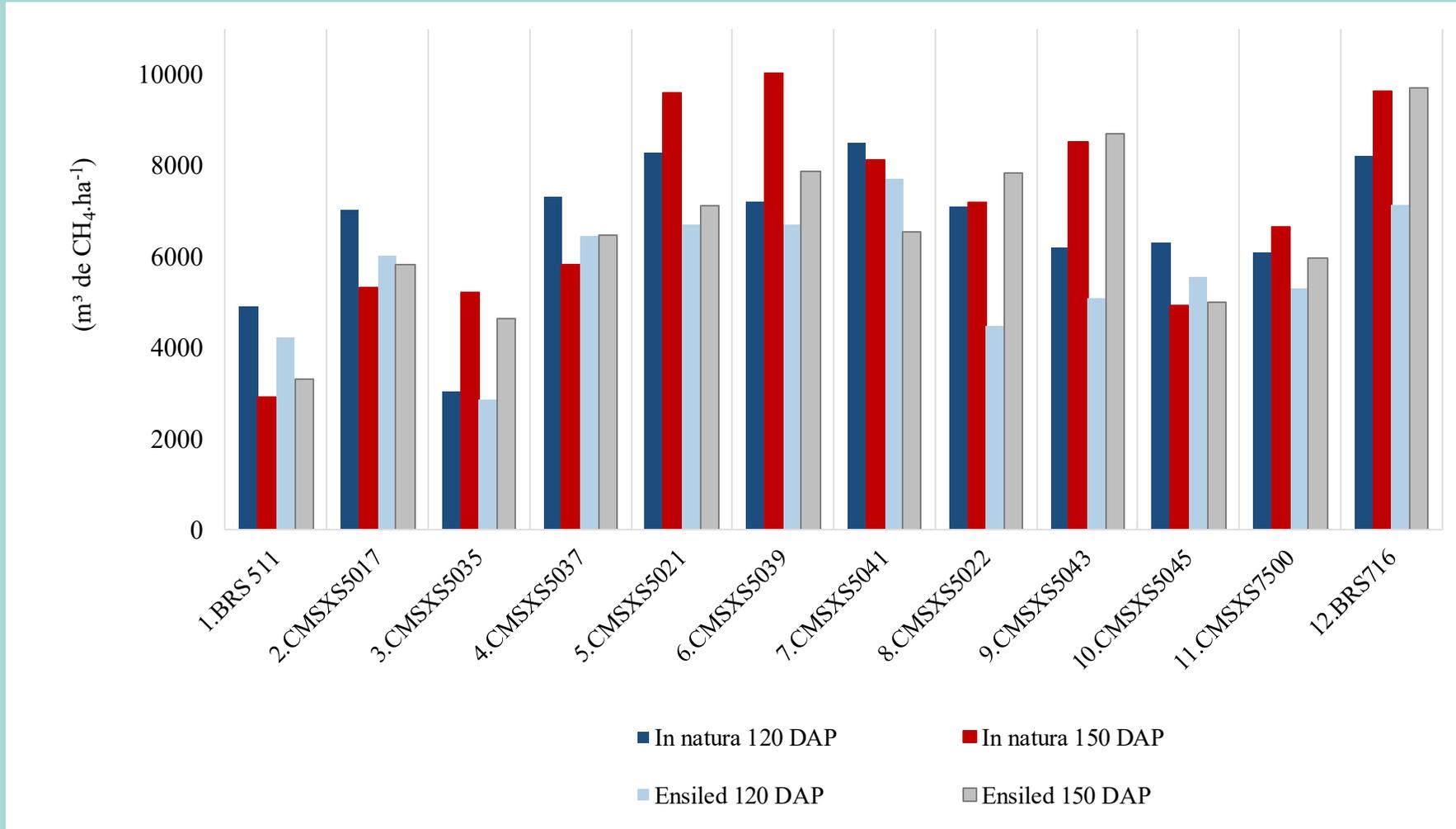




SORGHUM BIOGAS AND METHANE POTENTIAL



BIOCHEMICAL METHANE POTENTIAL FROM SORGHUM



Harvest 2022/2023

Sorghum BRS 716 as an energy crop for biogas production

Hybrid	DAP	Height	Fresh Biomass	Dry Biomass	BMP	Production CH ₄	Yield CH ₄
		(m)	(t _{FM} ·ha ⁻¹)	(t _{DM} ·ha ⁻¹)	(L _N kg _{sv} ⁻¹)	(m ³ t ⁻¹ _{FM})	(m ³ _N ·ha ⁻¹)
BRS 716	150	5,1	117,14	39,62	298,35	96,6	11.316

✓ Sorghum mono-digestion is viable up to an OLR of 2.5 kg_{vs} m⁻³·d⁻¹; however, co-digestion with swine manure stands out as it offers significant advantages for achieving higher OLRs and increased methane production.

LAZAROTO, Ana Claudia. Performance of sorghum BRS 716 as an energy crop for biogas production: monodigestion and co-digestion with pig manure. 2025. 120f. Dissertation (Master's in Biotechnology) - Federal Technological University of Paraná (UTFPR).

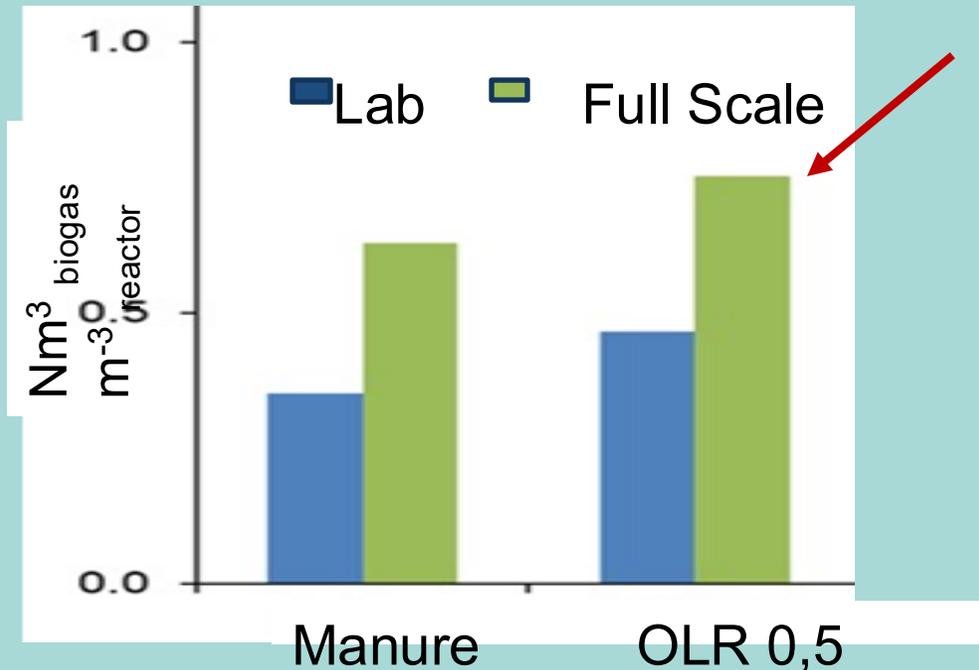


Biogas production using co-digestion of sorghum biomass with swine manure



Biogas production using co-digestion of biomass sorghum with swine manure at BIOKOHLE plant, Toledo -PR (BIOGRASS PROJECT (CNPq))

Productivity



Laboratory vs. Plant Comparison

- 55 days of processing with silage from BRS 716 biomass sorghum.

- Harvest 1: **61 t/ha** with 28% of DM

Production CH₄ = **340 m³N/d** (55 days)

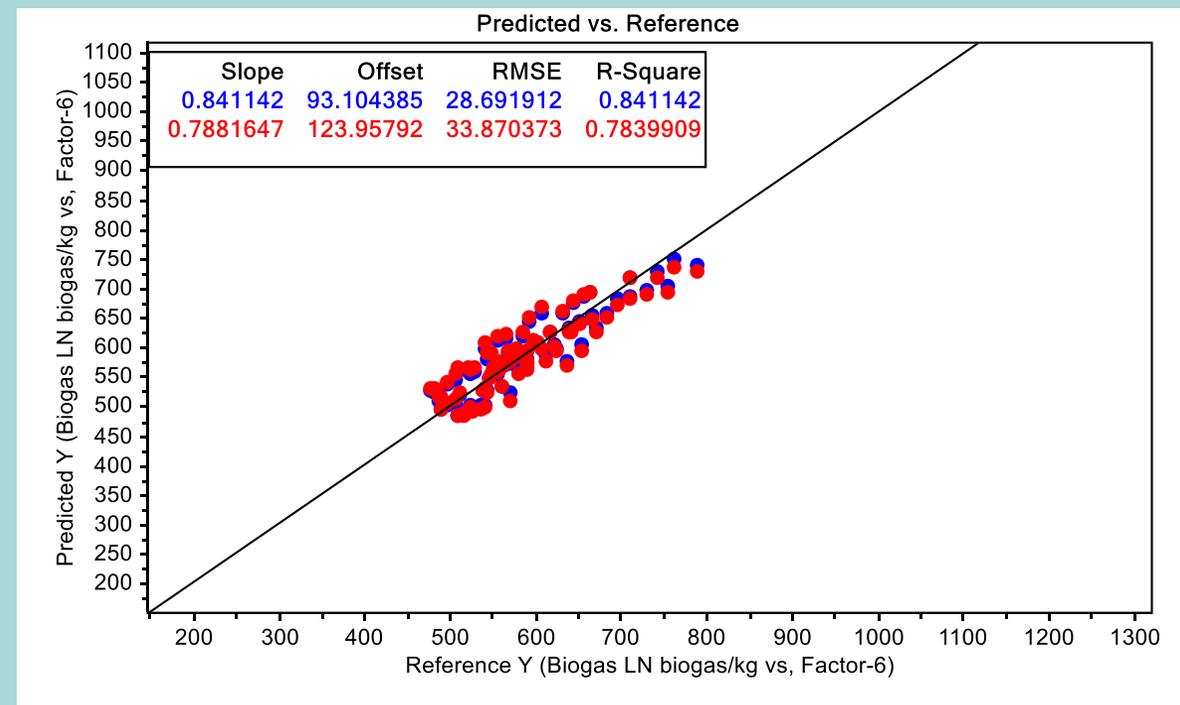
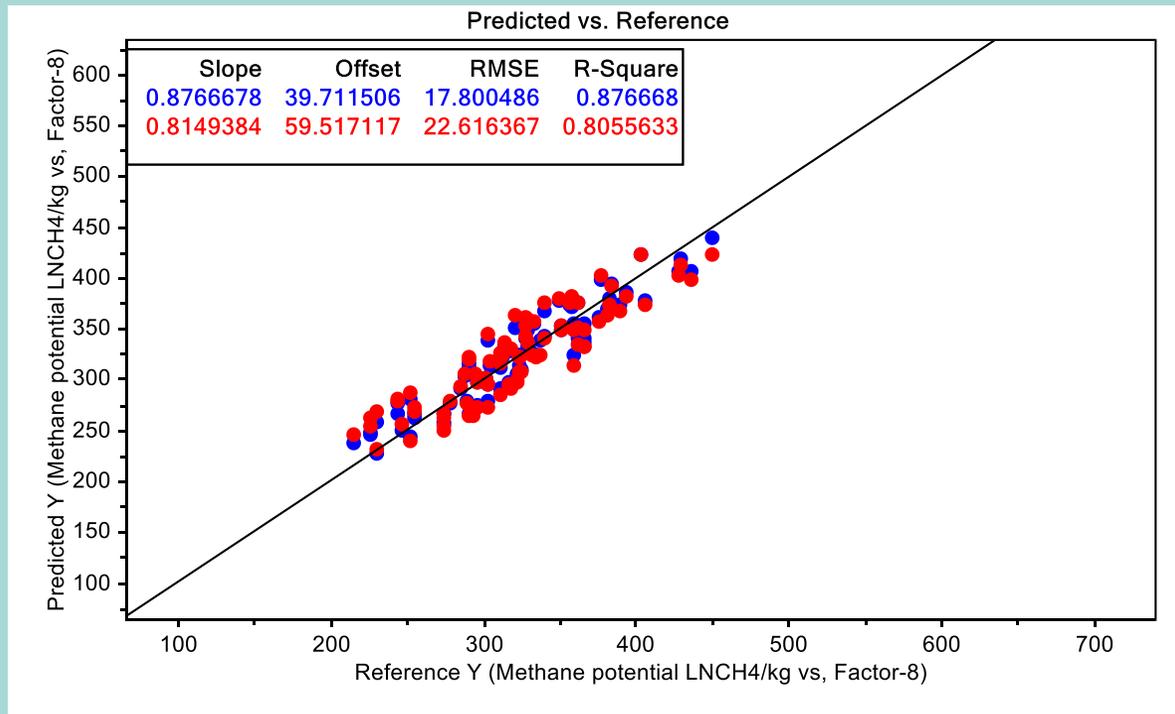
* Before supplying with sorghum: 284 m³N/d (production with daily supply of swine manure)

The performance of the complete mixing reactor was monitored along with the gradual increase in the volumetric organic load (VOL) de 0,5 g VS L⁻¹ d⁻¹ até 3,0g VS L⁻¹ d⁻¹. * Volatile Solids

Biogas



Methane



Elements:	82
Slope:	0.841142
Offset:	93.104385
Correlation:	0.917138
R2(Pearson):	0.8411421
R-Square:	0.841142
RMSEC:	28.691912
SEC:	28.868479
Bias:	0

Elements:	85
Slope:	0.8766678
Offset:	39.711506
Correlation:	0.9363055
R2(Pearson):	0.876668
R-Square:	0.876668
RMSEC:	17.800486
SEC:	17.906126
Bias:	0

Final Remarks – Take Away

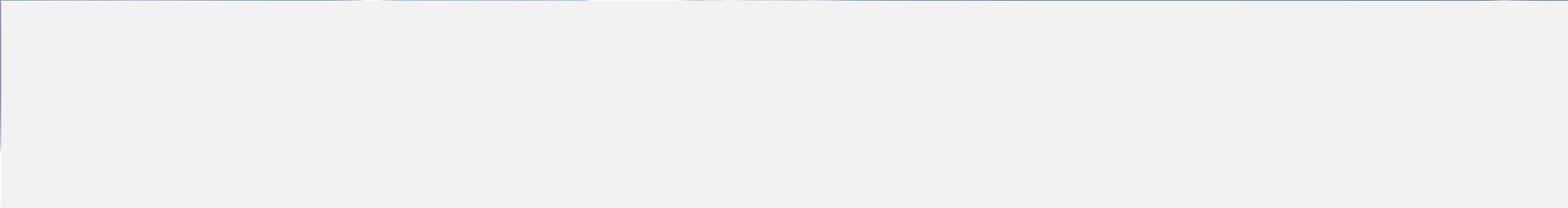
- ✓ Sorghum Has Great Potential to Meet the Requirements for Grain and forage for animal feed, and also for Bioenergy Production;
- ✓ The great productive potential of grain, forage, biomass and sweet sorghum makes them strategic crops in decarbonization, contributing to the reduction of global warming.
- ✓ We have different Types of sorghum with High Productive and High Quality for different purposes (Grain, forage, sweet and biomass);
- ✓ We are Interested in Collaborative Research & Development and Business Opportunities with Both Public and Private Sectors.

Embrapa Team

Name	Area	E-mail
Airton Kunz,	Industrial Chemist	airton.kunz@embrapa.br
Ana Paula Lazzrotto	Chemical Engineering	analazaroto@alunos.utfpr.edu.br
Deisi Tapparo	Agricultural Engineering	deise deisictapparo@gmail.com
Maria Lúcia Ferreira Simeone	Chemical Analysis	<u>marialucia.simeone@embrapa.br</u>
Rafael Augusto da Costa Parrella	Sorghum breeder	<u>rafael.parrella@embrapa.br</u>
Ricardo Steinmetz	Chemical Engineering	ricardo.steinmetz@embrapa.br
Rubens Augusto da Miranda	<i>Impact assessment and economic viability of technologies</i>	rubens.miranda@embrapa.br

Financial Support





Contact: rafael.parrella@embrapa.br

