Using soy molasses for energy production

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Sojaprotein (Bečej, Serbia), operating within the company Victoria Group (Beograd, Serbia), is a plant for processing soy protein concentrates that bases its production on domestically-produced soybean. Sojaprotein is located in the heart of Serbia's soy bean growing area, the northern part of Serbia, Vojvodina, in the Pannonian Plain. An annual capacity of the Sojaprotein is 70,000 t of non-genetically modified (NON-GMO) products (traditional soy protein concentrates), intended for human food and feed, and wildly used in the food processing industry for different meat, confectionary and pasta products, in catering industry and in dietary and pharmaceutical products. The annual processing capacity of Sojaprotein is 250,000 tons of soybean, which is about 66% of the total yield of soybean in Serbia (an average yield is 380,000 tons). Soy molasses is a by-product from the process. The plant processes 70 - 80 tons of molasses a day, and runs in continuous operation. Soy molasses can be converted into useful energy (heat or electricity) or energy carriers (gas) by both thermochemical and biochemical conversion technologies. Biochemical conversion technologies include fermentation for alcohol production and anaerobic digestion for production of methane-enriched gas [1]. Unlike beet molasses, which is the most utilized sucrose -containing feedstock for ethanol production, and/or which is processed to obtained additional quantities of sugar, in Serbia, soy molasses has only been only used as feed ingredient in mixed feedstuffs, added to soy hulls and soybean meal, and in liquid feed diets.
Before 2008., large quantities of natural gas had been used to generate process steam (2×12 t/h capacity, 12 bar pressure) in two gas boilers (Minel, Serbia), when a biomass boiler (Kirka, Serbia), burning soy straw and other agricultural residues in a moving grate furnace, was introduced into the system to produce 15 t/h of steam at 15 bar pressure and annual savings of up to about 1 million euros. In 2012, Sojaprotein started to use soy molasses incineration method to produce product steam and this measure had a positive effect on the budget. In years before 2012., when the factory started to use it thermally, due to a low market demand for soy molasses in Serbia, soy molasses threatened to be a significant environmental problem when being disposed of as liquid manure on agricultural fields.

Soy molasses properties

Soy molasses is a dark-brown, thick (viscous), syrupy (dense) liquid. Viscosity of molasses depends on sucrose content, but it is generally very high, from 15 to 40 cSt at 100°C, and it is frequently a problematic issue. Bulk density of soy molasses at 60°C is from 1200 to 1300 kg/m^3, and energy value is up to 10 MJ/kg (low heat value). With a dry matter content of about 55±10% (a high-water content of 45±10%), a carbohydrates content (dry basis) of about 45.0 %, a protein (N x 6,25) content (dry basis) of max. 12%, a fat content (dry basis) of max. 3% (max.), comprising about 60% of organic components, soy molasses is usually a significant environmental problem when being

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disposed of as liquid manure on agricultural fields [2, 3]. Properties of soy molasses as a biofuel are given in *Table 1*.

Table 1 Properties of soy molasses

Emission values [3]		NOx: < 300 mg/m^3 CO: < 100 mg/m^3
Lower heating values (LHV) (calculated)		8 MJ/kg
Dry matter	DIN EN 12880	55.4 %
Water	DIN EN 12880	44.6 %
Ash (815°C)	DIN 51719	7.7 %
Density at 60°C		1230 kg/m^3
Viscosity at 60°C DIN 61366		78.5 cSt
Elementary analysis of dry matter:		
C	DIN 51732 mod.	45.3
H	DIN 51732 mod.	6.3
N	DIN 51444 Chemolum.	2.07
S	DIN 51732 mod.	0.37
O	Calculated	38.1
Thermal ash behavior DIN 51730, extern		
SOT beginning of softening		1370°C
HT hemispheric point		1460°C
FT flowing point		1490°C
Calorific value of dry matter		
Lower heating values (LHV) Calculated (F=0.94)		16.5 MJ/kg
Gross calorific value of dry matter DIN 51900		17.6 MJ/kg

Soy molasses industrial combustion process

Soy molasses is co-fired with natural gas in a rotating flame burner of type SSB-GL 100 (Saacke, Germany) with a maximum output 20 MW [4]. The combustion air enters it tangentially before mixing with soy molasses and recirculated air. The combustion air – divided into two streams – with the secondary air being swirled, creates an extremely short, stable flame with internal recirculation. This burner is suitable for sub- and hyper-stoichiometric combustion with a lambda of 0.3 – 4, providing low-emission combustion of a wide variety of special fuels with low heat values [4]. Process steam (29 t/h, 12 bar pressure) is produced in a Vyncke (Belgium) boiler. Schematic diagram of the combustion system in shown in *Fig. 1.* The combustion system includes a large-volume water boiler, economizer, an exhaust gas filter system, fully automatic control system, automatic purging system, ash blow cleaners, valve and pump stations. Photographs of some parts of the combustion system are given in *Fig. 2.*
Soy molasses enters the burner at 80°C temperature and 10 bar pressure. Mass flow rate of molasses can be varied from 0 to 6.3 t/h. Natural gas serves as starting and supporting

fuel. Its share was minimized and accounts for less than 30% of the total amount of fuel. Maximum combustion air amount (at 25°C) is 20,000 m^3/h.

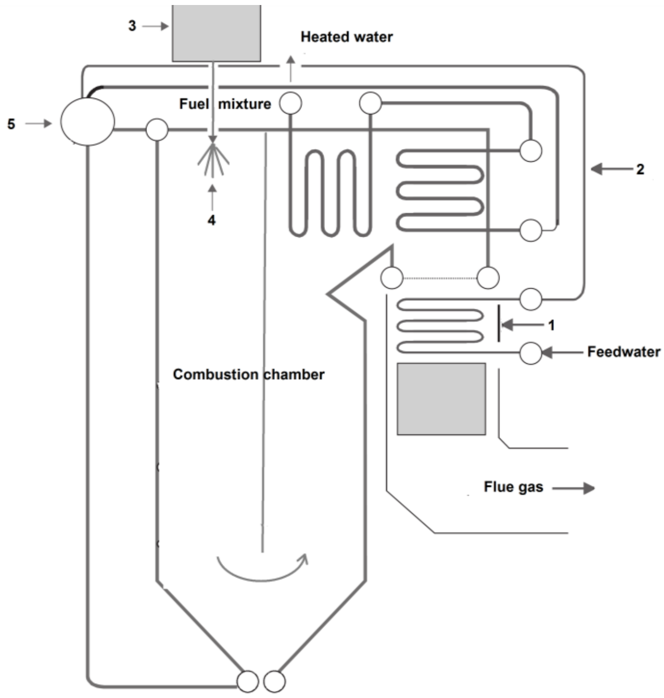

Fig. 1 Schematic diagram of industrial soy molasses combustion process. 1. Economizer; 2. Boiler drum; 3. Molasses and natural gas mixing; 4. Spray nozzle;5. Ash blow cleaner.

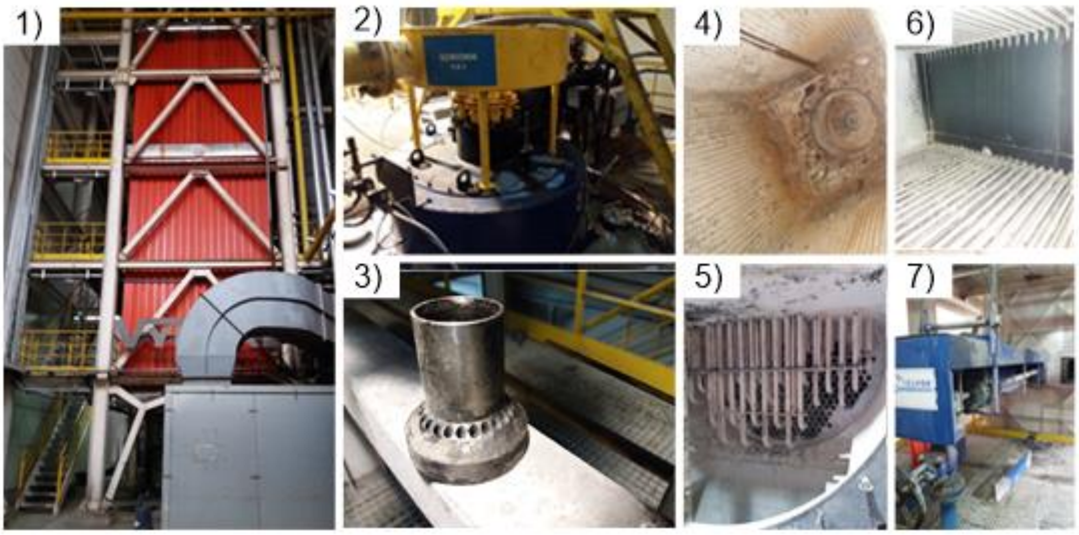

Fig. 2 Photographs of soy molasses industrial furnace. 1) Vyncke biomass boiler; 2) Saacke burner; 3) Spray nozzle; 4). The top of the combustion chamber (burner); 5) Boiler drum (Steam drum); 6) Economizer; 7) Ash blow cleaner.

When only natural gas is burned, at a flow of about 2,000 m^3/h, the boiler works at 99% capacity, and temperatures are: in the combustion chamber 1020 and 1030°C; in the economizer 240°C and temperature of flue gas before the filter is 165°C. Oxygen excess is 5.3 vol. %. When a mass flow rate of soy molasses is 4.5 t/h, and a flow rate of natural gas is 740 m^3/h the boiler works at 70% capacity, and temperatures are: in the combustion chamber 860 and 870°C; in the economizer 300°C and temperature of flue gas before the filter is 210°C. Oxygen excess is 4.8 vol. %. Emission of CO_2, NO_X, SO_2, and solids from combustion plant when natural gas accounts for 30% of the total amount of fuel are shown in *Table 2*.

Table 2. Emission of CO, NO_X, SO_2, and solids from combustion plant for molasses and natural gas (70:30). Measured and calculated values for flue gasses.

	Units	Run 1	Run 2	Run 3	Limit of detection	Emision limits	
Temperature	°C	132.38	137.27	145.14	-		SPRS ISO 9096
Mean velocity	m/s	13.07	13.98	14.29			SPRS ISO 9096
Dry flue gas flow	Nm^3/h	36581.60	37831.59	36887.0			SPRS ISO 9096
Solid content in the flue gas	mg/Nm^3	45.26 ±3.9	28.46 ±24	34.86 ±3.0		50	SPRS ISO 9096
Mass flow of solids	g/h	1655.69	1076.64	1285.73			
CO	mg/Nm^3	<1.16	<1.16	<1.16	1.16	300	SRPS EN 15058
NOx (as NO_2)	mg/Nm^3	418.5 ±8.4	412.6 ±8.3	416.8 ±8.3	2.05	650	SRPS EN 14792
Mass flow NOx (as NO_2)	g/h	15309.40	15609.31	15374.50			SRPS EN 14792
SO_2	mg/Nm^3	<2.62	<2.62	<2.62	2.62	1700	SRPS 1507935
O_2	vol%	10.46	10.70	10.62	0.1		SRPS EN 14789
CO_2	vol%	7.12	7.68	7.75	0.1		SRPS EN 12039

According to the oxygen content in the flue gas it can be calculated a lambda of about 2. The maximum measured value of solid content in the flue gas is 41.4 mg/Nm^3, and the maximum measured value of nitrogen oxides expressed as NO_2 is 410.1 mg/Nm^3. To the optimal mixing of combustion air and gas, NO_X emissions from molasses burning facility should be below 100 mg/m³, according to the burner producer. Although the measured values are lower than emissions limits in Serbia (50 and 650, respectively), they are still higher than values which can be obtained at the optimal mixing of combustion air and gas, meaning that there is still a place for process optimization.

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