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Characterization of Soybean Cultivars for Biodiesel Production

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***Abstract*— *Due to environmental issues involving the polluting gasesemission, Brazil has adopted the policy of using oil and biodiesel. For biodiesel production, the main raw material used in Brazil is soybean oil. The development of the numerous genotypes of this culture has always considered quantitative aspects. The objective was to qualitatively characterize 12 soybean cultivars for biodiesel production. The experimental design was randomized blocks with three replicates. The cultivars were sown in December 2016, in no-tillage system, in Ponta Grossa, Paraná, Brazil (-25.093056, -50.063327 UTM). The analyzed variables were: oil and protein contents, acidity index and specific mass. It was concluded that there were no significant differences among the cultivars for oil and protein contents. For the variables acidity index and specific mass, there were significant differences among the cultivars, being below the limits established by the Brazilian legislation for vegetable oil, but with potential for biodiesel production.*
Keywords*— *acidity index, Glycinemax,oil content, protein content,specific mass.

I. INTRODUCTION

In the global energy context, there is a growing discussion on alternative and renewable sources to traditional sources. The need to change the energy matrix aims to reduce the environmental impacts caused by the use of fossil fuels, especially in the greenhouse gasesemission (Rathore et al., 2016).

The term biofuel refers to liquid, gaseous and solid fuels produced predominantly from biomass. They can replace, partially or totally, fuels derived from oil and natural gas in combustion engines or other types of energy generation. Biofuels include energy security reasons, environmental concerns, foreign exchange savings, and socioeconomic issues related to the rural sector (Demirbas, 2008).

It is easy to predict that in the coming years biofuel will play an increasingly important role in the transport sector. The European Commission has set the proportion of biofuels in total transport fuel to 10% by 2020. In Brazil biodiesel might replace- in part or totally - the mineral diesel for light vehicles, trucks, tractors and generators; with the obligatory mixture expected to reach 10% of the fuel by 2019. The most common way to produce biofuel is through the vegetable oilstransesterification (Righi et al., 2016; Souza et al., 2016).

Soybean crop contributes with about 25% of the world production of vegetable oil. It can be used in the human feeding, textile industry, manufacture of paints, cosmetics and biofuels (Rosa et al., 2014).

In the 16,472 accessions of the “EmbrapaSoja” (Brazilian Agricultural Research Corporation) germplasm bank, the oil content in the dry soybean grains ranges from 8 to 25% and the protein varies from 32 to 58%, with respective means of 18 and 44% (Pípolo et al., 2015).

Analyzing the grains chemical composition of nine soybean cultivars, Sbardelotto & Leandro (2008) found average oil values of 11%. The protein, on average, was 38%. Such differences in the chemical composition of the soybean cultivars interferes with the financial return of the processing industry.

Determining the characteristics of 21 soybean cultivars for the biofuelproduction at different sowing times, Barbosa et al. (2011) concluded that there were significant differences for the oil content among the

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cultivars. Values ranged from 18.5 to 21.1%.

According to Administrative Rule Nº 795 (December 15th, 1993), it is considered degummed oil the one that the phospholipids were extracted. The rule establishes as limit of acid value a maximum of 1.0 mg KOH g^{-1} for oil type 1, up to 2.0 mg KOH g^{-1} for type 2 and the limit of 3.0 mg KOH g^{-1} for type 3; according to ordinance nº 795, MAPA/Brazil.

Evaluating chemical characteristics of 365 soybeans samples of different cultivars produced in three Brazilian states, Costa et al. (2001) stated that there were significant differences. The oil content varied from 18.6 to 19.8%, the protein was between 40.4 and 41.7% and the acidity index was 0.64 to 0.88 mg KOH g^{-1}.

Regarding the specific mass, the Brazilian standardization recommends that the value for soybean oil must be between 919 and 925 kg m^{-3}, at a temperature of 20 °C; according to normative instruction nº49, MAPA/Brazil.

Studying the thermal stability and thermomechanical behavior of the functionalized nanocomposite of epoxy/organo-clay modified with soybean oil, Sahoo et al. (2015) defined the oil density at 920 kg m^{-3}.

Working on the physical-chemical and dielectric characterization of biodegradable oils, Silva et al. (2011) concluded that soybean oil had the acidity index of 0.2 mg KOH g^{-1} and the density of 924 kg m^{-3}.

Aiming to transpose the limited qualitative analysis of the components of soybean oil production, the objective was to qualitatively characterize grains of 12 cultivars for biodiesel production.

II. MATERIALS AND METHODS

The experiment was carried out in field conditions, in Ponta Grossa city (PR, Brazil), crop 16/17, under geographic coordinates -25.093056, -50.063327 UTM, at 990 m of altitude, in no-tillage system. The climatological classification according to Köppen is Cfb (Garcia et al., 2000). The soil of the area had a medium texture, according to Table 1, and the routine chemical analysis shown in Table 2. The soil was classified as Cambisol Dystrophic.

The experimental design was in randomized blocks with twelve treatments and three replicates. The treatments consisted of 12 soybean cultivars. Each experimental unit (parcel) has an area of 15 m².

The 12 soybean cultivars used were: 96Y90®, Brasmax Garra IPRO®, BRS 1001 IPRO®, BRS 1003 IPRO®, BS 2606 IPRO®, FTR 2155 RR®, M5705 IPRO®, M6410 IPRO®, NS 5959 IPRO®, NS 6906 IPRO®, TMG 7062 IPRO® and TMG 7262 RR®. They were chosen because they excel in cultivation in the “Campos Gerais” region (PR).

Sowing was carried out on December 9th 2016 with 350,000 ha^{-1} seeds. The climatic conditions favored the culture development. The harvest was performed with an automated harvester of WINTERSTEIGER® experiments on April 27th 2017.

The analyzed variables were: oil and protein contents, acidity index and specific mass. For all the analyzed variables triplicates were made to increase the data reliability.

Thegrains oil content was determined based on the method presented by IAL (2005). The soybean grain samples were ground in a Marconi® mill, model MA 630/1. For the oil extraction, the mass was measured between 5.0 and 8.0 grams per repetition. The extraction was carried out through the Soxhlet® assembly, using hexane as solvent in a continuous process. The duration of the extraction was 360 uninterrupted minutes, under heating temperature of 80 ºC. Values have been converted to percentages.

The protein determination in percentage was based on the calculation of total nitrogen content. The semi-micro-Kjeldahl digestion method, consisting of sulfur digestion, the samples distillation and titration was used (Lima Filho &Malavolta, 1997).

The acidity index was defined based on the volumetric-titrametric method presented by IAL (2005). Such method determines the values of the acidity index in mg KOH g^{-1} of oil.

The specific mass was calculated in kg $m\text{-}^{3}$, using a DMA 4500M digital densimeter of Anton Paar® brand. The analysis was performed at a temperature of 20 °C, following the ASTM D5002 standard.

The data were subjected to Hartley test to verify the homoscedasticity of the variances and the Shapiro-Wilk test to examine the data normality. The measured variables were subjected to the Fisher-Snedecor and Scott-Knott tests, with a confidence level higher than 95% of probability.

III. RESULTS AND DISCUSSION

The Hartley test pointed to the homosedasticity of the variances and the Shapiro-Wilk test confirmed the data normality, for all the studied variables. There was no difference for blocks for all the analyzed variables, demonstrating the homogeneous conditions in which the soybean cultivars were developed.

When analyzing the oil content, the mean content was 17%. Even with cultivars with different characteristics, there was no significant difference in the analysis of variance among the treatments (Table 3).

The values are lower than the average of 19.2% of oil content in the soybean grains presented by Costa et al. (2001), 18.0% presented by Pípolo et al. (2015) and the 18.5% tabulated by Barbosa et al. (2011). However, they

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are higher than the average of 11% determined by Sbardelotto & Leandro (2008) when analyzing the grain chemical composition of nine soybean cultivars.

The results of this experiment contradict Costa et al. (2001) and Barbosa et al. (2011) who, when studying the behavior of several soybean cultivars in order toproduce biofuels, concluded that there were significant differences in the oil content among the samples. The similar and lower data, obtained in this work, can be attributed to the low soil fertility where the soybean was cultivated (Tables 1 and 2).

In the same way as the oil content, the protein content did not differ among the cultivars, with a confidence level higher than 95% of probability. The average result was 49%.

The mean obtained protein content is higher than the 44% determined by Pípolo et al. (2015), 38% measured by Sbardelotto & Leandro (2008) and the 41% calculated by Costa et al. (2001).

The differences among the results of the reviewed papers and from this experiment can be attributed to genotypic and phenotypic issues, evidencing the importance of evaluating the qualitative characteristics of soybean grains in order to analyze the impact on the financial return in the processing industry.

The data collected on the acidity index highlighted the highest value of the NS 5959 IPRO® cultivar with 15.7 mg KOH g^{-1}. Second, M6410 IPRO® (11.7 mg KOH g^{-1}) and BRS 1001 IPRO® (11.0 mg KOH g^{-1}) followed by Brasmax Garra IPRO® (7.0 mg KOH g^{-1}). Values dropped to 4.7 (FTR 2155 RR®) and 4.0 mg KOH g^{-1} (96Y90®). The other cultivars did not differ significantly from each other, with an average of 2.2 mg KOH g^{-1}.

Based on the Administrative rule Nº. 795 (December 15th 1993), none of the cultivars could be classified as degummed oil of type 1. Only three cultivars would be at the limit of type 2 and two cultivars below 3.0 mg KOH g^{-1} for type 3; according to ordinance nº 795, MAPA/Brazil.

The data obtained in the experiment also overcame those presented by Costa et al. (2001), which were 0.64 to 0.88 mg KOH g^{-1} and the 0.2 mg KOH g^{-1} acidity index indicated by Silva et al. (2011).

Thus, degummed oils from the cultivars could be used for biodiesel production, provided that there was basic catalyst consumption in the transesterification reaction, as stated by Righi et al. (2016) and Souza et al. (2016).

The specific mass of the cultivars was 96Y90®, Brasmax Garra IPRO®, BRS 1001 IPRO®, BRS 1003 IPRO®, FTR 2155 RR®, M5705 IPRO®, M6410 IPRO®, NS 5959 IPRO®, NS 6906 IPRO® and TMG 7262 RR®; with an average of 919 kg m^{-3}. The lowest values were presented by cultivars BS 2606 IPRO® and TMG 7062 IPRO®, with an average of 916.

The highest results were at the lower limit of Brazilian standardization, which recommends the specific mass variation between 919 and 925 kg m^{-3}; according to normative instruction nº 49, MAPA/Brazil. Likewise, they did not reach the 920 kg m^{-3} reached by Sahoo et al (2015) nor the 924 kg m^{-3} presented by Silva et al. (2011).

IV. CONCLUSIONS

There were no significant differences among the cultivars for oil and protein contents, with mean values of 17 and 49%, respectively.

For the variables acidity index and specific mass there were significant differences among the cultivars, falling below the limits established by the Brazilian legislation for vegetable oil, but with potential for biodiesel production.

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Table.1: Sand, silt and clay contents of the soil where the experiment was carried out. Ponta Grossa (PR, Brazil)

Sand ($g\ kg^{-1}$)	Silt ($g\ kg^{-1}$)	Clay ($g\ kg^{-1}$)
615	85	300

Table 2: Soil chemical analysis of the field trial area, Ponta Grossa (PR, Brazil), in the harvest season 2016/2017[1]

pH	C	Al^{3+}	Ca^{2+}	Mg^{2+}	K^+	H+Al	CEC	V	P
$CaCl_2$	$g\ dm^{-3}$	..............................cmolc	dm^{-3}	....				%	$mg\ dm^{-3}$
4.3	25.0	1.7	1.7	0.4	0.3	9.0	12.1	26.4	49.8

1 – C organic = Walkley-Black; H + Al = buffer solution SMP; Al, Ca, Mg exchangeables = KCl 1 mol L^{-1}; P and K = Melich 1 and effective CEC

Table.3: Oil and protein contents, acidity index and specific mass (20 °C) of soybean cultivars [Glycine max (L.) Merril] in the harvest season 2016/2017, Ponta Grossa (PR, Brazil)[1]

Cultivars	Oilcontent(%)	Proteincontent (%)	Acidity index (mg KOH g^{-1})	Specificmass (kg m^{-3})
96Y90®	16 a[2]	51 a	4.0 d	919 a
Brasmax Garra IPRO®	16 a	45 a	7.0 c	921 a
BRS 1001 IPRO®	17 a	48 a	11.0 b	920 a
BRS 1003 IPRO®	18 a	51 a	2.5 e	920 a
BS 2606 IPRO®	18 a	49 a	1.6 e	917 b
FTR 2155 RR®	16 a	49 a	4.7 d	920 a
M5705 IPRO®	17 a	51 a	3.2 e	918 a
M6410 IPRO®	18 a	49 a	11.7 b	921 a
NS 5959 IPRO®	18 a	50 a	15.7 a	919 a
NS 6906 IPRO®	17 a	49 a	1.8 e	919 a
TMG 7062 IPRO®	17 a	49 a	1.8 e	915 b
TMG 7262 RR®	17 a	47 a	2.6 e	919 a
Coefficientofvariation (%)	5.1	7.3	24.3	0.1

1 - Not significant for blocks by the Fisher-Snedecor test, for all the analyzed variables ($p > 0,05$).

2 - Means followed by the same letter in the column do not differ by the Scott-Knott test ($p > 0,05$).