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COMPARISON OF DIFFERENT ARTISAN METHODS TO OBTAINING BIODIESEL

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Abstract: In this study, two home-made methods to obtain biodiesel were compared, considering seven kinds of oil. Also, in one of the biodiesel, three washing methods were compared. The two criteria to obtain the methyl ester were: traditional, with the sodium methoxid reaction in one step and; by applying sodium methoxid in two-stages (3/4 and 1/4 respectively). The washing methods were the traditional, with three steps of low volume water and gentle shaking, and "Idaho University Method", where a water and vinegar mix goes through the biodiesel by an air bubble system. Also, a third method was used with only water. The cinematic and dynamic viscosity, density, pH, acidity index and free acidity were measured.

The two-phase method showed lower viscosity values in four of seven biodiesel, in relation with traditional method, and the first one is not recommended for soybean-sunflower and maize oils. Considering the other quality parameters, there are no conclusive differences between methodologies, the traditional method being recommended for its simplicity, and because it is faster and low energy consumer than the two phase method. The soybean-sunflower biodiesel obtained by two-phase method presented lower pH value than the traditional method; nevertheless, both methods have pH higher than 9.0, so it is necessary to wash them. The "Idaho University method" to wash the biodiesel promotes the excessive diminishing of pH (close to 6.0) so the traditional method, is recommended which allows carrying out the standard of diesel.

Keywords: Biodiesel, oil, methyl ester, Idaho University Method.

INTRODUCTION

The production of biodiesel within an industrialized concept is well defined, there exist on the market equipment for different levels of production. On the other hand, it could be interesting that small producers prepare they themselves their fuels, in an artisan way. It is because of this that the Web offers a lot of information within the criterion "make it your self", with the traditional methods, and alternative methods to compensate certain difficulties or deficiencies that are present in producing on a small scale and without suitable technology. Within this criterion "make it yourself", there appear two trends, one of them with the normal methodology (with some variations between different authors), where one makes the oil react with a mixture of methanol and hydroxide of sodium just once; the other form consists of the

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system called for two-stages [1], where to the oil one adds three quarters of the sodium methoxid in the first stage and then one adds the mixture with the rest of the corresponding sodium methoxid (1/4). In both methods it is necessary to realize a wash of the biodiesel.

In the wash there are also different postures, being two systems of interest. The most used form is by means of agitation, which consists in adding 10 % of water to the volume of biodiesel and shaking, but the risk is run of emulsification; to avoid this problem, agitation must be very soft, which constitutes a very delicate practice and might generate some type of complications on doing it in artisan form. In contraposition to this, there is the other method that is on the basis of aeration, which in the web is named "Method of bubble wash of the University of Idaho" [1].

For this reason the present research intends to compare 2 artisan methods of producing biodiesel from 7 diverse sources of oil, to evaluate the quality of biodiesel and, in addition, to compare 3 methods to wash biodiesel in an artisan form.

MATERIALS AND METHODS

Material

The present study was developed in the Laboratory of Agricultural Mechanization, belonging to the Engineering and Soils department of the Faculty of Agronomic Sciences of the University of Chile, located in the Campus Antumapu, commune The Pintana, Santiago, Chile.

For the tests to obtain biodiesel, commercial new oils were used: olive, pip of grape, maize, sunflower, soybean, an olive – sunflower mix and an oil denominated “vegetable”, made up of a mixture of vegetable oils (soybean and sunflower in undetermined percentages). With this last “vegetable” oil, new and waste oils, coming from the casino of the University Campus, combined every week, were utilised. Also, with this “vegetable” oil the washing test were realized.

The chemical compounds for the transesterification were methanol, acquired from laboratories of chemical products, and hydroxide of sodium, acquired in a supermarket.

The agitation of the sodium methoxid was realized in a magnetic agitator HEIDOLEH (1250 rpm), whereas those of oil to be transesterificated (250 mL) were done in flasks of 500mL, with a mechanical agitator (reel) GRIFFIN*GEORGE, on a BARNSTEAD THERMOLYNE heating plate.

The temperature control was by means of a digital thermometer (JUMO). To preheat the samples an oven to 70ºC was used.

Method

Obtaining biodiesel

Two methods were used for obtaining biodiesel in each of 7 types of oil (table 1), which gave a total of 14 types of biodiesel to compare between themselves, with the original oil (without transesterification) and with diesel. Both the methods to compare are the traditional and by two-stages, each of them with 4 repetitions.

In both methods, to carry out the transesterification, 250 mL of oil were warmed up to a temperature determined by the type of oil. For new oils the temperature was 39ºC and for waste oil it was of 52ºC. The temperature was kept during the whole process. In the traditional method, the sodium methoxid was made by means of agitation, during 10 minutes, of methanol (200 mL L^{-1} of oil) and sodium hydroxide (3.5 gL^{-1} of oil for new oils and 6.25 gL^{-1} of oil for waste oils). Then the sodium methoxid was added to the warm oil, shaking vigorously and uninterrupted during an hour. After the agitation it was left to rest for 12 hours, which allowed the decantation of the glycerines, and the methyl ester was separated from these by means of a decanter (figure 1).

In the production by two-stages, the procedure was basically the same, with the difference that it was done in two stages. In the first only 75 % of sodium methoxid was applied and later, with the fuel obtained, the second stage, which uses 25 % of the remaining sodium methoxid.

The variables evaluated were cinematic and dynamic viscosities according to NCh1950 [2], density according to NCh822 [3], pH, index of acidity and free acidity (expressed as percentage of oleic acid). The viscosities were obtained determining the apparent viscosity by means of a viscosimeter Ostwald. The density was measured by means of the use of a picnometer.

The pH was measured by a manual pHmeter calibrated with a buffer (pH 7.0 and pH 10.0) solution.

To determine the index of acidity and the free acidity or degree of acidity, the dissolution of the sample was realized in a mixture of solvents and valuation of the free fatty acids by means of an ethanol solution of hydroxide of potassium, using phenolphthalein as indicator. The reactives used were: mixture of ethylic alcohol-ether ethylic 1:1 neutralized, ethanolic solution of KOH 0.1 N and alcoholic phenolphthalein to 1%. The properties of the elaborated

biodiesel compared with the properties of the diesel oil and with oils without transesterification.

Biodiesel washing

For the washing test, 30 L were prepared of biodiesel with new soybean-sunflower oil. The acidity measured before the test and after each wash, using 3 repetitions, every wash was realized by 3 liters of methyl ester (biodiesel)**.**

The washing were the traditional method and the "Method of washing bubble of the University of Idaho" in two different version. In the traditional method, 10 % of water is applied on the basis of the biodiesel volume, and then agitated at low speed during 4 minutes. Later, left to decant during the night. The following day the water is extracted by means of suction. This process is realized three times to assure a good wash. To extract the remaining water, the biodiesel is warned slowly to 100 ºC, keeping this temperature until it is evident no bubbles are formed, which indicates the absence of water.

In the bubble method [1], the bubbles are formed making compressed air pass across a diffuser, for which in this case a small air pump and a bubble stone from an aquarium were used. A mixture of water with vinegar and biodiesel in equal volume is put in the washing tank; the vinegar is used to neutralize the pH of the biodiesel. The pH of the water solution with vinegar must be so many points under pH 7 as points over pH 7 that the biodiesel has; in this test a solution of pH 4.1 was used for a biodiesel with pH 9.9.

The water with vinegar solution has a higher density than the biodiesel, so stays at the bottom of the washing tank, where the bubble stone is located. The air bubbles rise first crossing the water and then the biodiesel. Every bubble remains covered by a thin firm of water and raises it across the biodiesel, washing it on the way. When the bubble comes to the surface it explodes and leaves a small drop of water that returns to the bottom, crossing again the biodiesel and washing it again. This process lasts 6 hours, so that one wash is sufficient. For the present research, also a wash of bubbles was tested using only water, without the application of vinegar.

The variables evaluated were: pH, index of acidity and free acidity, which was titrate by hydroxide of sodium and phenolphthalein as tint, measured before and after every wash.

Statistics

For the comparison of the evaluated properties an analysis of variance (ANDEVA) was made; where significant differences are found, the test of Duncan's multiple comparisons ($p \leq 0.05$) is applied.

RESULTS AND DISCUSSION

The initial properties of the oils are presents al table 1, with relevant information for its evaluation as possible raw material in the production of biodiesel. Included are some characteristics of the diesel used in the central area of Chile.

The density, though it is only 9 to 11 % more in the oils with regard to the diesel, becomes of high viscosity, being this, the principal limitation to the use of the oils in internal combustion engines. The mixtures of the oil with elements that help in its dissolution (petrol and ethanol, or paraffin) are not so effective as the transesterification, resulting in viscosities between 30 to 50 % more in respect to the viscosity of the oil, against 13 % for the transesterificated oil [4].

The oil mixes of soy bean and sunflower are the ones that possess the closest pH to neutral, even after using; nevertheless, in the process of transesterification an important increase of pH is expected. All the oils possess levels of acidity not recommended for biodiesel as a product, so that to obtain it, it is priority to neutralize such acidity. Emphasize the levels of acidity of the oil that has been used, more than 10 times higher that the new sources, with the exception of the samples that possess olive oil in its composition, which acidity is also high, though far from the levels of the waste oil.

As for the method of production by two-stages seeks to maximize the use of the catalyst, applying 3/4 of the quantity of caustic soda needed in the first stage, and repeating the process of agitation with the remnant. The idea is that when reactants and products reach equilibrium, the reaction stops, for that reason, retract the undesired product (glycerine), right direction again, pushing the reaction towards the product [1]. The method is longer and consumes more energy, so it was expected that the parameters of evaluation of the quality of the biodiesel would be better that in the traditional method, nevertheless this did not happen.

Viscosity and density (table 2) are indexes sensitive to the methodology of producing biodiesel, though together they do not mark a clear trend. Seeking the lower density, the method by two-stages would be advisable for soy bean - sunflower oil and olive oil, whereas the traditional method would be advisable to try the maize oil. Nevertheless, analyzing viscosity, the method by two-stages is not recommended for soy bean – sunflower oil, in any of its forms (new or waste) and not for maize oil, but yes for the rest of oils. Indistinctly of this, all parameters descend to values similar to those of diesel, and possess values comparable to biodiesel obtained by other sources, as is *Brassica carinata*, for which a range

of density from 0.86 to 0.89 g cm^3 has been described and values of viscosity from 3.5 to 5.0 cSt [5].

The process of transesterification does not imply an appreciable decrease of density, biodiesel resulting in values higher than 95 % in respect to the original oil. The principal change, that gives it the high potential of use to the product as source of energy for internal combustion engines, is the viscosity. These changes in a range, in respect to the original value, from 8.3%, with waste oil and traditional method, to 14% with maize and by two-stages method.

Although, before producing biodiesel, the waste oil, and both sources with olive oil, possessed values of acidity higher than the rest of the oils (table 1), once the process of transesterification was realised, the differences tended to disappear (table 3). As indicated previously, a considerable increase of the pH exists due to the generation of glycerol as secondary product and for the remnants of sodium hydroxide and methanol that do not take part in the reaction [6]. Except in the pH of new soy bean - sunflower oil, no statistical significant differences exist on comparing both methods of producing biodiesel. The objective of the by two-stages method is to maximize the reaction of the sodium hydroxide, in such a way as to favour an easier and efficient wash to diminish the pH. On having a statistically lower pH than the traditional method, but still over a value of 9.0, the by two-stages method is not justified as alternative of producing biodiesel, since it does not present comparative relevant advantages with regard to the traditional method. Both methods are effective in reducing the initial acidity, which drops to values of between 0.37 and 7 % of the original values of the oils, so falling within the ranges required by the European regulation FAME prEN [7] that limits the acidity index (IA) to values of KOH less than to 0.5 mg g^{-1}. The major relative decreases of the IA corresponded to waste oil and to olive oil, resulting in values 0.37 % and 0.66 % of the original value of the oil without transesterification.

If properties sensitive to the method of obtaining biodiesel are considered, that is to say, pH, density and viscosity, and the sources of oils are analyzed as the only population, it is possible to obtain a general result that compares both methodologies of obtaining biodiesel, shown in table 4.

The two-stages method presents advantages only in the values of pH, which, though they turn out to be significantly less with regard to the traditional method, present a level still high before the wash, so that this minor advantage does not justify the use of the two-stages method, which consumes more time and resources, since it considers two times of agitation. Assuming that the separation of phases (figure 1) should be must more effective with large

volumes of biodiesel, it becomes necessary to study other aspects of production, such as: volumes of decantation, design of the decanter and process of phase separation, quantity of reagents and time of agitation. With regard to density and viscosity, on considering the oils in conjunction (table 4), they do not present significant differences between methods of obtaining biodiesel, so the possible efficiencies of one or another methodology, depend on the type of oil. As commented previously, biodiesel presents the disadvantage that, though it is left to decant, in the methyl ester there still are remains of methanol and of sodium hydroxide, so that the pH is very alkaline (higher than 9 (tables 3 and 4)), which might damage the engines. It is for this reason that the oil must be cleaned or washed to extract the remains of caustic soda and to take pH to neutral values. The process of wash is one that provokes most losses of biodiesel, done in artisan form, since, if not properly prepared, the excess of water or agitation in the wash, provokes its emulsion (Figure 2), with formation of soaps that cannot be separated for decantation.

In the method by bubbles realized with a solution of water and vinegar, the wash provokes an excessive decrease of pH, resulting in a significantly lower value with regard to the other two methods (table 5). As the method of bubbles considers a wash of 6 hours, it would be enough to diminish the time to obtain a pH closer to neutral. That is why a third wash was carried out, the same as the "Method of the University of Idaho", but without vinegar. Nevertheless, this strategy does not assure satisfactory results in the levels of acidity, where none of the bubbles methods produces changes with regard to its condition before the wash. The method of traditional wash, together with diminishing the pH to acceptable levels for the use of biodiesel in internal combustion engines, diminishes the acidity, resulting in significantly lower values with regard to the wash by bubbles. This result may be due to the fact that the process of neutralization of the pH depends exclusively on water, so that a condition of permanent agitation provokes a better mixture water-biodiesel. The method by bubbles does not necessarily generate a water interface between the air bubble and the biodiesel, and even if it did, the volume involved in cleaning is less than in a water bubble.

Another disadvantage of the bubbles method is that it disguises an incomplete reaction in transesterification, since it does not form emulsion, as happens in the traditional method.

If the bubbles method is used to wash the biodiesel, it must be used as promptly as possible, since it has very little stability of oxidation, so that it favours the polymerization of the unsaturated fatty acids.

Though the traditional method considers washing three times, less time of agitation is needed and uses less water than the bubbles method, so that, together with the advantage of generating a biodiesel of better quality, there are advantages of a practical nature. Nevertheless, as presents in Figure 3**,** it is necessary to analyze the additive effect of each one of the washes.

The traditional wash method is effective in reducing the pH of biodiesel, so much so one wash is enough to generate reductions of pH of 30 %, the contributions of the following washes not being significant. The reduction of pH of the biodiesel shows up in an increase of the pH of wash water, though in very much smaller magnitudes, resulting in non risky levels for the environment. Both parameters of acidity diminish, both for the wash water and for biodiesel, which also helps to minimize the environmental risks of emptying wash water in to the drainage system.

Though pH becomes stable with the first wash, the parameters of acidity continue changing with successive events, presenting decreases of approximately 30, 50 and 56 % with regard to the initial condition of the biodiesel, changes not apparent in the wash by the bubbles method. The figure 4, which presents the relative percentage with regard to the condition before the wash, reflects these changes better.

As already indicated, the pH achieves values adequate for use with the first wash. Further, the Index of Acidity (IA) presents reductions of 30, 20 and 7 % with washes 1, 2 and 3, accumulating a total reduction of 57 % with regard to the condition without washing. It is logical to think that a fourth wash, together with provoking a null change of the pH, will diminish the IA in a not significant magnitude less than 7 %, so that practically two washes would be necessary to obtain an ideal biodiesel for its use. It is interesting to study more thoroughly if the reduction of the IA of the second washes is justified in practical terms, in regard to the quality of the biodiesel, since if the central aim is the decrease of the pH, one only wash would be enough to obtain satisfactory results.

Finally, considering that the traditional method of obtaining biodiesel is most recommended, a comparison was realized of the relevant properties of biodiesel depending on the source of oil. The results appear in the table 6.

Though the parameters of dispersion change according to the source of oil (table 2 and 3), the waste oil is the one that presents the major standard diversion (DS) in the parameters selected in table 6. For such reason it was eliminated from the analysis, since its high variability in the results did not allow complying with the equality requirement of DS's demanded by the

ANDEVA. This situation is logical if thought is given to the variables that the oil could have (different times of use, temperature and food to be fried), so that a correct characterization of waste oils will need a larger number of samples.

As for new oils, the pH does not present statistical significant differences, with ranges of pH from 9.66 to 9.89, which allows the standardization with one only protocol of wash, without having variations in the methodologies depending on the source. This facilitates managing, since quantities of biodiesel from different sources of oil can be produced to generate later a common wash including mixing the different products. Though statistical significant differences exist for density, these are not relevant, since, as was observed in the table 1, the density of the original oils is not very much higher than that of diesel, and the process of transesterification results in decreases of density that in average are 5 % of the original density (table 3).

The relevant parameter is given by viscosity, which presents important decreases with regard to the properties of the oil (table 3). In this respect, among the oils studied olive-sunflower, pip of grape and maize, correspond to sources that result in minor viscosities, so they are more recommendable for the manufacture of biodiesel. Though they are all within the proposed regulation of biodiesel, the final decision for its use, logically, needs an economic analysis to evaluate the efficiency of obtaining oil, availability on the market, economic result for the farmer and alternative uses, among others.

It is of note that the major viscosities are presented by biodiesel obtained from olive and sunflower oils processed separately, but that on being mixed together, the lower viscosity is obtained; likewise, that biodiesel of olive oil presents the least density and the highest viscosity among the sources analyzed. These aspects open new ways of research in the production of biodiesel from vegetable oils.

CONCLUSIONS

On comparing both artisan methods for obtaining biodiesel, no conclusive differences between the methodologies exist.

The traditional method is recommended, where one only application of sodium methoxid is realized, compared to the method by two-stages, where transesterification is realized in two phases (with 3/4 and 1/4 of the sodium methoxid, respectively), since the traditional method is simpler and more rapid than the method by two-stages.

From an economic point of view the traditional method is more profitable, since the method by two-stages has a double expense of energy and time.

Though the method by two-stages presents a slight advantage in producing biodiesel (soy bean-sunflower) with less pH, which might shorten the time of wash, the levels of pH are over 9,0, so there is need to wash. In the rest of the properties analyzed no significant differences appear nor clear trends between methods of obtaining biodiesel.

On analysing the quality of biodiesel, the products obtained from oils of olive-sunflower, pip of grape and maize; present the lowers values of density and viscosity, so are recommend for use in internal combustion engines.

As for the wash of biodiesel, the bubbles method of the University of Idaho generates excessive decreases of the pH, particularly when, together with water, vinegar is applied. The method of traditional wash is simpler and more rapid, a pH being obtained within the standard of biodiesel and lower parameters of acidity than with the bubbles method.

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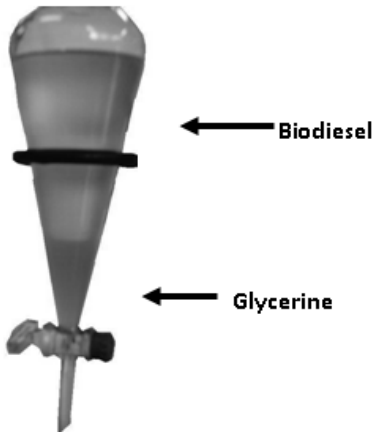

Figure 1. Biodiesel separation phases

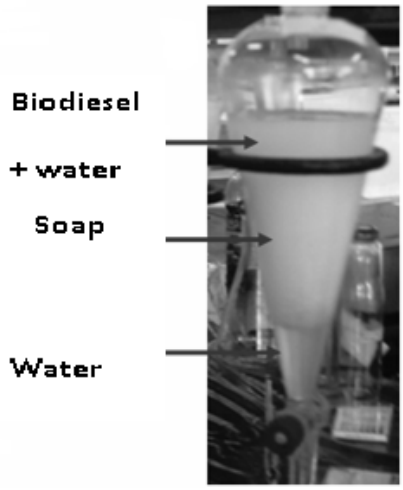

Figure 2. Biodiesel emulsified by excess of agitation in the washing

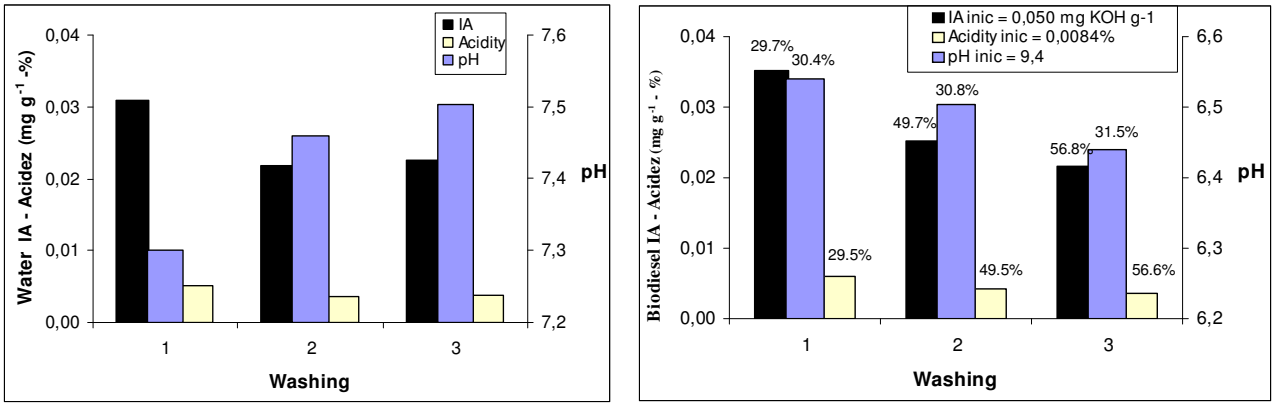

Figure 3. Variation in the time of the properties of the water and biodiesel with the successive washings. In the biodiesel are included the accumulated percentage of change with respect the initial value.

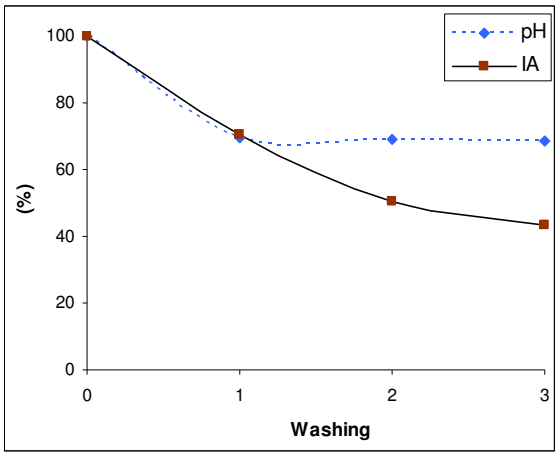

Figure 4. Percentage relative of the parameters of the biodiesel with respect the initial condition

Table 1. Main characteristics of selected oils and the diesel engine.

Oil	**Dynamic Viscosity (cP)**	**Cinematic Viscosity (cSt)**	**Density (g cm^{-3})**	**pH**	**IA (mg KOH g^{-1})**	**Acidity (%)**
Soybean-sunflower	24.54	26.95	0.9106	6.06	1.103	0.1860
Glape seed	26.61	28.93	0.9198	4.60	0.902	0.1523
Maize	26.82	29.25	0.9168	4.48	1.053	0.1772
Sunflower	25.48	27.75	0.9179	4.20	0.802	0.1349
Oliva	30.35	33.27	0.9123	3.89	4.661	0.7823
Olive-sunflower	27.72	30.19	0.9183	4.85	1.383	0.2333
Soybean-sunflower waste	32.33	34.95	0.9252	5.47	13.362	2.2456
Diesel*	2.53	3.02	0.8361			

*By D.S. Nº58 del 29 january 2004. [20]

Table 2. Densidad and viscosity of the biodiesel obtained from different oil sources.

Oil	Production method	Density (g cm^{-3})	Cinematic Viscosity (cSt)	Dynamic Viscosity (cP)
Soybean - sunflower	Traditional (4/4)	0.8842 (±0.0005) a	3.61 (±0.016) a	3.20 (±0.016) a
	Two-stages (3/4+1/4)	0.8824 (±0.0004) b	3.84 (±0.103) b	3.38 (±0.090) b
Glape seed	Traditional (4/4)	0,8807 (±0,0002) a	3,55 (±0,088) a	3,13 (±0,078) a
	Two-stages (3/4+1/4)	0,8810 (±0,0002) a	3,44 (±0,032) a	3,03 (±0,029) a
Maize	Traditional (4/4)	0,8807 (±0,0040) a	3,55 (±0,083) a	3,13 (±0,088) a
	Two-stages (3/4+1/4)	0,8871 (±0,0019) b	4,39 (±0,098) b	3,89 (±0,090) b
Sunflower	Traditional (4/4)	0,8817 (±0,0013) a	3,94 (±0,042) a	3,47 (±0,037) a
	Two-stages (3/4+1/4)	0,8799 (±0,0007) a	3,73 (±0,038) b	3,29 (±0,035) b
Olive	Traditional (4/4)	0,8763 (±0,0011) a	4,35 (±0,038) a	3,81 (±0,038) a
	Two-stages (3/4+1/4)	0,8713 (±0.0027) b	4.28 (±0.013) b	3.73 (±0.023) b
Olive - sunflower	Traditional (4/4)	0.8789 (±0.0005) a	3.47 (±0.048) a	3.05 (±0.043) a
	Two-stages (3/4+1/4)	0.8787 (±0.0003) a	3.31 (±0.053) b	2.91 (±0.048) b
Soy bean - sunflower waste	Traditional (4/4)	0.8804 (±0.0016) a	3.05 (±0.144) a	2.68 (±0.132) a
	Two-stages (3/4+1/4)	0.8816 (±0.0008) a	3.36 (±0.034) b	2.96 (±0.032) b
Diesel		0.8361	3.02	2.53

For the same oil. different letters in the columns denote statistical significant differences between methods of production (Duncan, $\alpha \leq 0.05$)

Table 3: Parameters of acidity of the biodiesel obtained from different oil sources.

Oil	Production method	pH	Index of Acidity (mg KOH g^{-1})	Acidity (%)
Soybean - sunflower	Traditional (4/4)	9.89 (±0.24) a	0.053 (±0.026) a	0.0089 (±0.0045)a
	Two-stages (3/4+1/4)	9.28 (±0.35) b	0.049 (±0.016) a	0.0082 (±0.0026)a
Glape seed	Traditional (4/4)	9,83 (±0,14) a	0,063 (±0,024) a	0,0106 (±0,0040)a
	Two-stages (3/4+1/4)	9,30 (±0,42) a	0,051 (±0,005) a	0,0086 (±0,0008)a
Maize	Traditional (4/4)	9,75 (±0,12) a	0,025 (±0,011) a	0,0042 (±0,0018)a
	Two-stages (3/4+1/4)	9,32 (±0,33) a	0,026 (±0,006) a	0,0044 (±0,0011)a
Sunflower	Traditional (4/4)	9,74 (±0,09) a	0,031 (±0,001) a	0,0052 (±0,0002)a
	Two-stages (3/4+1/4)	9,35 (±0,32) a	0,025 (±0,008) a	0,0042 (±0,0014)a
Olive	Traditional (4/4)	9,66 (±0,11) a	0.029 (±0.008) a	0.0049 (±0.0013)a
	Two-stages (3/4+1/4)	9.30 (±0.27) a	0.033 (±0.012) a	0.0055 (±0.0020)a
Olive - sunflower	Traditional (4/4)	9.67 (±0.08) a	0.031 (±0.004) a	0.0052 (±0.0007)a
	Two-stages (3/4+1/4)	9.34 (±0.37) a	0.033 (±0.006) a	0.0055 (±0.0011)a
Soybean - sunflower waste	Traditional (4/4)	9.64 (±0.23) a	0.043 (±0.015) a	0.0073 (±0.0026)a
	Two-stages (3/4+1/4)	9.46 (±0.34) a	0.057 (±0.011) a	0.0096 (±0.0019)a

For the same oil. different letters in the columns denote statistical significant differences between method of obtaining (Duncan, $\alpha \leq 0.05$)

Table 4. Properties of the biodiesel considering all the oil sources.

Method of obtaining	Density (g cm^{-3})	Cinematic Viscosity (cSt)	Dynamic Viscosity (cP)	pH
Traditional (4/4)	0.8804 (±0.0024) a	3.65 (±0.406) a	3.21 (±0.353) a	9.74 (±0.093) a
Two-stages (3/4+1/4)	0.8803 (±0.0048) a	3.76 (±0.436) a	3.31 (±0.383) a	9.34 (±0.060) b

Different letters in the columns denote statistical significant differences between methods of obtaining (Duncan, $\alpha \leq 0.05$)

Table 5: Comparison of methods of washing of the biodiesel obtained from the oil soybean-sunflower.

Wash	pH	Index of Acidity (mg KOH g^{-1})	Acidity (%)
Traditional	6.44 (±0.17) b	0.022 (±0.003) a	0.0037 (±0.0005) a
Bubbles (water + vinager)	6.04 (±0.17) a	0.052 (±0.008) b	0.0087 (±0.0013) b
Bubbles (water)	6.47 (±0.18) b	0.053 (±0.003) b	0.0090 (±0.0005) b
Biodiesel without washing	9,89 (±0,24)	0,053 (±0,026)	0,0089 (±0,0045)

Different letters in the columns denote statistical significant differences between methods of obtaining (Duncan, $\alpha \leq 0,05$)

Table 6. Comparison of quality by means of the parameters measured in the biodiesel, according to different oil sources, for the method of traditional obtaining.

Oil	Cinematic Viscosity (cSt)	Viscosity (cP)	Density (g cm^{-3})	pH
Olive-sunflower	3.47 a	3.05 a	0.8789 a b	9.67 a
Pip of grape	3.55 a b	3.13 a b	0.8807 b	9.83 a
Maize	3.55 a b	3.13 a b	0.8807 b	9.75 a
Soybean-sunflower	3.61 b	3.20 b	0.8842 c	9.89 a
Sunflower	3.94 c	3.47 c	0.8817 b c	9.74 a
Olive	4.35 d	3.81 d	0.8763 a	9.66 a
Soybean-sunflower waste *	3.05	2.68	0.8804	9.64

Different letters inside the column denote statistical significant differences between sources of oil (Duncan, $\alpha \leq 0.05$).

* The waste Soy bean-sunflower oil is not included in the analysis.