Investigation of possibilities for prediction of automobile bio-oils parameters by color image analysis

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Abstract: - Investigation of possibilities for predicting the physico-chemical parameters viscosity and density of automotive bio-oils using color image analysis is described in the paper. Data of bio oils is compared with those for standard engine oils. The results show that the oil density can be predicted with an accuracy of 85% and the viscosity at an accuracy of 57% with low error rates of 2-9% with R (RGB), G (RGB), V (HSV), L (Lab), L (LCH), and K (CMYK) color features. The results obtained can be used in the design of optical sensor devices operating in the visible area of the spectrum for rapid and non-destructive determination of physico-chemical parameters of automotive oils.

Key-Words: Image processing, Color features, Automotive oils, Partial least squares regression, Physico-chemical parameters, Classification

1 Introduction

The application of Bio-Lubricants is becoming more and more popular and begins to displace the conventional mineral products used. With the indisputable environmental qualities and benefits of bio-lubricants, these products are becoming more and more widely used and are the preferred segment in many industries [8, 13].

The use of bio-lubricants in the Forest-Industrial Complex, the Agriculture, the Railways, the vehicles in which there is a particularly high risk of pollution of the environment through the application of lubricants and the operation of lubricants through the direct contact of oils and greases in the soil.

The important characteristics of oils and bio-oils such as viscosity, density, combustion temperature are determined by technical tools and laboratory methods [9, 10].

Determination the parameters of motor oils in the laboratory requires specialized equipment, multiple operations in carrying out the analysis and experience of the technologist who performs it. The disadvantages of this method is that it requires preliminary procedures for the preparation of the measurement samples.

Organoleptic evaluation of oils such as color, odor, general appearance is done manually, through visual control, primarily based on the routine of the assessor.

Disadvantages are related to the high percentage of subjectivity in the assessment, the requirement for qualified human resources and the long processing time when multiple samples are available. The accuracy of the analysis is not high and depends on the expert's qualifications. Therefore, the creation of highly efficient automated technologies for analyzing organoleptic properties of oils is an important task.

Image analysis and image acquisition systems have been used in the rapid and non-destructive analysis of various food [2, 5, 7, 11] and industrial products [4]. The values of color components obtained from visual images can be used to analyze various industrial products [1, 6].

The purpose of this study is to provide a method for rapid and non-destructive evaluation of the physico-chemical properties of bio-oils using image analysis techniques to be used as an indicator for detecting deviations in product characteristics.

2 Material and methods

Five types of automobile oils are used, each of three samples – rapeseed, transmission, engine, sunflower and grapeseed (the rapeseed oil is used as a fuel), purchased commercially. From each sample, three measurements are made. Two parameters viscosity and density are measured. Measurements were made at room temperature 20°÷22° C and relative humidity 49 ÷ 51 RH %.

All data are processed at level of significance α=0,05.

In Figure 1, the automotive oils used, are presented in their general view. Visually rapeseed and transmission oils are hard to distinguish, but other three oils have difference in their appearance.

Rapeseed oil | Transmission oil | Engine oil | Sunflower oil | Grapeseed oil

Fig.1. Automotive bio-oils – general view

Table 1 shows the values of viscosity and density of automobile oils studied under the specified conditions. The descriptive statistics of these two parameters mean – arithmetic mean; SD – standard deviation; CV – coefficient of variation are presented too. High values of viscosity show rapeseed and transmission oils, but the density of these oils is lower than sunflower and grapeseed oils.

The color digital images of used oils are obtained with the DFK 41AU02 industrial video camera (The imaging source, inc) with 1/2 inch Sony CCD sensor (ICX205AK); 1,280×960 (1.2 MP), up to 15 fps, Sensitivity of 0.15 lx and 8 bit dynamic range. White LEDs with the highest intensity of light at 450 nm and color temperature 6500K (corresponding to average daylight with UV component) are used as lighting unit. The bio-oil images are obtained in a RGB color model, then converted to HSV, Lab, LCH, CMYK models [3]. The oils are represented by the following 16 color features: the following features are generated: R(RGB), G(RGB), B(RGB), H(HSV), S(HSV), V(HSV), L(Lab), a(Lab), b(Lab), L(LCH), C(LCH), H(LCH), C(CMYK), M(CMYK), Y(CMYK), and K(CMYK).

To verify the possibility of predicting the physico-chemical indicators of bio-oils, a partial least squares regression (PLSR) method is used [12]. The PLS family of methods are known as bilinear factor models. PLSR is a statistical method that bears some relation to principal components regression; instead of finding hyperplanes of maximum variance between the response and independent variables, it finds a linear regression model by projecting the predicted variables and the observable variables to a new space. PLS is used to find the fundamental relations between two matrices (X and Y), i.e. a latent variable approach to modeling the covariance structures in these two spaces. Both the X and Y data are projected to new spaces.

The computations were performed in MATLAB environment (Mathworks, USA).

Table 1. Automobile oils parameters

Parameter	Viscosity, Pa.s			Density, g/ml		
Descriptive statistics / Bio-oils	mean	SD	CV	mean	SD	CV
Rapeseed oil	0,7900	0,000125	0,000158	0,9073	0,0001	0,0001
Transmission oil	0,4928	0,365809	0,742308	0,8292	0,0005	0,0006
Engine oil	0,2873	0,000122	0,000425	0,8787	0,0002	0,0002
Sunflower oil	0,2470	0,000630	0,002551	0,9500	0,0001	0,0001
Grapeseed oil	0,0466	0,000251	0,005386	0,9210	0,0001	0,0001

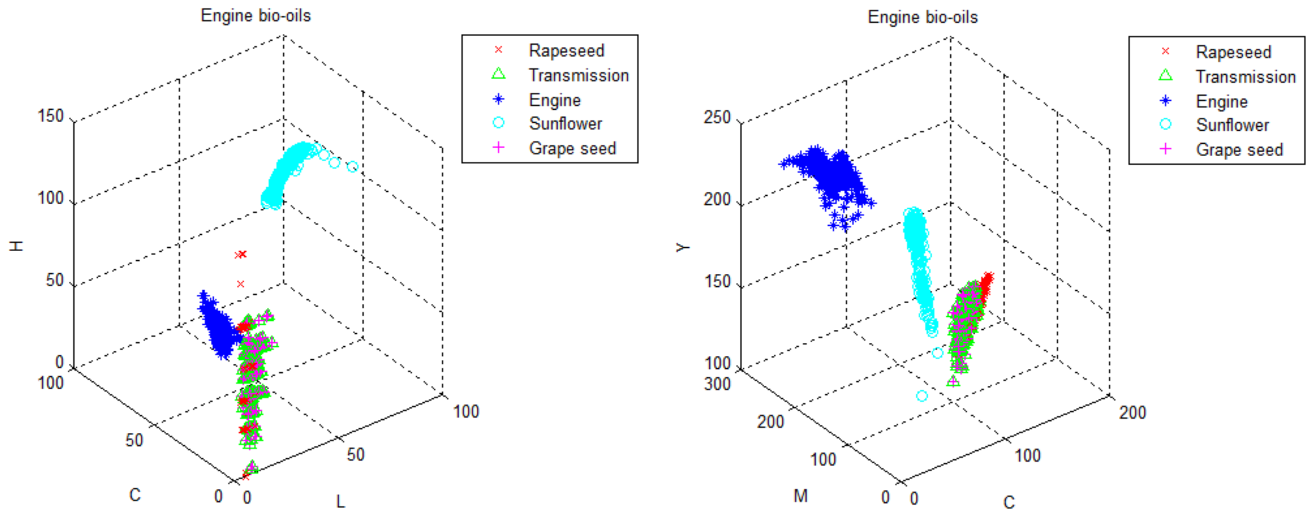
3 Results and discussion

The used bio-oils in CMYK and LCH color models respectively are shown in Fig.2a and Fig.2b. It can be seen that engine and sunflower oils are clearly distinguishable from others.

The prediction of the physico-chemical parameters of the bio-oils is done by the PLSR method. Two latent variables describing 95% of the dispersion in the experimental data were used to describe the color components.

Examples for predicting density and viscosity respectively, by color components, are shown in Figure 3a and Figure 3b. The density can be estimated with an accuracy of 55% by L (LCH) color component, while the viscosity by 85% accuracy by R (RGB) color component.

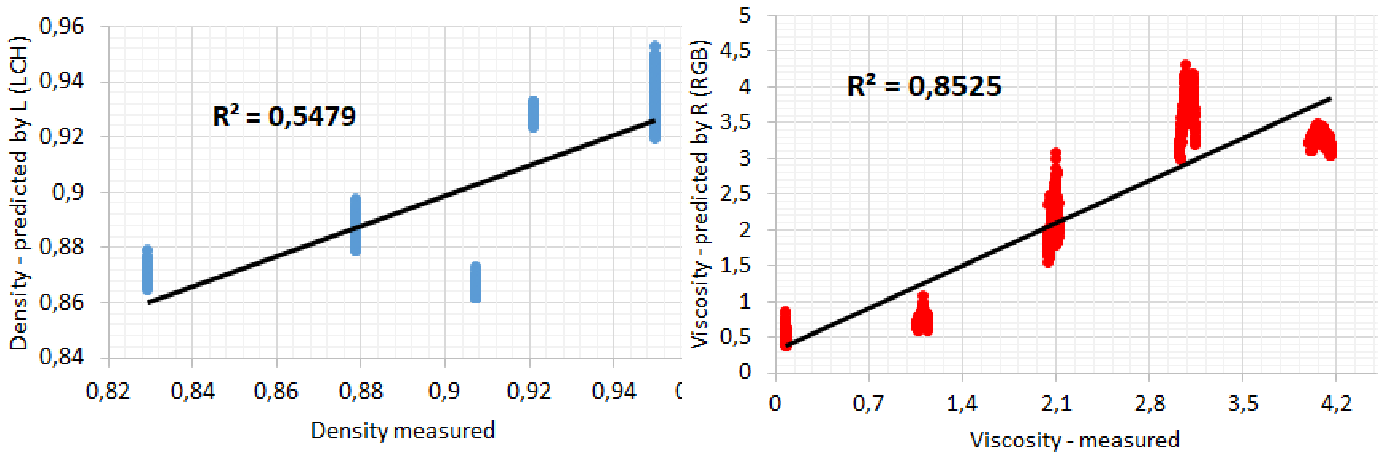
A summary analysis of the results of the verification of the possibility of predicting physico-chemical indicators by color components is presented in Table 2.



a) LCH

b) CMYK

Fig. 2. Bio-oils represented by color components



a) density by L (LCH)

b) viscosity by R (RGB)

Fig. 3. Prediction of physico-chemical parameters of bio-oils by color components

There are presented the following coefficients resulting from PLSR: R^2 - coefficient of determination, SSE - Sum of Squares of Error and RMSE - root-mean-square error. The data in the table shows that the density of bio-oils can be predicted with an accuracy of up to 57%, while the viscosity is accurate up to 85%.
Suitable for predicting density and electrical conductivity parameters are R (RGB), G (RGB), V (HSV), L (Lab), L (LCH), and K (CMYK) color components.
The results obtained show that the analysis of color digital images is a suitable technique for analyzing bio-oils, because the precision of the physico-chemical parameters of the product is comparable to that of spectral analysis in the near infrared region [13]. An advantage of the method proposed here is that it can be realized with accessible technical tools. Unlike spectroscopic techniques that are basically available in laboratory conditions and are difficult to apply for "on-site" express bio-oil analysis.

Table 2. Prediction accuracy of automobile bio-oils parameters by color components

Parameter	Density			Viscosity		
Color component	**R^2**	**SSE**	**RMSE**	**R^2**	**SSE**	**RMSE**
R (RGB)	**0,51**	**0,84**	**0,02**	**0,85**	**0,51**	**0,51**
G (RGB)	**0,57**	**0,83**	**0,02**	**0,76**	**0,72**	**0,61**
B (RGB)	0,16	0,45	0,02	0,64	0,92	0,68
H (HSV)	0,31	0,17	0,02	0,14	4,61	0,48
S (HSV)	0,11	0,32	0,01	0,17	5,54	0,52
V (HSV)	**0,51**	**0,84**	**0,02**	**0,85**	**0,51**	**0,51**
L (Lab)	**0,55**	**0,83**	**0,02**	**0,84**	**0,53**	**0,51**
a (Lab)	0,17	0,46	0,02	0,03	10,25	0,23
b (Lab)	0,48	0,84	0,02	0,44	9,84	0,71
L (LCH)	**0,55**	**0,83**	**0,02**	**0,84**	**0,53**	**0,51**
C (LCH)	0,37	0,79	0,02	0,41	9,59	0,69
H (LCH)	**0,51**	**0,84**	**0,02**	0,21	6,36	0,56
C (CMYK)	0,34	0,76	0,02	**0,84**	**0,53**	**0,51**
M (CMYK)	0,41	0,81	0,02	0,37	9,30	0,68
Y (CMYK)	0,10	0,31	0,01	0,02	5,71	0,17
K (CMYK)	**0,52**	**0,84**	**0,02**	**0,85**	**0,51**	**0,51**

4 Conclusion

In the analysis of organoleptic parameters, and in particular the external appearance and color of automotive oils, a large percentage of judgment subjectivity, a requirement for qualified human resources, and a long processing time in the presence of multiple samples are observed.
The proposed method tends to discriminate between different engine bio-oils. Six of the used color components are suitable for prediction of viscosity and density of the oils.
The results show the potential for the use of color digital images for fast and non-destructive determination of physicochemical properties of automotive oils. This provides a solution to the major problem in the cuvette methods used and the continuous preparation of the samples for analysis.
The presented results encourage that a low-cost optical system can be developed and can contribute to the investigation and identification of bio-oils, especially in the express analysis. Such an approach can be used for bio-oil testing and quality control.

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