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PHYSICO-CHEMICAL CHARACTERIZATION OF ARABICA AND ROBUSTA SPENT COFFEE BLENDS

BY

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Abstract. Market surveys have lately shown that coffee is the second best-selling commodity – after oil. Our paper is aimed at analyzing the spent coffee blends in a professional DeLonghi coffee maker in which four types of coffee available on the market were used. The analyzed coffee contains blends of Arabica and Robusta coffee in various proportions. Spent coffee blends density and viscosity was measured experimentally at different temperatures. The browning index was measured by reading sample absorbance at 420 nm, using a spectrophotometer. We used fir-wood boards to determine whether spent coffee blends may be used for the beautification and protection of wood. The contact angle was measured and values ranging from 63° and 83° were read for the treated plates, whereas the value on the untreated control plate was 52°. These results confirm that the spent coffee blends could be used to beautify and protect wood.

Keywords: spent coffee blends; physico-chemical characterization; density; viscosity; browning index; contact angle keywords.

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1. Introduction

The analysis of the best-selling products on the market indicates coffee as the second best-selling commodity - after oil. Coffee is the second most popular edible product in the world and the most popular beverage after water. Commercially, the most sold types of coffee are mixtures of Arabica and Robusta in different proportions. Arabica coffee has lower caffeine content, but the aroma is more intense and therefore is preferred by most consumers. Robusta coffee is bitter and has much higher caffeine content. Experts believe that the most appreciated coffee is obtained through automatic espresso machine which involves the passage of pressurized water through the finely ground coffee. Coffee consumption is on an upward trend worldwide. This trend also includes Romania, where the increase of purchasing power and the elimination of excise duty since 2016, have contributed to a significant increase in coffee consumption in recent years. The increase in coffee consumption generates the increase in the amount of residues that could be used (Rivera *et al*., 2020; Iriondo-DeHond *et al*., 2019; Karmee, 2018). Researchers' attention is largely focused on harnessing the solid residue that results after the preparation of various coffee processes (Brunerová *et al*., 2020; Manni *et al*., 2019; Campos-Vega *et al*., 2015; Dugmore *et al*., 2019) and less in the use of liquid residues (Barbero-López *et al*., 2018). Peshev and his colleagues have highlighted the possibility of using liquid coffee residues in the production of soft drinks and energy drinks due to their main characteristics (antioxidants concentration, caffeine content and browning index) (Peshev *et al*., 2018). Barbero-López et al. recently indicated the possibility of using liquid coffee residues, which have a high content of chlorogenic acids to reduce wood-decaying fungi growth (Barbero-López *et al*., 2018).

The aim of this paper is to analyze the liquid residues obtained after using four types of commercial coffee in a DeLonghi professional coffee machine. The analysed coffee samples contain different proportions of Arabica (WA %) and Robusta (WB %): WA/WB = 70/30, 50/50, 35/65 and 20/80. The density and viscosity of coffee residues are experimentally determined at different temperatures. The browning index for these residues is evaluated with the help of a spectrophotometer. The liquid coffee residues can be applied on fir boards to improve aesthetic and to protect the wood items. For the first time, by our knowledge, the contact angle of the treated surfaces is measured.

2. Materials and Methods

The analyzed liquid residues resulted from the use of four types of commercial coffee in a DeLonghi professional coffee machine. The analyzed coffee samples contain different proportions of Arabica (WA %) and Robusta

(WB %): WA/WB = 70/30, 50/50, 35/65 and 20/80. To obtain comparable results the following recipe for coffee preparation was used in the professional DeLonghi automatic: 12 g of coffee and 40 mL of water.

Fir wood plates with the size: LxWxT = 120x30x5 mm were used to evaluate the possibility of using liquid coffee residues for the redecoration and protection of the wood. The liquid coffee residues were applied by brushing the wood items.

The experimental density measurement for the different liquid coffee residues was performed with the Anton Paar DMA 4500 densimeter, at different temperatures: 10°C, 20°C, 30°C, 40°C and 50°C. The measuring range of this type of densimeter is from 0 to 3 $g \cdot cm^{-3}$, while the temperature variation range is between 0°C and 90°C. Thanks to the two integrated platinum thermometers Pt 100, a high accuracy of temperature control (0.01°C) is ensured. In order to determine the density, the amount of sample in the measuring cell must be approximately 1 mL and the measurement time for such a device is approximately 30 seconds.

The viscosity of liquid coffee residues was measured with a Physica MCR 501 modular rheometer (Anton Paar, Austria) equipped with a Peltier temperature control system. As a measuring system, concentric cylinders were used, recommended for low viscosity samples. The rotational tests (flow curves) were performed at different temperatures: 10°C, 20°C, 30°C, 40°C and 50°C with a variation of the shear rate in the range 0.1 – 100 s^{-1}.

Browning index was measured by reading the sample absorbance at 420 nm, using a T60 Vis spectrophotometer (PG Instruments). 1 mL sample was introduced into 40 mL distilled water.

With the help of a KRUSS Goniometer the contact angle was measured for the fir wood boards treated with liquid coffee residues. This system allows the recording and evaluation of video images and the calculation of surface energies and surface tension. The main features of the equipment are: DSA1 software, EASYDROP, measuring range (contact angle 1 to 180°, surface tension 0.01 to 1000 $mN \cdot m^{-1}$, measuring resolution (contact angle 0.1°, surface tension: 0.01 $mN \cdot m^{-1}$, 79 fps camera system (656 × 492 px).

3. Results and Discussions

The four liquid residues obtained in the professional DeLonghi machine were made from types of coffee that have different proportions of Arabica and Robusta. Table 1 presents the codes and the composition of the coffee samples. After cooling at room temperature, the liquid coffee residues samples were physico-chemical characterized by the determination of density, viscosity and browning index.

Table 1
Coffee and Composition Sample Codes

Sample codes	%Arabica	%Robusta
P1	70	30
P2	50	50
P3	35	65
P4	20	80

The densities of the different liquid coffee residues were measured with an accuracy of 10^{-5} g·cm^{-3} with the help of the Anton Paar DMA 4500 densimeter. This type of densimeter ensures a high accuracy of temperature control ± 0.01°C, and the apparatus has been calibrated with bidistilled water. For each sample at each temperature, the experimental determinations were repeated more than nine times until at least three times the same value was obtained, in order to ensure good reproducibility of the obtained data. The results obtained are shown in Fig. 1. As the temperature increases, as expected, the density decreases for all analyzed samples. Higher values at all temperatures for density were obtained in the case of sample P3. The average density values for the four samples were calculated for each temperature and it was found that it decreases from 1.01975 g·cm^{-3} to 10°C, to 1.00170 g·cm^{-3} at 50°C. In the specialized literature, Parenti *et al*. measured at 20°C the density for two assortments of liquid coffee residues using a pycnometer and obtained 1.022 and 1.057 g·cm^{-3}, respectively (Parenti *et al*., 2013). The values obtained in this study are comparative with those reported in the literature and we should mention that the densimeter with which we measured the density experimentally offers much better accuracy.

Viscosity values for liquid coffee residues at temperatures: 10°C, 20°C, 30°C, 40°C and 50°C were obtained in the rotational mode with a Physica MCR 501 modular rheometer. The tested samples show Newtonian behavior (Fig. 2) with viscosity independent of the shear rate. Based on these results, the influence of temperature on the viscosity of the samples is presented in Fig. 3. The experimental values of viscosity are close for the four analyzed samples, at different temperatures. The average viscosity values for the four samples calculated for each temperature range from 1.745 mPa·s to 10°C, to 0.774 mPa·s at 50°C. Parenti *et al*. obtained at 20°C with an Ostwald viscometer for two types of coffee residues the following values for viscosity: 1.38 mP·s and 1.59 mPa·s, respectively (Parenti *et al*., 2013). Also, a newtonian behaviour highlighted in their study Telis-Romero et al. for coffee solutions with mass fractions of water between 76 and 90%. The viscosity determined experimentally by them varied between 2.81 and 0.32 mPa·s, for temperatures between 22 and 92°C (Telis-Romero *et al*., 2001).

Moreno *et al*. experimentally determined the density and viscosity for coffee solutions with mass fractions between 5 and 50% water, in the temperature range from -6°C to 20°C. Density values ranged from 1.236 to 1.000 g·cm^{-3}, and viscosity between 10.37 and 1.99 mPa·s (Moreno *et al*., 2015).

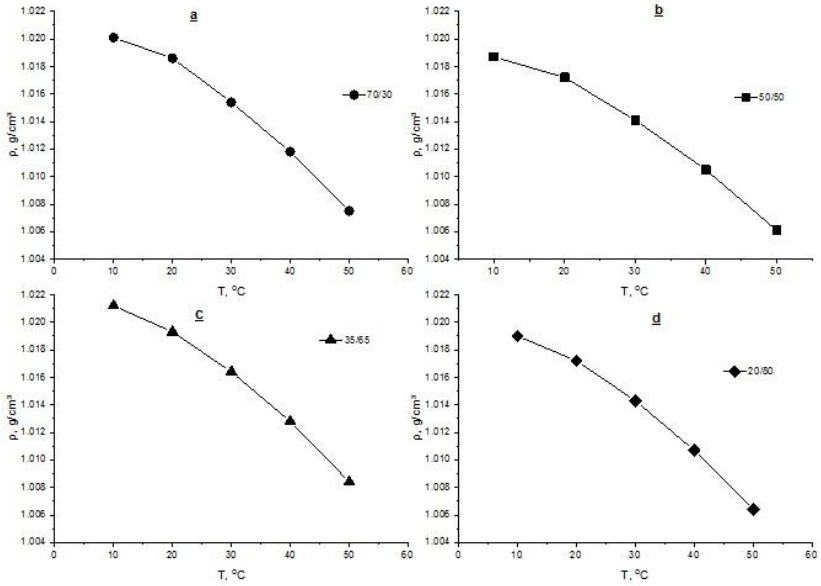

Fig. 1 – Variation of density with temperature: *a*) P1, *b*) P2, *c*) P3 and *d*) P4.

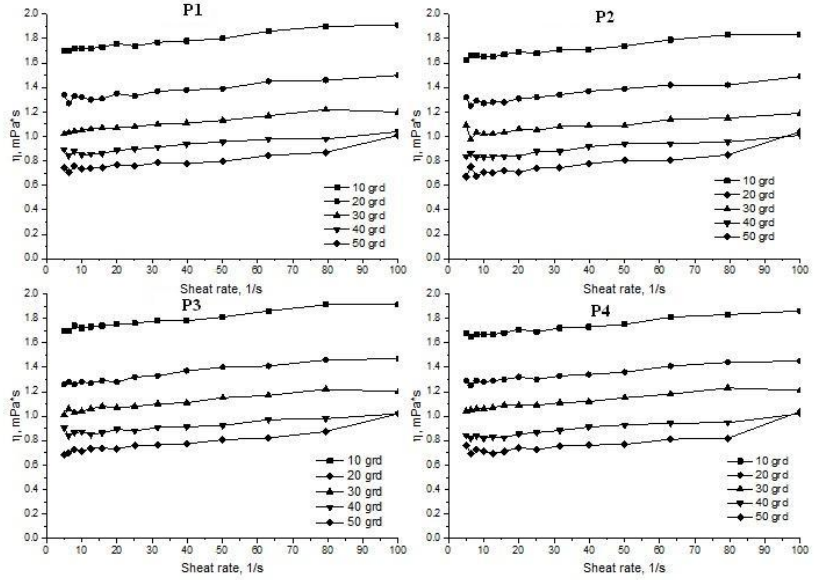

Fig. 2 – Viscosity variation with shear rate at different temperatures.

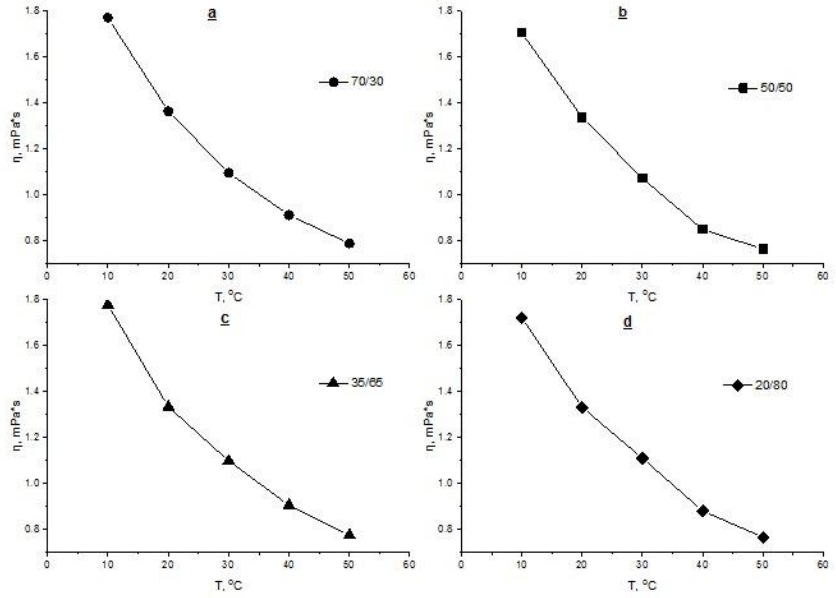

Fig. 3 – Variation of viscosity with temperature: *a*) P1, *b*) P2, *c*) P3 and *d*) P4.

The browning index was determined for the four liquid coffee residues using a spectrophotometer. After introducing 1 mL sample into 40 mL distilled water the absorbance was measured at 420 nm. The results obtained are presented in Table 2. According to the literature, browning index can be used to estimate the content of melanoidins (Almeida and Benassi, 2011). Almeida and Benassi analyzed liquid residues resulting from the use of different types of coffee in the trade with different proportions of Arabica and Robusta. For browning index, they obtained values between 0.291 and 0.690 (Almeida and Benassi, 2011). According to the data presented in Table 2 in our study browning index varies between 0.580 and 0.682.

Table 2
Browning Index

Sample code	P1	P2	P3	P4
Absorbance	0.595	0.646	0.682	0.580

In order to evaluate the possibility of using liquid coffee residues for the beautification and protection of the wood we applied samples on fir wood boards with the size: Lxlxg = 120x30x5 mm and allowed them to dry. Then with the help of a KRUSS Goniometer we measured the contact angle with bidistilled water. The obtained results are presented in Table 3.

Table 3
Contact Angle

Sample	Control	Treated with P1	Treated with P2	Treated with P3	Treated with P4
Contact angle, °	52±3	64±2	72±1	83±2	63±1

The evaluation of the obtained results reveals that the contact angle of the fir wood boards treated with liquid coffee residues increases by 11 up to 30°. The increase in hydrophobicity is greater as the browning index grows and there is a linear dependence (Fig. 4). These results confirm that browning index can be used to estimate the content of melanoidins in liquid coffee residues.

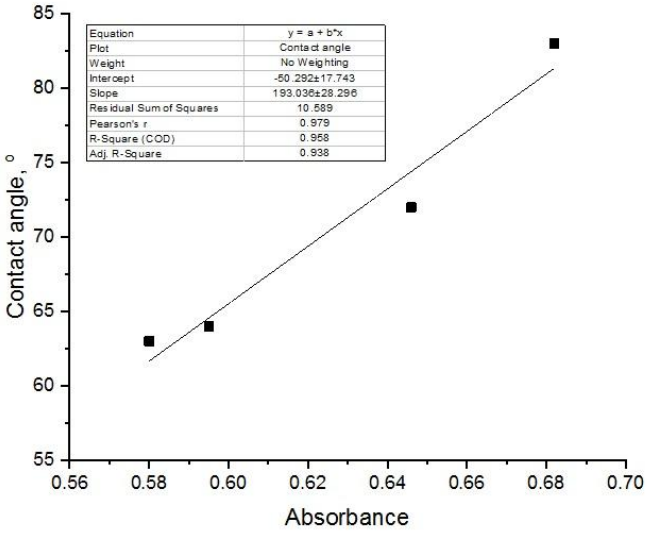

Fig. 4 – Dependence of the contact angle according to the absorbance.

4. Conclusions

In this study we analyzed the liquid residues obtained after using four types of commercial coffee in a DeLonghi professional coffee machine. The analyzed coffee contains different proportions of Arabica (WA %) and Robusta (WB %): WA/WB = 70/30 (P1), 50/50 (P2), 35/65 (P3) and 20/80 (P4). The density and viscosity of liquid coffee residues at different temperatures were determined experimentally: 10°C, 20°C, 30°C, 40°C and 50°C. Comparative values have been obtained to what has been reported in the literature so far, but we specify that in our study we used high performance equipment that offers a very good accuracy for the experimental results. With the help of a spectrophotometer was also established a browning index for these residues. For the first time, the liquid coffee residues were applied on fir boards and the

contact angle was measured. There was a significant increase in the value of the contact angle for the plates treated with liquid coffee residues compared to the control sample (fir wood plate). This increase in hydrophobicity is even greater as the browning index grows and there is a linear dependence between these sizes: **Contact angle** = 193.04·**Absorbance** - 50.29. The results confirm that liquid coffee residues can be used to redecorate and protect the wood.

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CARACTERIZAREA FIZICO-CHIMICĂ A UNOR REZIDUURI DE AMESTECURI DE CAFEA ARABICA ŞI ROBUSTA

(Rezumat)

Studiile de piaţă, au indicat în ultimii ani, cafeaua, drept cea de a doua cea mai vândută marfă – după petrol. Lucrarea îşi propune să analizeze reziduurile obţinute după utilizarea a patru tipuri de cafea comercială, într-un automat de cafea profesional DeLonghi. Cafeaua analizată conţine proporţii diferite de Arabica şi Robusta. S-a măsurat experimental densitatea şi vâscozitatea pentru reziduurile de cafea la diferite temperaturi. Browning index a fost măsurat citind absorbanţa probelor la 420 nm, cu ajutorul unui spectrofotometru. Pentru a evalua posibilitatea utilizării reziduurilor de cafea, pentru înfrumuseţarea şi protejarea lemnului, s-au utilizat plăcuţe de lemn de brad. S-a măsurat unghiul de contact şi s-au obţinut valori cuprinse între 63° şi 83° pentru plăcuţele tratate, iar pentru plăcuţa martor netratată 52°. Rezultatele obţinute confirmă faptul că reziduurile de cafea ar putea fi utilizate pentru înfrumuseţarea şi protejarea lemnului.