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Effect of the roasting process on glass transition and phase transition of Colombian Arabic coffee beans

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Abstract

This paper presents results of the analysis of organic coffee beans cultivated in Departamento del Cauca - Colombia. Beans studied are of the C*offea Arabica* species cultivated in mountain soils of altitude close to 1500 m. Samples from green and roasted beans were characterized using differential scanning calorimetry (DSC), thermogravimetric analysis (TGA), and X-ray diffractometry (XRD). We intend to relate the features of the heating spectra with the transformation experimented by the coffee. Glass transition and phase transitions were examined. DSC and TGA spectra show that the green coffee experiments a high and fast decomposition after 200°C until 289°C with a remarkable transformation in a close range around 210°C. XRD shows significant changes for green and roasted beans associated to the amount of caffeine hydrates and caffeine anhydrous. Fit of XRD curves by Lorentzian shows a considerable increase of the active crystalline phase at 2θ equal to 20.4^0 for the roasted coffee. The results obtained from this study contribute to the insight associated with the final quality of coffee dependent on roasting methods. Better quality of coffee requires a refined and very controlled roasting process around of 218°C with a slow thermal treatment since the room temperature until the 200°C.

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Keywords: Coffee; roasting; phase transition; glass transition; DSC-TGA- XRD.

1. Introduction

Coffee bean is a complex system of several constituents (water, carbohydrates, lipids, amino acids, aliphatic acids, caffeine, and minerals) that experiment irreversible changes by the roasting process, including phase and structural transitions that must affect its quality and stability. The characteristic

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flavor and aroma of coffee result from a combination of hundreds of chemical compounds produced by the reactions that occur during roasting which are still not well understood [1]. Roasting process, besides water elimination, produces changes in chemical and physical properties, as well as in the color, aroma and taste. The production of high quality coffee requires excellent crop procedures, correct harvesting methods, and adequate industrial processing. After the natural drying process the green beans are roasted before they are ground and ready to prepare beverages. Although defining quality is an issue of astounding complexity—more than 800 volatile compounds can be detected in the aroma of roasted coffee [2], processing, especially roasting, dramatically modifies the phenolic composition of coffee, producing the aroma, flavor and color characteristic of coffee [3]. Another component to be considered is the caffeine that contributes to bitterness and has known pharmacological effects. The aim of this work was to study the effects on organic coffee beans of the roasting process in a temperature range of 210–230 °C. We have examined in detail the evolution and transformation that takes place in green coffee beans as well as in roasted coffee, through measurements by Differential Scanning Calorimetry (DSC), Thermogravimetric Analysis (TGA) and X-ray diffraction (XRD). The points of singularity in the thermal process, the temperature range where the coffee suffer the greatest decomposition, the glass transition, and the change of phase that the caffeine experiments as consequence of the thermal treatment of the coffee samples were determined.

2. Materials & Methods

Survey and sampling of organic coffee beans was carried out during the year 2010 in several farms of the Departamento del Cauca in southwest Colombia. Beans studied are of the C*offea Arabica* species cultivated in mountain soils of altitude close to 1500 m. Green coffee beans (200 g) with a moisture content of around 12% were roasted at different temperatures ranging between 210 to 230°C, roasting times up to 10 minutes were selected from trials using as criteria the visual colour (light, medium, and dark) of the processed beans. To study the transformations experimented by the coffee beans after roasting, three techniques were utilized to analyse powder samples of green and roasted material. DSC was done with a Q100 of TA Instruments operating in the modulated mode with a scanning rate of 5°C/min. The instrument was calibrated for temperature and heat flow with Indium. TGA was realized with a Q5OO from TA Instruments with a heating rate of 10^0C/min at a temperature range of 24 to 800°C in a N_2 atmosphere. Broker D8 Advanced with k_α 1.5406 Å in the 3° grazing angle mode was used for XRD.

3. Results & Discussion

Modulated DSC (MDSC) characteristic curves of the coffee samples are shown in Figure 1. Left panel of Figure 1 shows the MDSC curves of four roasted samples belonging to two varieties of coffee denominated as S1 and S2. S1a was roasted to 210°C, S1b roasted to 230°C, S2a roasted to 210°C, and S2b roasted to 230°C. The evolution of the heat flow in function of the temperature gives information of the reversible and irreversible changes that the samples experiment; these curves have significant differences of shape which reveal the variability of the thermal transition points. By direct observation of the MDSC spectra and its derivatives it is possible to notice an inflexion associated to a glass transition around 59°C for the four samples of roasted coffee, and also for the two samples of green coffee (right sight of Figure 1). Other points of interest of these spectra are seen at 92°C, 118°C, 218°C, and 235°C for the sample S1a; at 135°C, and 218°C for the sample S1b; at 115°C, and 208°C for the sample S2a; and at 124°C, and 218°C for the sample S2b. The transition at 218°C results remarkable, transition that