*The Annals of the University Dunarea de Jos of Galati*
*Fascicle VI – Food Technology 38(2):43-56*

**ORIGINAL RESEARCH PAPER**

# EFFECT OF ROASTING CONDITIONS ON SEVERAL CHEMICAL CONSTITUENTS OF VIETNAM ROBUSTA COFFEE

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Received on 10th June 2014
Revised on 5th November 2014

This study was conducted to determine the effect of roasting conditions on chemical constituents of Vietnam robusta coffee. The contents of acrylamide, chlorogenic acid and tannins were higher in green coffee than in roasted coffee and decreased as roasting condition increased, which ranged from 6.53 to 91.36 μg/100g, 1.54 to 55.51 mg/g and 3.14 to 651.59 mg/10g, respectively. In addition, the content of trigonelline ranged from 1.43 to 64.24 mg/10g, which gave the highest value in green coffee, then decreased rapidly, while in the Italian roast it was not present at all. Caffeine content ranged from 15.30 to 35.91 mg/g and presented the lowest value in the case of green coffee, then increased reaching the highest value at 240 °C, after that decreasing gradually and slowly.

**Keyword**: caffeine; tannin; trigonelline; acrylamide; chlorogenic acids

## Introduction

Coffee is one of the most popular and consumed beverages around the world (Mussatto *et al.*, 2012). The composition of green coffee beans depends on several factors such as variety, origin, field conditions, climate and soil (Van Dam and Feskensm, 20112; Riksen *et al.*, 2009). Nevertheless, the chemical composition of roasted coffee beans seem to play a major role in defining the quality of this beverage. During the roasting process, the beans suffer physical changes and go through several chemical reactions which change, generate and degrade several substances responsible for the flavor and aroma of coffee (Wei *et al.*, 2011).

Aroma formation is a very complex process, including Maillard and Strecker's reactions and thermal degradation during roasting (De Maria *et al.*, 1994). Some aroma precursors, such as sucrose and trigonelline, give rise to appreciated flavour products (De Maria *et al.*, 1996). Roasting is a complex process from a chemical point of view, since hundreds of chemical reactions take place simultaneously, such as Maillard and Strecker reactions, degradation of proteins, polysaccharides, trigonelline and chlorogenic acids (De Maria *et al.*, 1996). Sugars and trigonelline

will act as aroma precursors, originating several substances which will affect both the flavor and aroma of the beverage. The thermal degradation of chlorogenic acids will result in phenolic substances that contribute to bitterness.

Major chemical alterations have been quantitatively described for chlorogenic acid (Trugo and Macrae, 1984), sucrose, trigonelline (Casal *et al.*, 2000) and amino acids, trigonelline, chlorogenic acids and caffeine, in both green and roasted coffee. Those modifications are supposed to be related to coffee quality. Furthermore, a few studies have proposed the use of these substances for the determination of the degree of roast (Stennert and Maier, 1996), as genotype selection criteria (Guerrero and Sua´rez, 2001), and for species differentiation (Martın *et al.*, 1998, Ky *et al.*, 2001). The antioxidant capacity of coffee has been attributed to its content of polyphenols and melanoidins (Anese and Nicol, 2003). Acrylamide and melanoidins are both Maillard reaction products (MRPs) formed during coffee roasting, which is typically conducted at temperatures between 210 and 250 $^{o}$C. Theoretically, any attempt to inhibit the Maillard reaction as a possible measure to minimize the formation of acrylamide would lead to a reduction of the antioxidant capacity of coffee, as it has been already observed in cookies (Summa *et al.*, 2006).

Caffeine is found in varying quantities in the seeds, leaves, and fruit of some plants. It is most commonly consumed by humans in infusions extracted from the seed of the coffee plant and the leaves of the tea bush (Peters, 1967). Also caffeine is found in various kinds of foods and drinks that we consume in daily life (Singh and Sahu, 2006). In humans, caffeine acts as a central nervous system stimulant, temporarily warding off drowsiness and restoring alertness (Lovett, 2008). Also it causes various physiological effects such as the relaxation of the bronchial muscle, the stimulation of the central nervous system, gastric acid secretion and dieresis. Caffeine has a number of effects on sleep, but does not affect all people in the same way. It improves performance during sleep deprivation but may lead to subsequent insomnia (Snel and Lorist, 2011). In shift workers it leads to fewer mistakes caused by tiredness. In athletics, moderate doses of caffeine can improve sprint, endurance and team sports performance, but the improvements are usually not very large (Conger *et al.*, 2011). On the other hand, the chemical analysis of caffeine in coffee beans is also used as an additional tool for evaluating coffee quality (Franca *et al.*, 2005). This study evaluated the product quality coffee after roasting. Tannins are water-soluble polyphenolic compounds, recalcitrant to biodegradation and with wide prevalence in plants. Hydrolysable and condensed tannins are the two major classes of tannins. These compounds play important roles as resistant agents to microbial decomposition, mainly due to the ability of these molecules to inhibit microbial growth by binding strongly to proteins and polysaccharides like cellulose and pectin (Lewis and Starkey, 1969; Bhat *et al.*, 1998). They may activate paltelets, and they are involved in the epithelial injury of bronchi by cotton dust that may play an important role in the woodworkers' nasal sinus cancer. Condensed tannins are more resistant to microbial decomposition, while hydrolysable tannins are more easily degraded by some microorganisms (Lewis and Starkey, 1968; Lekha and Lonsane, 1997; Aguilar and Gutie'rrez-Sa'nchez, 2001). Tannins occur universally in higher plants and are present in significant

quantities in many food crops. Tannin precipitates with heavy metals and alkaloids so it is commonly used to treat gastrointestinal toxicity.

Trigonelline is an alkaloid and a zwitterion formed by the methylation of the nitrogen atom of niacin. It is a product of niacin metabolism that is excreted in urine. Since nicotinic acid is produced during coffee processing, it is highly available in the beverage, unlike in natural sources where it is present in bound form. Besides, trigonelline appears to have anti-invasive activity against cancer cells (Hirakawa *et al.*, 2005) and may regenerates dendrites and axons, in addition to memory improvement in animal models (Tohda *et al.*, 2005). Acrylamide (2-propenamide) is a known neurotoxin and carcinogen (Prasad and Muralidhara, 2012), present in heated foods and cigarette smoke. Acrylamide is particularly formed in heated plant foods >120°C, peaking at 150°C (Gökmen et al. 2006), treated between 160-180°C, or at 210°C (Elmore *et al.*, 2005). Chlorogenic acid is a natural chemical compound which is the ester of caffeic acid and quinic acid and it is an important biosynthetic intermediate in lignin biosynthesis (Boerjan *et al.*, 2003). This compound, known as an antioxidant, may also slow the release of glucose into the bloodstream after a meal (Johnston *et al.*, 2003). Chlorogenic acid was found in green and roasted coffee bean extract (Onakpoya *et al.*, 2010).

This study determined the influence of roasting time and temperature on the weight loss of coffee beans and measured the amount of caffeine, tannins, trigonelline, chlorogenic acid and acrylamide in green and roasted Vietnam robusta coffee.

## Materials and Methods

*Preparation of coffee beans*

Coffee beans were purchased from the robusta coffee commercial market in Ban Me Thuat city, the Dak Lak province of Vietnam. The relative humidity was around 12%. Good quality coffee beans were handpicked.

*Chemicals and Reagents*

Caffeine and acrylamide standards were obtained from Sigma Chemical Co. (St. Louis, MO, EUA). Tannin and chlorogenic acids standards were purchased from Aladdin Chemistry Co., Ltd. (Shanghai, China). Trigonelline standard was purchased from Lvyuan biochemical Co., Ltd. (Shanghai, China). All reagents were analytical grade, while HPLC reagents were LC grade. Ultrapure water was obtained from a Milli-Q System (Millipore Corp., Milford, MA, USA). The mobile phases were filtered in HAWP and HVWP membranes, respectively, for aqueous and organic solvents (47 mm diameter and 0.45-mm pore size, Millipore Corp., Milford, MA, USA).

*Roasting of coffee beans*

Randomly selected coffee bean samples were placed into a pan and then roasted using a muffle roaster. Each time the pan was positioned in the same place of the muffle roaster in an effort to ensure uniform roasting conditions. After roasting, the beans were cooled immediately using an electric fan. Five different roasting degrees (coffee roasting at 250 $^{o}$C for different roasting times - 8, 12, 14, 18 and 20 min - called American roast, Vienna roast, French roast, Italian roast and Spanish

roast, respectively) and five different roasting temperatures (210, 220, 230, 240 and 250 $^{o}$C) were adopted. Weight loss was determined based on the difference percentage in sample weight before and after roasting, and the effect of temperature on weight loss during roasting coffee beans was evaluated. Ultimately, the roasting degrees were established based on weight loss measurements and visual inspection of the external color of beans, which is the most widely used in the coffee roasting industry.

*Grinding and storage*

Roasted coffee samples were stored in sealed containers at ambient temperature for a maximum period of 24 h. Just before each analysis, roasted coffee beans were finely ground with an electric coffee grinder (Multi-purpose disintegrator MJ-04) at 3.5 screen size (0.30 mm) and keep refrigerated in sealed plastic bag prior to analysis.

*UV-Vis spectrophotometer analysis*

Analysis of tannins with UV-Vis spectrophotometer: Tannin was measured with a ultraviolet visible spectrophotometer at 276 nm. Samples were dissolved in high pure water, and then filtered through 0.45 mm membranes. The solution was determined by the spectrophotometer before and after adding enough chromed hide powder (to absorb the tannin) in Quartz color dish, as recently reported (Clifford *et al.*, 1991; Zhang and Ou, 2005; Jiang *et al.*, 2012).

*Trigonelline analysis*

Trigonelline was extracted from samples (2.0 g) with 10.0 ml methyl alcohol. After extraction for 40 min in an ultra-wave, the solution was filtered through 0.45 mm membranes. The trigonelline was separated by ion-pair reverse phase HPLC. Liquid chromatograph consisted of a Jasco integrated system (Japan) equipped with two model PU-980 pumps, a AS-950 automated injector, a MD-910 multiwave length diode-array detector (DAD), and a FP-920 fluorometric detector (excitation 252 nm, emission 500 nm). A reversed-phase Tracer-Excel 120 ODS-A (250 × 4.6 mm) column (Teknokroma, Spain), operating at 30 °C, with a mobile phase of gradient of acetonitrile/ water = 80/ 20 and a flow rate of 0.8 mL·min$^{-1}$, as reported by Hornero-Mendez and Garrido-Fernandes, was used. Quantification was carried out using calibration curves obtained with standard solutions of trigonelline at 265 nm, as recently reported (Trugo and Macrae, 1984; Casal et al., 2000; Ky et al., 2001).

*Chlorogenic acids analysis*

Chlorogenic acid was extracted from samples (1.0g) with 10.0 ml 70% methyl alcohol solution. After extraction for 30 min in an ultra-wave, the solution then was filtered through 0.45 mm membranes. Chlorogenic acid was separated by ion-pair reverse phase HPLC. The liquid chromatograph consisted of a Jasco integrated system (Japan) equipped with two model PU-980 pumps, a AS-950 automated injector, a MD-910 multiwavelength diode-array detector (DAD), and a FP-920 fluorometric detector (excitation 252 nm, emission 500 nm). A reversed-phase Tracer-Excel 120 ODS-A (250 × 4.6 mm) column (Teknokroma, Spain), operating at 30°C, with a mobile phase of gradient of acetonitrile/0.5% acetic acid solution =

1/9 and a flow rate of 1.0mL.min$^{-1}$. Quantification was carried out using calibration curves obtained with standard solutions of chlorogenic acid at 327 nm (Trugo and Macrae, 1984; Casal *et al*., 2000; Ky *et al*., 2001).

*Caffeine analysis*

Caffeine was extracted from samples (1.0 g) with 10.0 ml trichloromethan. After extraction for 30 min in an ultra-wave, certain amounts of anhydrous sodium sulphate and saturated sodium chloride were added to the solution, shaken and after that the solution was filtered through 0.45 mm membranes. Caffeine was separated by ion-pair reverse phase HPLC. The liquid chromatograph consisted of a Jasco integrated system (Japan) equipped with two model PU-980 pumps, a AS-950 automated injector, a MD-910 multiwavelength diode-array detector (DAD), and a FP-920 fluorometric detector (excitation 252 nm, emission 500 nm). A reversed-phase Tracer-Excel 120 ODS-A (250 × 4.6 mm) column (Teknokroma, Spain), operating at 30°C, with a mobile phase of methanol/ acetonitrile/water = 57/29/14 (50 mL 0.8 mol/L acetic acid solution was added to per 1000mL mobile phase. Quantification was carried out using calibration curves obtained with standard solutions of caffeine at 286nm according to Trugo and Macrae, 1984; Casal et al., 2000; Ky et al., 2001; Horzic et al., 2009.

*Acrylamide analysis*

Acrylamide was extracted from samples (2.0g) with 10.0 ml high pure water. After extraction for 40 min with oscillation, the solution was centrifuged then filtered through 0.45 mm membranes. The acrylamide was separated by ion-pair reverse phase HPLC. The liquid chromatograph consisted of a Jasco integrated system (Japan) equipped with two model PU-980 pumps, a AS-950 automated injector, a MD-910 multiwavelength diode-array detector (DAD), and a FP-920 fluorometric detector (excitation 252 nm, emission 500 nm). A reversed-phase Tracer-Excel 120 ODS-A (250 × 4.6 mm) column (Teknokroma, Spain), was operated at 28°C, with a mobile phase of acetonitrile/ water = 4/96 and a flow rate of 1.0 mL min$^{-1}$. Quantification was carried out using calibration curves obtained with standard solutions of Acrylamide at 200nm, as recently reported (Kit and Fagt, 2004; Kristina et al., 2008).

*Statistical analysis*

All results were analysed using the statistical software SPSS 17.0. The average value and the standard deviation of five replications for each roasting condition were calculated.

## Results and discussion

*Effect of decreasing temperature on weight loss during roasting*

The results for weight loss during roasting at 250$^{o}$C are shown in Figure 1. The external color of the beans changed according to roasting time (8 min, 12 min, 14 min, 18 min and 20 min) from green to beige, brown, dark brown, dark and very dark, respectively. The mass loss values were 7.05, 12.34, 15.7, 21.8 and 24.27 %, for American roast, Vienna roast, French roast, Italian roast and Spanish roast, respectively. The weight loss rate was increased with increasing roasting time and

is probably attributed not only to water removal but also to volatilization of volatiles in crude coffee during the roasting stage. As the roasting time increased, the roasting process turned from the drying stage into the roasting stage, so the weight loss rate occurred faster during the last 10min.

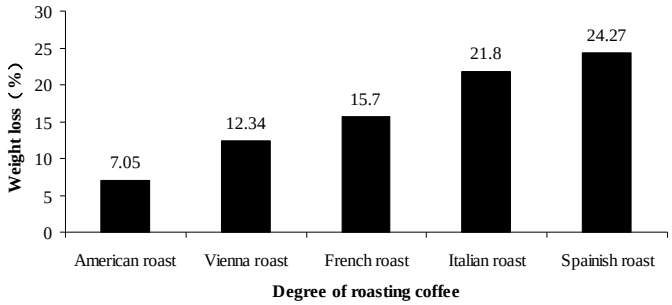


**Figure 1.** Weight loss during roasting at 250 °C

The weight loss results during different roasting temperatures for 20 min are shown in Figure 2. The roast temperature was 210, 220, 230, 240 and 250 °C, with weight loss values of 8.54, 11, 12.74, 18.12 and 24.27 %, respectively. Notice that higher weight loss was shown at higher temperature, indicating that coffee roasted faster at higher temperature. Weight loss increased with increasing roast temperature until the maximum value was reached at the highest temperature. On the other hand, lower temperature slowed down the weight loss rate.

*Effect of roasting conditions on the tannin content of coffee*

The tannin content results in green and Vietnam robusta coffee with different roasting degrees and temperatures ranged from 3.15 to 51.60 mg/10g as shown in Figure 3 and Figure 4. The results showed that the highest tannin content was observed in green coffee. Tannin content was lower than that reported by Savolainen (1992), who found that tannins content in Indian robusta green coffee beans was 660 ± 6 mg/100 g (Savolaien, 1992). On the contrary, there was another study which stated that tannin content of robusta green coffee was 27.00 mg/10g which was considered higher than in the present results (Clifford *et al.*, 1991).

According to Figure 3, it is obvious that tannin content was affected by roasting temperature. It decreases sharply with increasing roasting temperature. In green coffee, tannin content was 51.60 mg/mg followed by American roast and French roast (40.72 and 25.04 mg/10g, respectively). On the other hand, Italian roast and Spanish roast gave the lowest tannin contents (4.15 and 3.15 mg/10g, respectively). A possible reason might have been that most of the material was burned during the roasting process, the high color of coffee changed into dark or very dark, and the percentage of ash in coffee increased gradually. Figure 4 shows that tannin content followed the same decreasing trend with increasing temperature at a 20 minute roasting time. A roast temperature rising from 210° to 240°C slightly reduced tannin content. In this study, the tannin content for Vietnam robusta coffee

decreased during roasting; this result disagrees with the results of Savolainen (1992), which reported that tannin content of roasted coffee increased 3 times more than tannin content in green coffee (Savolaien, 1992).

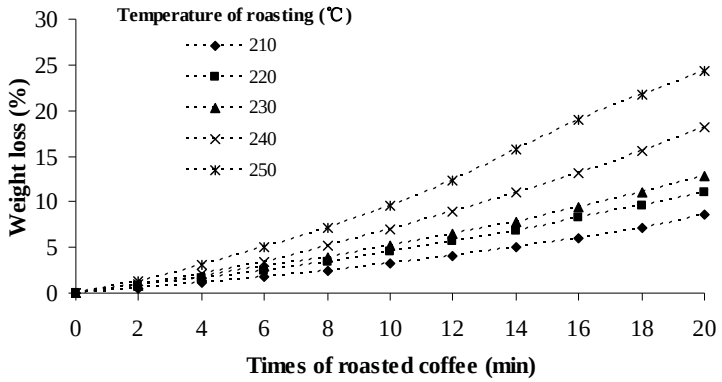


**Figure 2.** Weight loss at different roasting temperatures

*Effect of roasting conditions on the trigonelline content of coffee*

The quantitative determination of trigonelline content was carried out using a calibration curve of standard ($R^2$ = 0.9931). Figure 3 and Figure 4, respectively, show that the trigonelline content in green and Vietnam robusta coffee with different roasting degrees and temperatures ranged from 1.43 to 64.24 mg/10g. Results also showed that, at a 20-minute roasting time, the trigonelline content varied in roasted coffee under different roasting degrees (Fig. 3), for green Vietnam robusta coffee being 642.36 mg/100g. These values are in agreement with other studies that reported a trigonelline content, for the same type of robusta coffee, ranging from 66.00 to 68.00 mg/10g (Stennert and Maier, 1994) and 63.00 mg/10g (Casal *et al.*, 2005), 64.00 mg/10g (Franca *et al.*, 2005). The trigonelline content, at roasting degree levels from American roast to Spanish roast, has plummeted quickly. In the American roast, it was 12.72 mg/10g and in the France roast, its value was 1.43 mg/10g. On the other hand, Italian roast and Spanish roast did not have any trigonelline, as shown in Figure 3.

Similar results were obtained at 20-minute roasted coffee. The trigonelline content at 220$^o$C was 48.99 mg/10g, and then it reduced quickly with increasing temperature. At 230$^o$C the tannin content remarkably decreased to 9.83 mg/10g at 230$^o$C, while at 240$^o$C it was 1.70 mg/100g; at 250$^o$C, trigonelline was altogether absent, as shown in Fig. 4. A possible explanation may be that, during the roasting process, trigonelline partially degraded to produce two important compounds - pyridines and nicotinic acid. As a result, dark roast will only leave a fraction of its original trigonelline content. It was observed that trigonelline is thermally labile and degrades during the roasting process (Casal *et al.*, 2000; Perrone *et al.*, 2008).

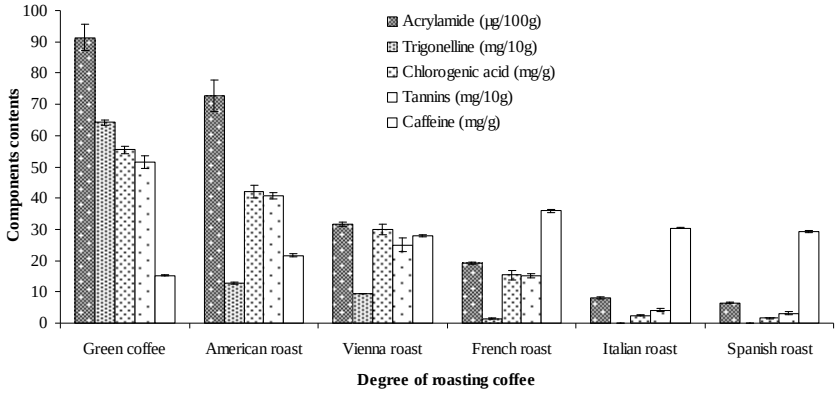


**Figure 3.** Content of caffeine, trigonelline, acrylamide, tannins and chlorogenic acids in green coffee and coffee roasted degree. Values followed by the same letter for a specific roasting degree do not differ significantly by the Duncan test at a 5% probability

*Effect of roasting conditions on the acrylamide content of coffee*

The quantitative determination of acrylamide content was carried out using a calibration curve of standard ($R^2$ = 0.9928). The acrylamide content in green and Vietnam robusta coffee with different roasting degrees and temperatures ranged from 6.53 to 91.36 µg/100g. In green coffee, the content was 91.36 µg/100g, and then declined with increasing roasting degree and temperature. In the process of roasting coffee from low to high level, the acrylamide content markedly declined with increasing roasting degree and temperature. It slightly reduced to 72.72 µg/100g in American roast and started to decline rapidly in Vienna roast, the lowest level being reached in Spanish roast, as shown in Fig. 3. Attendant decreasing of acrylamide content with increasing roasting temperature was also observed at 210 to 230$^o$C. The content slightly decreased to 54.67 µg/100g at 230 $^o$C and then started to decrease significantly at 240 $^o$C and 250 $^o$C (22.642 µg/100g at 240 $^o$C and 6.531 µg/100g at 250 $^o$C, respectively), as shown in Figure 4. The decrease of acrylamide content was inversely proportional to the rising of temperature, as well as of the roasting degree. Kristina et al. (2008) reported that a 240$^o$C roasting temperature for 7.5 min in Vietnam robusta coffee resulted in an acrylamide content of 65.30 µg/100g, which was in agreement with present results. Kristina et al. (2008) have also reported that acrylamide concentrations at 250$^o$C ranged from 31.00 to 76.00 µg/100g for each different type of coffee. These results are in line with many other studies. The acrylamide content in coffee may reach 70.80 µg/100g in Robusta coffee, and 37.40 µg/100g in Arabica coffee (Ascherio *et al.*, 2001). In another study, the content was 37.80 µg/100g and 25.10 µg/100g in Robusta and Arabica medium roasted coffees, respectively (Lantz *et al*, 2006). This difference seems to come from an increased content of asparagine in robusta raw beans in comparison with arabica beans. While a study reported that acrylamide levels in roasted coffee were much higher than the current results. Madihah *et al.* (2013) reported the contents of acrylamide in roasted Arabica coffee with

temperatures ranging from 150.02 to 179.90°C for 15-30 min to range in acrylamide content from 100.00 to 175.00 µg/100g. Moreover, the highest acrylamide content was observed in roasting at 179.9°C for 17-20 min (1750 µg/100g), which was much higher than the present study.

*Effect of roasting conditions on the chlorogenic acid content of coffee*

The quantitative determination of chlorogenic acid was carried out using a calibration curve of standard ($R^2$ = 0.992). The chlorogenic acid content in green and Vietnam robusta coffee with different roasting degrees and temperatures ranged from 1.54 to 55.51mg/g. The chlorogenic acid content was highest in green coffee, and then declined with increasing roasting degree and temperature. In different roasting degrees, the chlorogenic acid content markedly declined with increasing roasting degree. It slightly reduced to 42.20 mg/g in American roast, 29.94 mg/g in Vienna roast, and started to decline rapidly from French roast, the lowest value being reached in Spanish roast, as shown in Figure 3. The decreasing of the chlorogenic acid content with increasing roasting temperature was also observed at 210 to 230°C. It slightly decreased to 42.20 mg/g at a 220°C temperature, decreased also to 34.58 mg/g at 230°C and then started to decrease significantly at 240°C and 250°C (13.494 mg/g at 240°C and 1.54 mg/g at 250°C, respectively), as shown in Figure 4.

The decrease of chlorogenic acid content was inversely proportional to the rising of temperature, as well as of the roasting degree. These findings were lower than what was reported in other studies, ranging from 52.00 to 57.00 mg/g in arabica coffee and 75.00 mg/g in robusta coffee, from 41.00 to 57.00 mg/g in robusta coffee (Ky *et al.*, 1997), and from 61.15 to 86.42 mg/g in robusta coffee (Joon *et al.*, 2009). It was found that the content of chlorogenic acid in green robusta (Uganda coffee) was 88.04 mg/g and decreased during or after roasting process, the value being higher than ours (Somoza *et al*., 2003). Trugo *et al.* (1984) have reported that the content of chlorogenic acid in roasted robusta coffee (from light to very dark) ranged from 17.6 to 59.7 mg/g, being the same with the one in this study. Moreira *et al*. (2005) have reported that the chlorogenic acid content ranged from 19.00 to 25.20 mg/g, from 27.00 to 31.00 mg/g (Schrader and Kiehne, 1996), and from 16 to 20.5 mg/g (Joon *et al.*, 2009), all lower than the values in our studies.

*Effect of roasting conditions on the caffeine content of coffee*

The quantitative determination of caffeine content was carried out using a calibration curve of standard ($R^2$ = 0.9825). The caffeine content in green and Vietnam robusta coffee with different roasting degrees and temperatures ranged from 15.30 to 35.91 mg/g. The caffeine content detected in green coffee was 15.30 mg/g, and was previously studied by Hecimovic *et al* (2011), who reported that the levels of caffeine in green coffee ranged from 6.60 to 20.70 mg/g, whereas other reports showed that it was lower than that observed in the current results, ranging from 10.10 to 11.90 mg/g (Belay *et al.*, 2008), from 9.60 to 12.60 mg/g (Farah *et al.*, 2006), from 7.30 to 10.70 mg/g (Franca *et al.*, 2005) and from 7.53 to 10.54 mg/g (Belay *et al.*, 2008).

The content of caffeine increased with the roasting degree (from American roast to Spanish roast), reaching the highest value at 35.91 mg/g in the French roast, and then gradually decreased to 29.24 mg/g in the Spanish roast, as shown in Figure 3. A similar trend of caffeine content was found as the higher roasting temperature, the higher the content of caffeine. It reached the highest value of 29.89 mg/g at 240$^{o}$C and reduced to 29.24 mg/g at 250$^{o}$C, as shown in Figure 4. Also, many other studies have reported that caffeine content increased during the roasting process, ranging from 10.10 to 11.90 mg/g (Belay *et al.*, 2008), from 9.60 to 12.60 mg/g (Farah *et al.*, 2006), and from 20.44 to 25.15 mg/g, and it was higher in the French roast (Joon *et al.*, 2009).

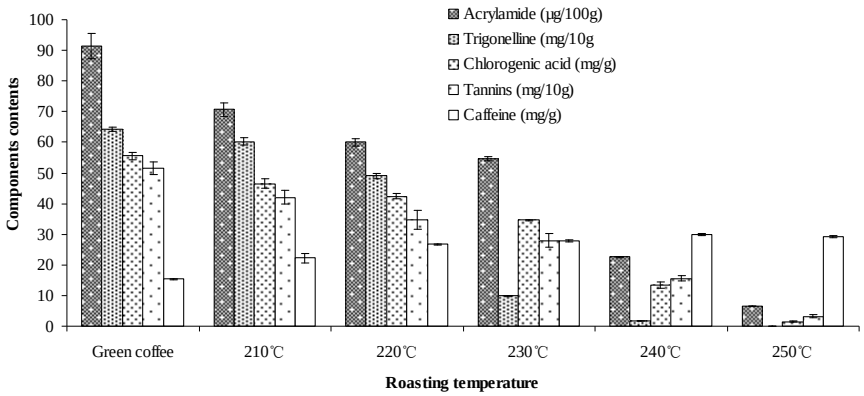


**Figure 4**. Content of caffeine, trigonelline, acrylamide, tannins and chlorogenic acids in green and different roasting temperatures of coffee. Values followed by the same letter for a specific roasting temperature do not differ significantly by the Duncan test at a 5% probability

Hecimovic *et al.* (2011) reported on the rise of caffeine from green, light, medium to dark roasted coffee, reaching the highest value of 10.70 mg/g in the case of light roasted coffee Minas, and of 22.40 mg/g in light roasted coffee. Furthermore, coffee Cioccolatato records 24.70 mg/g in the medium roasted coffee for Vienna roast and 25.20 mg/g in the medium roasted Cherry coffee. On the contrary, there are some reports that show that caffeine content reduced during the roasting process, which was contrary to the present results. Franca *et al.* (2005) showed that there was a decrease in caffeine levels from 10.70 to 17.30 mg/g in green coffee and from 5.10 to 6.70 mg/g in roasted coffee.

In this study, Vietnam robusta coffee was roasted with different degrees of roasting, starting from American roast to Spanish roast, and with different roasting temperature, from 210 to 250$^{o}$C. The content of the five different types of coffee was measured, and each experiment was repeated 5 times to get accurate results.

## Conclusion

The results of this study showed that the contents of all measured compounds in green coffee were higher than roasted coffee, with the exception of caffeine. Gradual weight reduction was observed during the first 10-12 min due to the slow release of water and volatile components. After that interval, the weight loss rate increased, which can be attributed to an intensive release of organic compounds and $CO_2$ due to pyrolysis. For the five types of compounds analyzed in this experiment, the contents of trigonelline, acrylamide, tannins and chlorogenic acids in green coffee were highest. As the roasting degree and temperature increased, the content of these compounds decreased. In addition, trigonelline was absent when the roasting degrees were Italian and Spanish, as well as when the roasting temperature was 250$^{o}$C. During the roasting process, the content of caffeine increased gradually until reaching the highest value in the French roast and then decreased gradually.

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