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Changes in Properties of Coffee Brew Due to Roasting

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Abstract: Roasting of Arabica coffee beans was carried out in a batch-type rotary heating unit using about 2 kg of test sample under controlled heating of product at a temperature of 170, 190 or 210°C. The roasting duration was varied from 0 to 70 minutes through intermittent sampling of coffee beans at selected time intervals. The pH, light transmittance and sensory quality of coffee brew prepared from withdrawn samples were determined. The pH of brew initially decreased with increase in roasting duration and reached minimum levels after approximately 20 minutes of roasting for all three roasting temperatures. Thereafter, the pH increased continuously with roasting time. The overall sensory quality of coffee initially increased and then declined with further roasting. Although light transmittance in brew depended upon the wavelengths, its values increased at the start of roasting and then declined for all wavelengths in the range of 400 to 700 nm.

Key words: Coffee . roasting . coffee brew . sensory quality . properties

INTRODUCTION

The real quality of coffee rests in the final cup quality as defined by the aroma and taste attributes of the brew. Both the aroma and taste can be described using many terms which have been developed in the history of coffee drinking. However, the perceptions of quality still vary widely due to individual and cultural differences [1].

Published work on quality of coffee brew is scanty and incomplete since researchers have mostly concentrated on the commercially available roast coffee (ideal roast) and many have reported the results subjectively. Even with over 700 compounds of coffee aroma already identified many more compounds remain undetected and the particular compounds responsible for the different sensations of coffee aroma and taste have not been positively identified. Some researchers [2-4] have shown that there exists a good correlation between the amount of free acid and sensory acidity. Sivetz and Desrosier [5] also found that the pH and transmittance of coffee brew increased when the roast degree was increased from 4 to 12% weight loss. Other properties that have been considered include surface tension, light refraction and viscosity [5-8].

The present work concerns with quantifying the change in pH, light transmittance and sensory quality of coffee brew over a large range of roasting degrees and conditions ranging from the green bean to very dark roasted beans. It is expected that the results will lead to a better understanding of the relationship between quality and degree of roasting.

MATERIALS AND METHODS

Equipment: The equipment used to roast the coffee beans is shown in Fig. 1. This rotary heating unit consisted of an inner cylinder with two-cm deep straight flights welded on its inner surface to assist in tumbling the coffee beans as the cylinder rotated. The rear side of this cylinder was mounted on to a drive shaft using four bolts which allowed it to rotate about a horizontal axis. The front of the cylinder was covered with a bolted 3-mm thick steel sheet, which had small perforations to allow the gases to escape during roasting. A small hinged flap on this cover could easily be swung back when loading or when withdrawing a sample from the roster.

The heating chamber was made by covering both the back and sides of the rotating cylinder leaving a 5-cm thick air gap [9]. To reduce heat loses, the inner surface of the enclosure was covered with two layers of 0.32 cm thick asbestos sheets while the outer surface was covered with a 5 cm thick layer of microfibre. Four heater elements were placed in between the cylinders in such a way that they occupied at least half the circumference of

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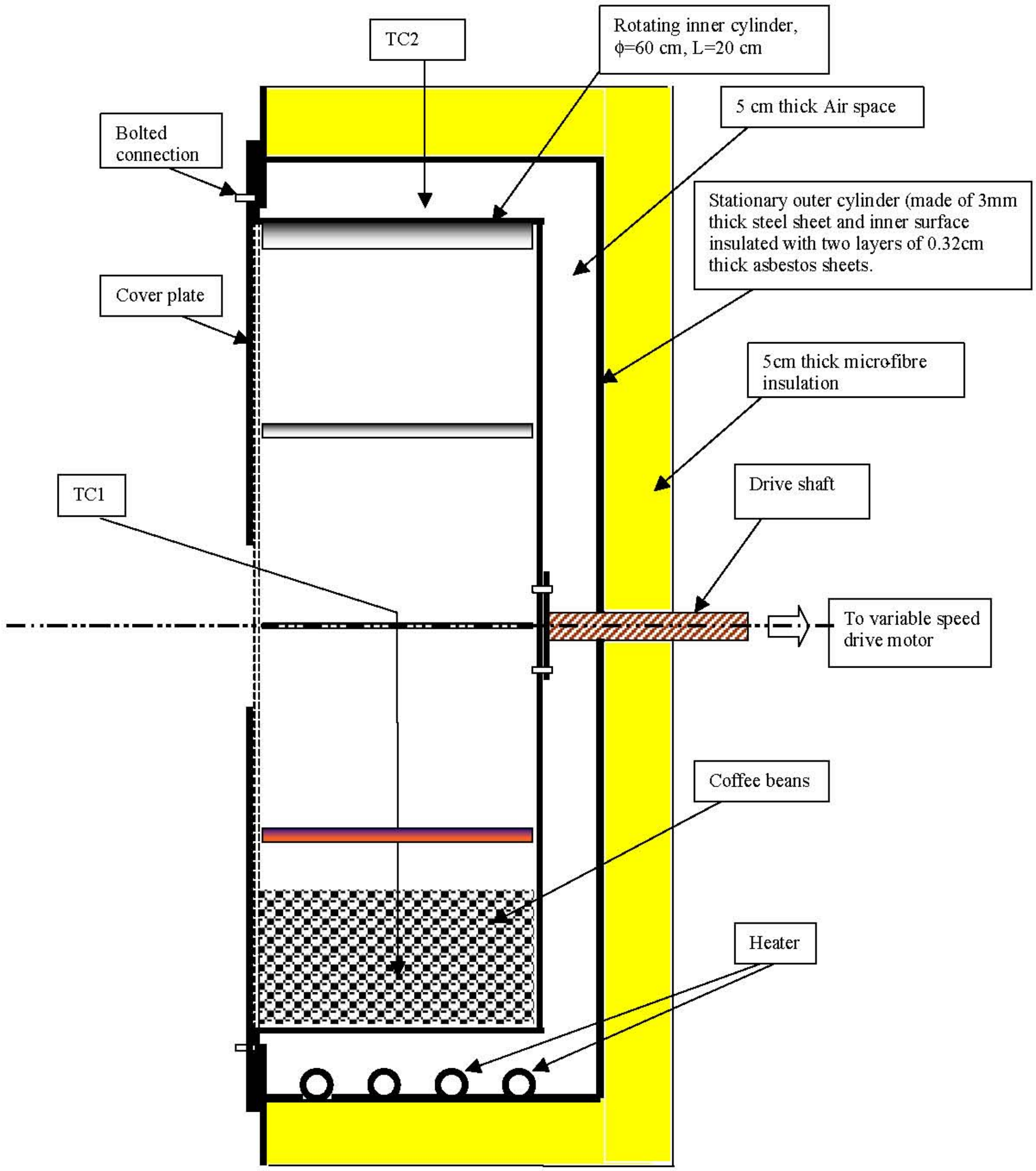

Fig. 1: Diagram of the laboratory roaster showing the position of measurement of coffee beans (product) temperature (TC1) and cylinder surface temperature (TC2)

the air space. Thus the entire air space surrounding the inner cylinder had a nearly uniform temperature and could reach a maximum of about 270°C when under no load. This air temperature was also assumed to be nearly equal to that of the surface of the inner cylinder and is therefore hereafter referred to as cylinder surface temperature.

Both the rotary cylinder and the electrically heated enclosure were supported on a frame made of 5-cm diameter mild steel pipes. This frame also supported the 1-kW variable speed motor used to rotate the drive shaft at a speed of 10 RPM.

Temperature measurement and control: Both the temperature of the cylinder surface and the coffee beans (product) temperature were measured using a 21X data logger (Campbell Scientific, Inc) and K-type thermocouples. The position of the both thermocouples is shown in Fig. 1. For the coffee beans temperature the thermocouple was sufficiently immersed in the tumbling

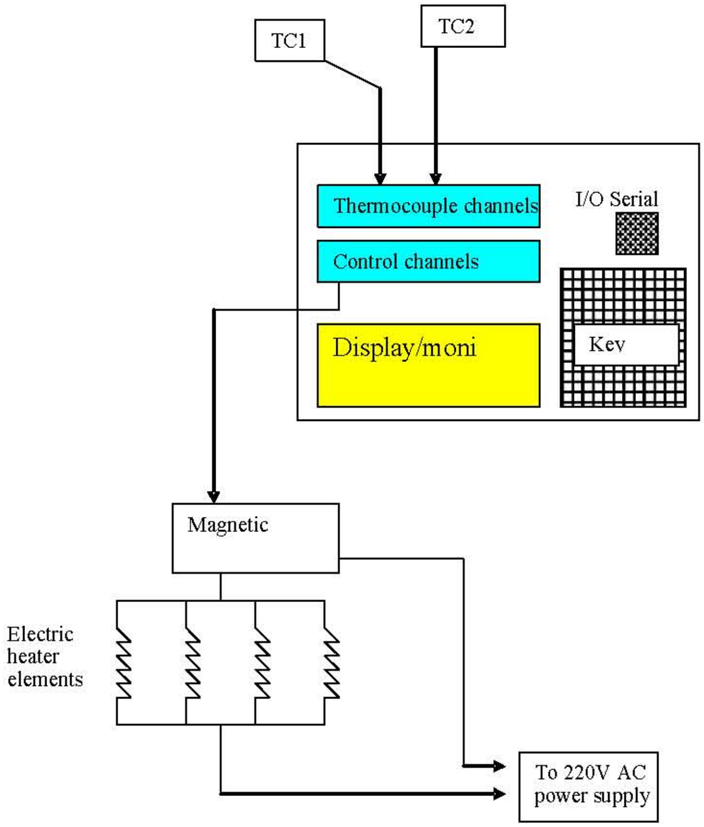

Fig. 2: A schematic diagram of the temperature measurement and control system using thermocouple signals TC1 and TC2

mass of moving coffee beans enclosed inside the rotating cylinder while being far enough from the heating surface to prevented contact with the cylinder flights. A second K-type thermocouple sensed the air temperature between the stationary and rotating cylinder hereafter referred to as cylinder surface temperature. The output of the thermocouples was recorded and stored by the data logger every 15 seconds. This data was latter transferred to a personal computer using a Campbell SM192 storage module and an RS-232 interface.

It was possible to control the temperature the coffee beans by means of an on-off control of the power supply to the electrical heaters. A signal from the data logger could automatically switch-off the heaters when the temperature equaled or exceeded the set value and then switch on automatically when the temperature fell to a value more than 1°C below the set value (Fig. 2). The data logger was programmed to compare the actual temperature and the set value after every 15 seconds and then send an appropriate signal to the magnetic switch. Thus the temperature being controlled could be maintained within $\pm 5^0$C during roasting.

Experimental setup: The parchment Coffee was hulled and cleaned with an air blower. The resulting green coffee beans were then introduced into the roaster. The cylinder surface temperature was first raised to 240°C before introducing the coffee beans. This initial heating ensured a quick rise in the temperature of the coffee beans. On introduction of the coffee beans the data logger was activated to control the temperature of coffee beans using thermocouple TC1. The set values in this case were 170, 190, or 210°C and each run was also repricated once.

In all experiments a 2-kg batch load of coffee was initially put into the roaster and the speed was maintained at 10 RPM throughout. On introducing the coffee beans the control program was set to maintain the cylinder surface or coffee beans temperature at the desired level and samples of approximately 100 g were periodically withdrawn until the end of the roasting duration. Withdrawal of the samples did not significantly change the volume of coffee in the roaster because of the corresponding increase in volume due expansion of coffee beans during roasting. These samples were later used to determine the transmittance, pH and sensory quality of the brew.

Preparation of coffee brew: The infusion method as described by Illy and Viani [4] was used for the preparation of the coffee brew. Samples of roasted coffee were ground and sieved to pass through ASTM No.18 sieve. About 6g of ground coffee was put in a labeled cup and 100g of de-ionized boiling water poured in. After resting for about two minutes the spent grounds were filtered living a clear coffee brew.

Light transmittance and pH of coffee brew: A Philips spectrophotometer (UNICAM 8620 UV/VIS, type Pu 8620/00, Model No EE419191) was used to measure the transmittance of the coffee brew at wavelengths of 400, 500, 600 and 700 nm. The pH was measured using a pH meter (Model SK-80TRH, Sato Keiryoki, Japan).

Sensory evaluation of quality: It is recognized that there exists a distinction between the features of quality and those of popular appeal. This distinction can be made by professional tasters who have both the vocabulary pertinent to the coffee quality indicators and a depth and breadth of coffee tasting experience [5]. The sensory evaluation of coffee quality by a trained and experienced taster can therefore be classified as "objective" because it refers to definable variables of taste and aroma and can be reproduced by other experienced tasters [1].

In this study, a single panelist with considerable experience of more than 20 years in the coffee industry conducted the test. The panelist performed a through evaluation of the taste and aroma and recorded an overall score for each attribute on a standard information sheet. The nine-point hedonic scale was used in sensory evaluation of each attribute. A score of either 9 or 0 represented the extreme for any attribute depending on whether the particular attribute is considered desirable or not.

A maximum of 12 cups of coffee brew per session was offered for sensory evaluation. The cups were arranged on a long rectangular table in such a way that the sample having the lowest roast degree was first while the darkest roast was tasted last. This arrangement helped to avoid the overwhelming taste of a sample prejudicing that of another as explained by Rothfos [1]. A spiting sink and cleansing water was provided.

RESULTS AND DISCUSSIONS

The change in the temperature of coffee beans with duration of roasting is shown in Fig. 3. It is obvious that the temperature initially rose sharply and reached the set value in less than 20 minutes. Thereafter the control system maintained the product temperature fairly constant with minor fluctuations of ±5°C.

Changes in transmittance of coffee brew due to roasting operation: It is known that a solution transmits its own color and absorbs complimentary colors. Therefore, a high transmittance value at a particular wavelength indicates that the solutions pigment concentration has the color associated with that wavelength. The transmittance of coffee brew prepared from samples roasted at 170, 190 and 210°C is shown

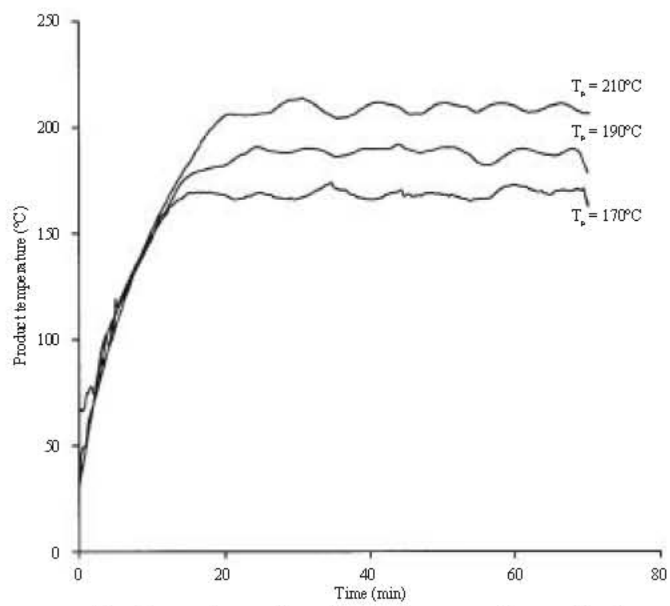

Fig. 3: Product temperature as a function of roasting time when roasting cofee beans under controlled product temperature conditions

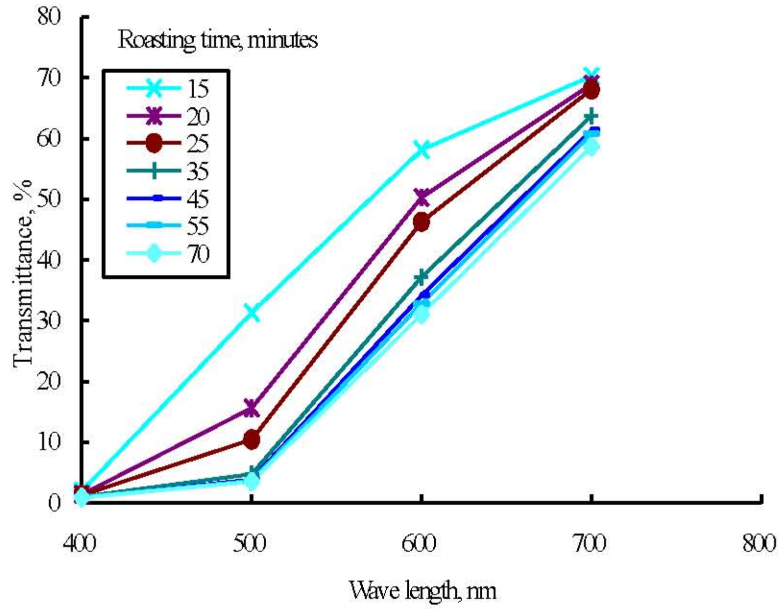

Fig. 4: Transmittance of coffee brew as a function of wave length and roasting time for coffee roasted at a controlled product temperature of 170°C

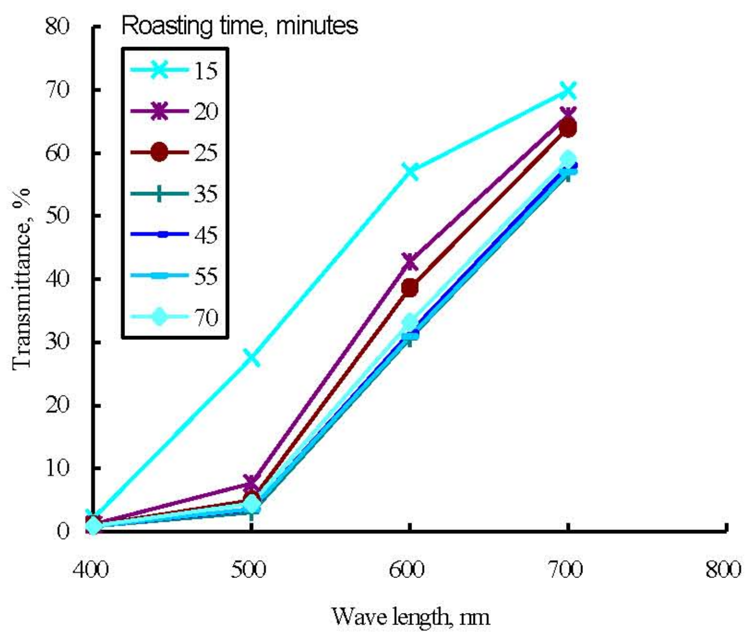

Fig. 5: Transmittance of coffee brew as a function of wave length and roasting time for coffee roasted at a controlled roasting temperature of 190°C

in Fig. 4-6. In general, the transmittance of the brew increased with an increase in the wavelength in the range of 400 to 700 nm. The differences in the transmittance curves of brew at 400 nm prepared from coffee roasted at different product temperatures were small and could not be easily discerned in Fig. 4-6. Also the effect of roasting duration was relatively more obvious in case of the transmittance of brew determined at 500 and 600 nm for all roasting temperatures.

The changes in transmittance of brew at wavelengths of 500 and 600 nm are presented as a function of roasting time in Fig. 7 and 8, respectively. At the 500 nm wavelength, the transmittance of coffee brew increased slightly initially and then decreased

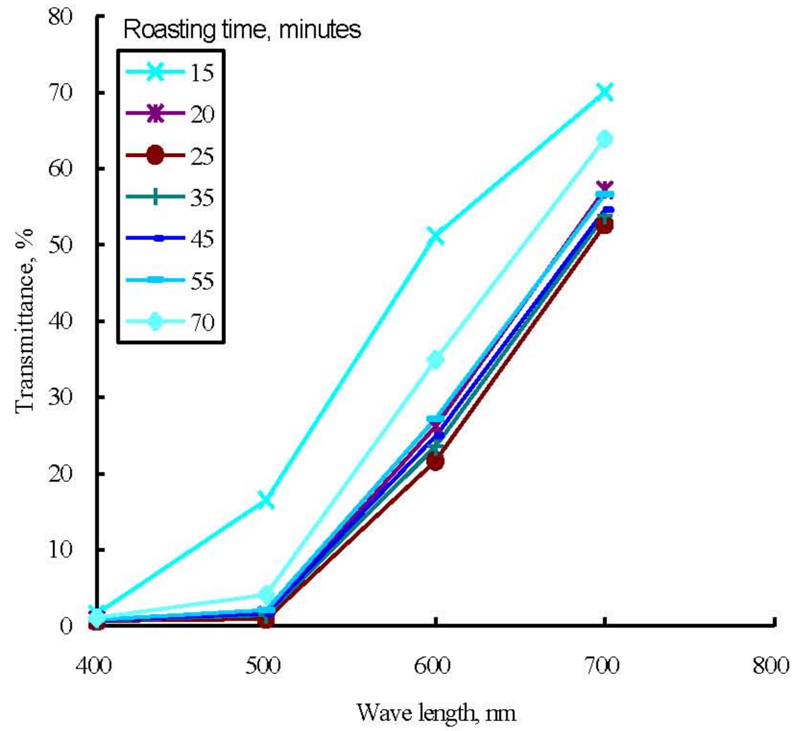

Fig. 6: Transmittance of coffee brew as a function of wave length and roasting time for coffee roasted at a controlled product temperature of 210°C

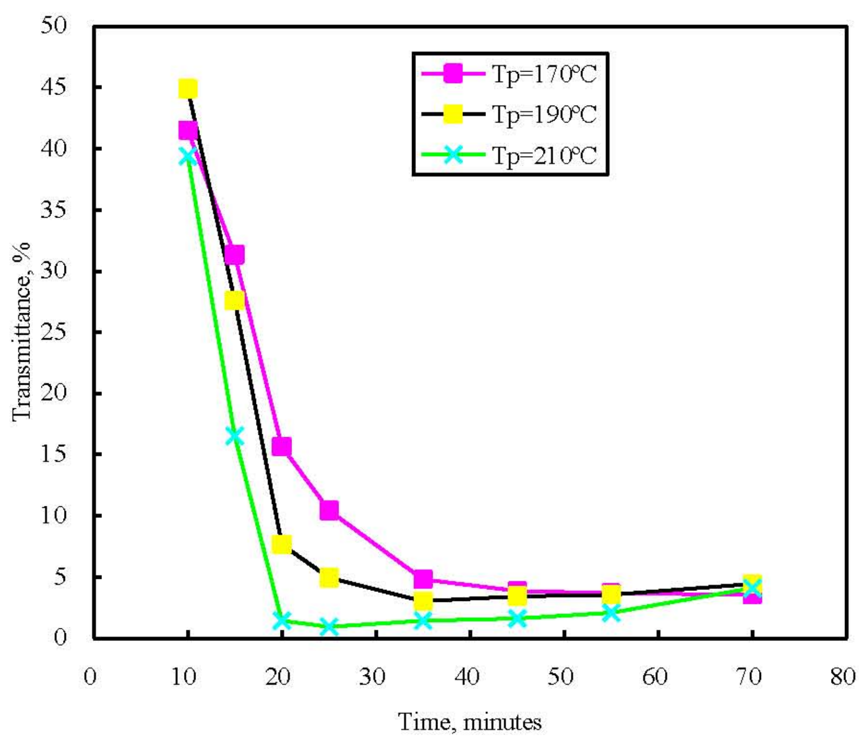

Fig. 7: Light transmittance in brew at a wave length of 500 nanometer as a function of time for coffee roasted under controlled product temperature conditions

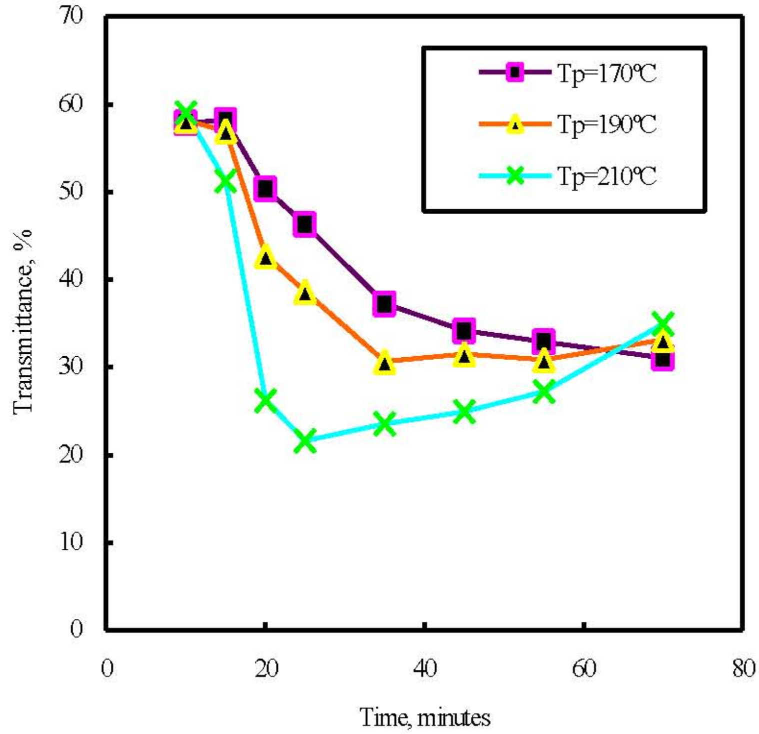

Fig. 8: Light transmittance in brew at a wavelength of 600 nanometer as function of time for coffee roasted under controlled product temperature conditions

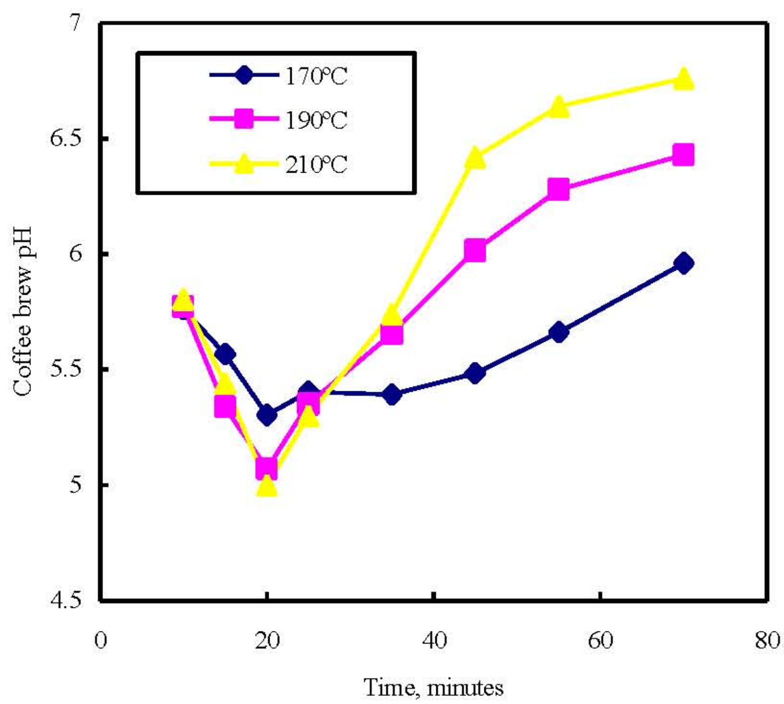

Fig. 9: The pH of coffee brew as a function of roasting time when roasting coffe under controlled product temperature conditions

continuously for the remainder of the roasting period. The decrease in transmittance after the initial rise was relatively faster for the higher level of roasting temperature used. At the wavelength of 600 nm (Fig. 8), light transmittance increased to slightly initially and this was then followed by a general decrease in yellowness (the predominant color) with time. For the controlled product temperature roasting at 210°C, the lowest value of transmittance was reached after 25 minutes and was followed by a gradual increase in transmittance thereafter.

The trends followed by the transmittance of brew in Fig. 7 and 8 were typical for the selected wavelengths and product roasting temperatures. It was also observed that the change in transmittance with wavelength had a definite shape at all roasting times and only its magnitude changed.

pH of coffee brew: The moisture content of the green coffee beans prior to roasting was 12.6% db and the pH of brew prepared from this coffee was found to be 5.85. It is well recognized that the pH of brew depends on the method of preparation, type and age of the coffee [8]. In the absence of any reported data on the pH of green coffee brew, it was not possible to compare the experimental values obtained in present study.

The change in pH of brew as a result of roasting of coffee beans is shown in Fig. 9. The pH first decreased with time of roasting to reach its lowest value of about 5.0 after 20 minutes of roasting. Thereafter, the pH showed a continuous increase in its value with roasting time. The highest values of pH were 5.90, 6.43 and 6.76 for roasting temperatures of 170, 190 and 210°C, respectively. At high values of pH, the coffee would normally be considered watery if under roasted or as flat (or bitter) if over-roasted [1]. The reported values of pH of coffee brew prepared from roasted Arabica coffee under normal conditions range from 4.85 to 5.4 [1, 4, 5]. In the context of present study, these values of pH correspond to about 20 to 35 minutes of total roasting duration as indicated in Fig. 9.

Sensory quality: The coffee brew was evaluated only for samples subjected to the roasting operation for at least 25 minutes or longer. This was the period considered necessary to develop the essential coffee taste and aroma, since samples roasted for shorter periods of time had distinctive flavor resembling to the cereals.

An overall sensory score as a measure of the general quality of coffee brew at the three roasting temperatures is presented in Fig. 10 as a function of time. It appeared that this overall score was a function of the roasting temperature and time. The highest taste overall scores recorded for the coffee brew were 5.5, 6.4 and 6.0 for the roasting temperature of 170, 190 and 210°C, respectively. Figure 10 shows that the sensory score at a roasting temperature of 210°C was 6.0 at the 25th and 35th minute of sampling but fell rapidly thereafter. It is therefore possible that the peak score was a value higher than 6.0 and occurred sometime between the two sampling intervals of 25 and 35 minutes. Also, the peak score for roasting at 190°C occurred between the 35th and 45th minute of roasting

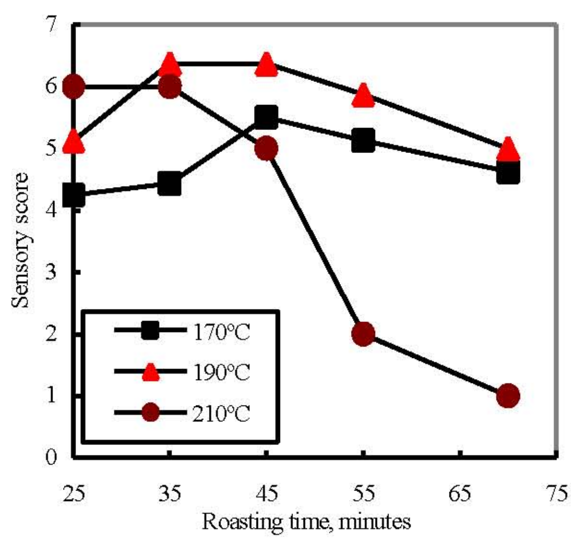

Fig. 10: Sensory score of coffee taste as a function of roasting time for coffee roasted at controlled product temperatures

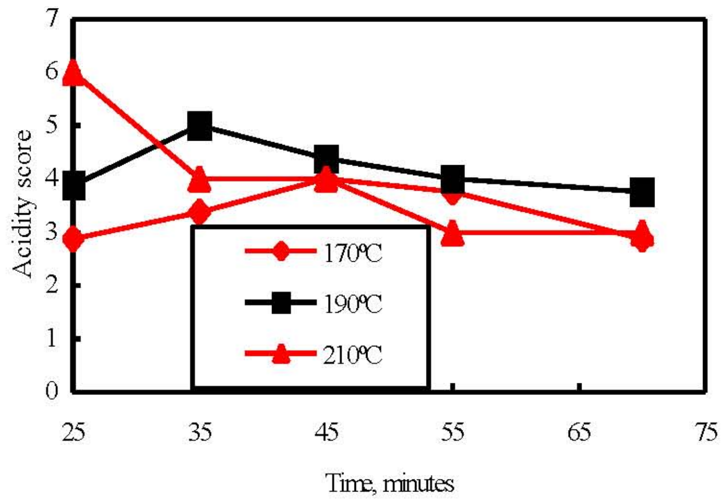

Fig. 11: The sensory acidity of cofee brew for cofee as a function of roasting time for coffee roasted under controlled product temperature conditions

while the peak value for roasting at 170°C occurred in the neighborhood of the 45th minute. These results indicated that coffee roasted at constant product temperature of 190°C resulted in highest values of sensory scores of the brew.

The sensory score of acidity of coffee brew is presented in Fig. 11 as a function of roasting time. It was noted that there was a peak acidity score for each roasting temperature and that the peak value increased with increase in temperature. Also, the roasting duration required to reach the peak value decreased with increase in temperature. There was poor correlation ($R^2 = 0.147$) between sensory acidity and pH values indicating that perceived acidity was not directly related to hydrogen ion concentration. This has also been observed by Maier [3].

CONCLUSIONS

The transmittance of coffee brew is dependent on the roasting degree and time-temperature history during roasting. There is a distinct continuous change in light transmittance with time-temperature history of coffee beans and wavelength of transmittance in the range of 400 to 700 nm. The highest quality of coffee brew as indicated by overall sensory score was obtained in the range of 25 to 45 minutes depending on temperature of roasting. This also corresponds to the pH values of 4.85 to 5.40 reported in literature.

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