ORIGINAL ARTICLE

Roasting green coffee beans using spouted bed roaster: changes in physical characteristics

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Abstract Pea-berry grade of green coffee (*Coffea arabica*) beans were roasted in a laboratory model spouted bed roaster at different temperatures (150–250°C) and times (30–300 s). The roasted samples were analysed for instrumental colour (hue, chroma and brightness) and texture. Brightness of the roasted samples varied between 5.2 and 20.4%, and time of roasting markedly decreased the brightness values. The chroma showed a curvilinear decrease with both time and temperature of roasting; the lowest values were with highest roasting times and temperatures. The hue or dominant wavelength increased from 576 to 603 nm due to roasting. The maximum force offered by the roasted beans decreased with temperature and/or time of roasting. An appropriate condition for spouted bed roasting of green coffee beans was obtained considering colour of samples and desirable low failure/fracture force.

Keywords Coffee beans · Instrumental colour · Roasting · Spouted bed

Introduction

Conversion of green coffee bean into a consumable fragrant beverage by roasting process is followed in which beans undergo a series of reactions leading to the desired changes in chemical composition (Dutra et al. 2001) and green coffee beans acquire a delicate dark brown colour having characteristic flavour profile. The roasting process exposes the beans to a dry heating temperature of more than 180°C that is sufficiently rapid enough to drive off the free and bound moisture (Sivetz and Desrosier 1979). This high temperature leads to pyrolysis (thermal decomposition in addition to marked chemical and physical changes) and the kinetics of these remarkable changes is a function of time and temperature (Clarke and Macrae 1987).

The present study employed the spouted bed roasting (SBR) technology which operates on the principle of high temperature short time processing. The spouted bed roaster, an alternate to fluid bed roasting, is also suitable for particulate solids like green coffee beans and similar materials (Nagaraju et al. 1995). Although the areas of application of a spouted bed overlap with fluid bed system, the functional mechanism in the two cases is different (Epstein and Grace 1984). A steady axial jet causes agitation of particles in a spouted bed technique, while it is regular and cyclic in fluid bed system. There is very good mixing of solids and effective gas-particle contact in SBR which facilitates HTST processing and provides clean uniformly roasted products (Nagaraju and Ramalakshmi 2002).

With the advancement of the instrumentation and technique of measurement, it is now possible to determine the colour of the sample in short time and the measured values can easily be simulated with the physical changes. In the present scenario, the colour measurement techniques such as Hunter system (Lab) and L*a* and b* and Commission Internationale de l'Esclairage (CIE) systems are most popularly used for colour measurement. Hunter system can only partially explain the colour of a sample and CIE system can generate data in terms of 3 basic tristimulus characteristics such as hue, chroma and brightness making it possible to express colour completely. However, CIE values for colour changes in green coffee beans are not available.

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In the post-roasting step, the materials are subjected to mechanical stresses to render the cellular structure into fragments. The production of CO_2 during roasting causes the grain to expand leading to softening of native bean structure. In the HTST roaster, the pressure of gas may vary from 15 to 25 atmospheres (Pintauro 1969), which is directly responsible for the bean to swell.

It is, thus, desirable to have colour and texture data of raw and roasted beans that would help in understanding the behaviour of the beans and for designing specific grinding systems because the roasted beans are conveniently used as powders. The objective of the present study was to determine the effect of time and temperature of roasting of green coffee beans on physical characteristics such as colour and texture of the product roasted by employing a SBR.

Materials and methods

Roasting of green coffee beans Green coffee (*Coffea arabica*) beans (Indian pea-berry) were procured from local market and after removal of impurities and immature seeds, they were roasted in batches of 500 g in a SBR. The schematic diagram and details of the roaster have been described earlier (Nagaraju and Ramalakshmi 2002). After adjusting the required temperature, green coffee beans were discharged into the roasting chamber of the SBR and roasted. The roasted coffee samples were drawn quickly from the roasting chamber after the desired roasting time. The time and temperature of roasting were varied between 30 and 300 s and 150 and 250 C, respectively. On cooling, the roasted samples were collected in HDPE pouches, and samples were analysed for colour and texture. The number of repetitions of roasting process were two. The moisture content and total soluble solids were determined according to AOAC (1990).

Colour measurement The colour of coffee beans, prior to and at different stages of roasting, was determined by using a colour meter (Shimudzu Spectrophotometer, Japan) with reflective attachment employing illuminant C. The colours of samples were measured within 2 h of roasting, and were reported in terms of hue, chroma and brightness as per CIE system. Each time, 5 samples were tested for colour measurement and the mean values are reported.

Texture Coffee beans, raw and roasted, were subjected to compressive stress by employing a Universal testing machine (Model 4301, Instron, UK) at a crosshead speed of 50 mm for 1 min. The extent of compression was 50% and 10 samples were tested each time. The peak force or failure force, whichever was higher during compression, has been reported as maximum force.

Data analysis The independent variables were the roasting temperature and time. The contour graphs were generated by fitting response data to second order polynomial against these 2 independent variables (Bhattacharya et al. 2006). The optimized zone of roasting was obtained by superimposing 2 required contour plots of response functions (texture and brightness) and finding the desirable zone.

Sensory evaluation The brew was prepared for sensory assessment by adding 100 ml of boiling water to 5 g of coarsely ground freshly roasted sample and extracting. The extracted brew was evaluated by 8 panelists using descriptive profile method in order to study the strength and organoleptic properties of the roasted coffee.

Results and discussion

Colour The hue, indicating the dominant wavelength of the sample, varied from 576 and 603 nm for roasted coffee beans (Fig. 1). These values are comparable with that of raw beans which has a hue of 582 nm. Any increase in time and/or temperature of roasting markedly increases hue indicating a shift of colour towards red for the roasted samples. Intense processing involving a combination of high levels of both these variables is associated with hue values even more than 600 nm. A low time of roasting below 80 s has a marginal effect on hue. The chroma, an indication of samples' own colour, shows a curvilinear relationship with time and temperature of roasting. The raw beans have a chroma of 52.9% while the roasted beans were in the range of 12.5 and 45.3% (Fig. 1). Low chroma values are associated with higher time and temperature combinations. This trend indicates that the raw beans change the characteristic green colour to dark brown while roasting. The rate of change of slope, an indication of the effect of time and temperature, is high at low temperatures while an opposite trend is observed at high temperatures. This implies that a change in chroma is more dependent on temperature compared to time of roasting.

The brightness of the sample is indicative of its reflecting power in comparison to incident light. The brightness of raw and roasted beans was 28.5, and between 5.2 and 23.6%, respectively, and was primarily dependent on time of roasting while the effect of temperature was marginal (Fig. 1). An increase in the time of roasting progressively decreased the brightness of sample such that highly dull samples take longer roasting time (more than 250 s). The sample loses all its brightness to appear as dull black and was disliked by the panelists. On the other hand, panelists liked samples with a dark brown colour having a

(a) Hue or dominant wavelength

(b) Chroma

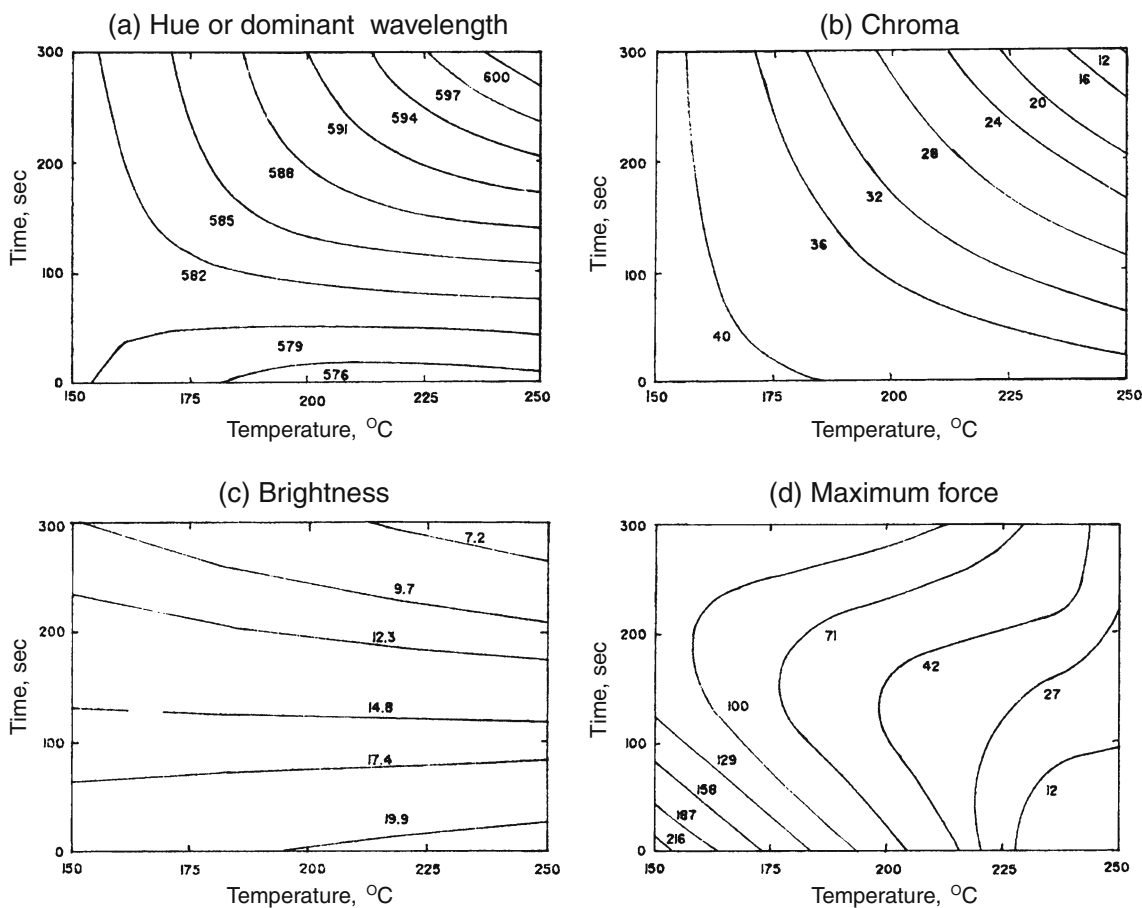## (c) Brightness

(d) Maximum force

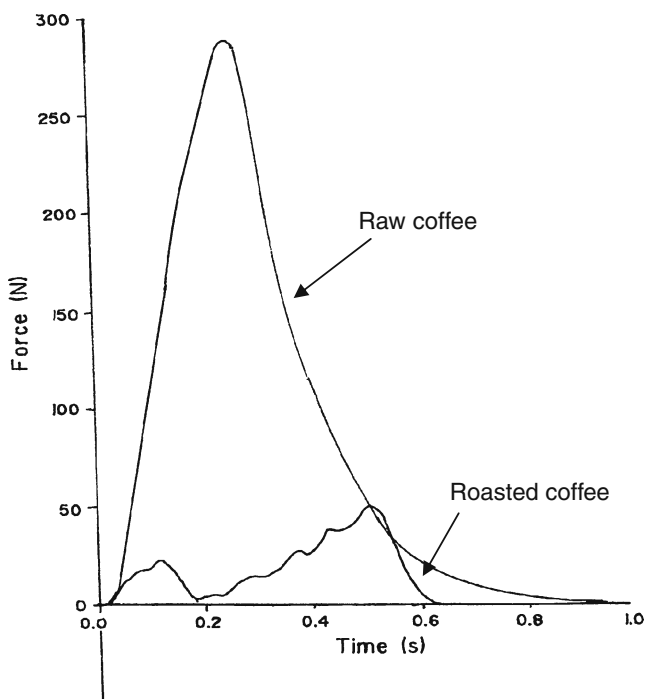Fig. 1 Physical changes in coffee beans as a function of time and temperature of roasting

Fig. 2 Sample compression curves for raw and roasted (at 250°C) coffee beans

brightness value above 10%. To obtain this desirable value, the time of roasting should be below 200 s.

Texture Marked change in texture of beans occurred due to roasting as evidenced by the sample compression curves for raw and roasted beans (Fig. 2; Table 1). The raw bean showed a tough texture having a peak force in the range 250–300 N and high firmness without fracture. On the other hand, roasted beans showed multiple fractures during compression to give 4 to 7 pieces, and low magnitudes of fracture forces; low values (less than 25 N) are associated

Table 1 Product characteristics of roasted coffee samples using spouted bed roaster

Inlet air temp, °C	Time, sec	Product Temp, °C	Moisture[a] after roasting,%	Total soluble solids[a],%
200	360	175	1.3	31.7
225	300	190	1.9	35.2
240	300	200	1.8	36.2
250	180	210	1.4	36.4

[a] (n=4)

only when the roasting temperature was more than 225 C (Fig. 1). A low fracture force is desirable considering the conversion of coffee beans into powder, the form in which the roasted coffee beans are used. Low temperature roasting resulted in hard textured beans because the beans got dried in this condition instead of roasting.

Optimisation The sensory assessment of the roasted coffee beans indicated that dark brown colour was more preferred by panelists than very dark black ones; the brightness values, in such a situation, were between 10 and 12%. Considering the low maximum value of less than 30 N, the superimposition (graph not included) of Fig. 1c and d yields the optimized values of temperature and time of roasting as 237–250 C and 180–240 s, respectively. The quality of sample (T_1), in terms of desirable low moisture (less than 2%) and high soluble solids (about 36%) content also matches with the optimized roasting conditions.

Conclusion

Roasting green coffee beans in the spouted bed roaster led to marked change in colour and texture of products. Roasting process drastically reduced the brightness of samples but sensory assessment indicated that dark brown roasted beans were preferred over very black samples. The raw beans did not show any fracture during compression up to 50% level but offered a very high resistive force. On roasting, the seeds became brittle with low fracture forces. An optimized combinations of temperature and time of roasting were 237–250 C and 180–240 s, respectively considering the brightness and maximum force of samples.

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