COMPARATIVE STUDY OF SENSORY PROPERTIES AND COLOR IN DIFFERENT COFFEE SAMPLES DEPENDING ON THE DEGREE OF ROASTING

Przemysław Dmowski, Joanna Dąbrowska
Gdynia Maritime University
Poland

ABSTRACT

According to market research on Polish consumers, color and aromatic components are very important in coffee beverages as they are the main constituents of the sensory experience of coffee drinkers. This study investigated the impact of degree of roasting on the evolution of coffee sensory features. Furthermore, the aim of the study was to evaluate the relationship between selected sensory parameters and L*a*b color values. The aroma profiles of coffee beverages were influenced by the degrees of roasting the coffee beans. Our study showed that there is evolution and change in the aroma characteristics from light to dark roasting coffee. Furthermore, our data do not show the significant correlation between selected sensory attributes and color parameters L*, a*, b.

Key words: coffee, color, market, sensory attribute.

INTRODUCTION

Coffee has been consumed for over 1,000 years and today it is the most consumed drink in the world. The global spread of coffee growing and drinking began in the Horn of Africa, where, according to legend, coffee trees originated in the Ethiopian province of Kaffa. Coffee began to be savored in Europe in 1615, brought by travelers. Germans, Frenchmen, and Italians were looking for a way of developing the plantation of coffee in their colonies [7].

Coffee is produced in a multistage process, with beans extracted from the berries of several species of evergreen bush belonging to the genus Coffea. The coffee tree or shrub belongs to the family Rubiaceae. Coffee beans are produced from the plant *Coffea L.*, of which there are more than 70 species. However, only two of these species are commercially explored worldwide: *Coffea arabica* (Arabica), is considered as the noblest of all coffee plants and provides 75% of world’s production; and *Coffea canephora* (Robusta), is considered to be more acid but more resistant to plagues, and provides 25% of world's production. *C. arabica* is a bush originally from Ethiopia and develops well in high altitudes (600 – 2000 m), while *C. canephora* plantations adapt well in altitudes below 600 m. The processing of coffee initiates with the conversion of coffee cherries into green coffee beans, and starts with the removal of both the pulp and hull using either a wet or dry method. The roasting of coffee beans is another very important step in coffee processing, since specific organoleptic properties (flavors, aromas, and color) are developed and affect the quality of the coffee and the excellence of the coffee beverage, as a consequence. This process is time–temperature dependent and leads to several changes in the chemical composition and biological activities of coffee as a result of the transformation of naturally occurring polyphenolic constituents into a complex mixture of Maillard reaction products, as well as the formation of organic compounds resulting from pyrolysis. Sulfur compounds are also changed by oxidation, thermal degradation, and/or hydrolysis, and the vanillin content increases considerably during the roasting process. Besides the chemical reactions during coffee roasting, moisture loss and other major changes (color, volume, mass, form, pH, density, and volatile components) occur, while CO_2 is generated [6]. Therefore, coffee roasting is a quite complex process considering the importance of the heat transferred to the bean. After the roasting process, coffee beans should be rapidly cooled in order to stop exothermic reactions and to prevent excessive roast, which might jeopardize the product quality [8].

1. COFFEE MARKET EXPANSION

The importance of coffee to the world economy cannot be overstated. It is one of the most valuable primary products in world trade, for many years second in value only after oil as a source of foreign exchange to producing countries. Its cultivation, processing, trading, transportation and marketing provide employment for hundreds of millions of people worldwide. Coffee is crucial to the economies and politics of many developing countries; for many of the world's Least Developed Countries, exports of coffee account for more than 50 percent of their foreign exchange earnings. Coffee is a traded commodity on major futures and commodity exchanges, most importantly in London and New York. The dynamics of world coffee production are generally characterised by considerable instability, with a large crop in one year frequently followed by a smaller crop in the next. Over the last 50 years, there has been steady growth in world production, interspersed with periodic falls. The average growth rate since 1963 was 2.4%, with 2.8% annual growth in the market-controlled period, and 2% since 1990. In crop year 2012/13, world coffee production reached 145.1 million bags, the largest on record. Analysis by type of coffee shows a dramatic growth in the production of Robusta, which increased from 18.8 million bags year during the regulated market period to 39.3 million bags from 1990/91 to 2012/13. Total

Robusta production in crop year 2012/13 is estimated at 56.5 million bags, representing a share of 38.9% of world coffee production, compared to 25.9 million bags in 1989/90, representing a share of 27.5%. This huge increase in the production of Robusta can mostly be attributed to the growth of Vietnam. Arabica production averaged 73.4 million bags for the period 1990/91 to 2012/13, compared to 57.5 million bags during the regulated market period, representing an average increase of 1.3 % a year. Total Arabica production in crop year 2012/13 is estimated at 89 million bags, accounting for 61.3 % of world production, compared to 68.3 million bags in 1989/90 (72.5% of world production) [8, 12].

Coffee is among the most widely consumed beverages in the World. Although some possible negative effects, such as spontaneous abortion and stillbirth have been suggested during pregnancy, habitual coffee consumption has been associated with a substantially lower risk of mortality as well as degenerative, progressive and chronic diseases, including Alzheimer's disease, Parkinson's disease, type 2 diabetes, and coronary heart disease. Coffee is the major source of caffeine. Some animal studies have reported caffeine to both stimulate and suppress tumors, depending upon the species and the phase of administration. Coffee contains two specific diterpenes, cafestol and kahweal, that give biological effects compatible with anticarcinogenic properties, including the induction of phase II enzymes involved in carcinogen detoxification, specific inhibition of the activity of phase I enzyme responsible for carcinogen activation and stimulation of intracellular antioxidant defence mechanisms. Coffee is an important source of polyphenols, such as lignan phytoestrogens and flavonoids, that exhibit anticarcinogenic properties in several laboratory and epidemiological studies. Coffee is also a major source of the chlorogenic acid that contributes to its antioxidant effect [3, 9, 10].

World consumption increased at an average annual growth rate of 1.9% over the last 50 years, from 57.9 million bags in 1964 to 142 million bags in 2012. This growth rate accelerated since 1990 to 2.1%, and to 2.4% since 2000. Total consumption in importing countries was estimated at 98.6 million bags in 2012 compared to 70.4 million bags in 1990 and 47.5 million bags in 1964. The leading coffee consuming countries are Germany (an average of 9.5 million bags a year), Japan (6.5 million), France (5.4 million) and Italy (5.2 million) [12].

In year 2012 green coffee imports in Western Europe achieved 54.8 million bags, and a small increase of 1.6% compared to the almost 54 million bags in 2011 was observed. The Western European market is dominated by the EU. Green coffee imports into the EU27 – including intra-EU trade – increased by 1.8% from 51.2 million bags in 2011 to 52 million bags in 2012. According to ICO data, Central and Eastern European imports of coffee in all forms in 2011 (the most recent year available for most of these) amounted to 7.2 million bags, 2.8% lower than the year before. In year 2012 green coffee import in Poland was 1.8 million bags, a small increase of 4.8% compared to the almost 1.70 million bags in 2010. In past years Vietnam, Laos, Brazil, Uganda and Peru were consistently the top-5 suppliers to Poland. In year 2012 coffee consumption in Poland was 1.9 million bags, a small decrease of 10.6% compared to the almost 2.16 million bags in 2010 [4].

In Poland coffee is also very popular beverage and it was shown evidence that consumers are very often interested in *pure* coffee or coffee of a single origin. According to Polish consumers, aromatic components are articularly important in coffee beverages as they are the main constituents of the sensory experience of coffee drinkers. Previous study showed that there are six factors that affect the sensory properties of coffee: plant varieties, growing region/conditions, processing methods (from coffee cherries to green coffee bean), roasting levels, grinding size, and brewing methods [2]. A few previous studies have also investigated the impact of coffee origin, degree of roasting and roasting time and temperature combinations on the formation of volatile compounds responsible for the coffee flavors and aromas [1, 5]. However, finding the relation between the content of the hundreds of volatile compounds present in coffee and the complex aroma of coffee is not an easy task. Sensory analysis has become a useful tool for quality assessment of coffee beans and brews.

This study investigated the impact of degree of roasting on the evolution of coffee sensory features. Furthermore, the aim of the study was also evaluation of the relationship between selected sensory parameters (black and brown color of coffee brew) and L^*a^*b color values.

2. MATERIAL AND METHODS

In this paper, the sensory features and color parameters (L^*a^*b) of coffee beverages of the *Coffee Arabica* samples from Guatemala were studied. Green beans of each coffee variety were roasted for 10 min in three roasting degrees (mild, medium, espresso), under the conditions displayed in Table 1.

Table 1. Applied roasting parameters of coffee beans

Parameters of roasting	Roasting degree		
	Light roasting Mild	**Medium roasting Medium**	**Dark roasting Espresso**
Temperature [°C]	192	195	198
Time [min]	10	10	10

Sensory properties

Sensory properties were evaluated by QDA method on the basis of certain quality markers of color, taste and aroma. Descriptive sensory analysis is still regarded as the most comprehensive and useful sensory method to obtain detailed information regarding perceived sensory attributes of sample products. However, there are problems associated with these descriptive sensory analyses. For example, it is time consuming and expensive to screen and train panelists involved in the studies.

Additionally, the unanimous consensus of trained panelists could induce a subjective bias caused by the characteristics of the panel group or the opinions held by the leader of the panel. Finally, the different perception of the same attribute when the sample is at different temperatures during evaluation, has been overlooked, especially for foods that are usually consumed when hot (e.g. coffee, tea, and soup). To address such problems, we had used a modified descriptive analysis, *Time Scanning Descriptive Analysis* (TSDA) according to Seo et al. [11].

A total of 50 g of ground coffee beans were then brewed with 1.200 mL of water. The temperature of freshly brewed coffee was around 85°C. A total of 180 mL of each coffee were presented in a paper cup coded with a random 3-digit number. The samples were served at a temperature range from 70°C to 60°C. Because the temperature of freshly brewed coffee was around 85°C, the samples were cooled at room temperature.

A total of 3 coffee samples were evaluated in two sessions on different days and all samples were rated three times. The samples were randomly presented to the trained panelists. In each session, the time interval between the sample presentations was 5 min, and after evaluation of the first three samples a 10 min break was provided prior to presentation of the other three samples. All attributes were evaluated on a structured 10 cm line scale that provided a zero to ten score range. The time required for evaluation of each attribute, the order of evaluation, and the time to break were then determined based on the results of the preliminary analyses. 10 s were allowed to evaluate each attribute, and additional 10 s were provided for a rest at the end of each sensory category. Moreover, to reduce fatigue, an additional 10 s break was allowed in the middle of the evaluation of the flavor and flavor-by-mouth/taste tests. During the evaluation, the staff checked the time and instructed the panelists to evaluate the sensory attribute according to the list of sensory attributes.

L, a*, b* parameters

CIE *L*, a** and *b** values of coffee beverages samples were determined with Konica-Minolta CR 400 colorimeter. The color values were expressed as L*, a*, and b* at any time. Color value, L*, indicates how brightness/darkness the sample is (varying from 0 black to 100 white), a* is a measure of greenness/redness (varying from -60 to +60), and b* is the grade of blueness/yellowness (also varying from -60 to +60). All the experiments were performed in triplicate.

Statistical analyses

All measurements and analyses were carried out in triplicate. The results were analysed statistically using the Statistica 10.0 MR1 program to determine the average value and standard error. Variance analysis (Kruskal-Wallis), with a significance level of $p = 0.05$, was performed to determine the differences in the sensory features and color parameters due to different roasting degrees. Correlation analysis was also run with the same statistical package.

3. RESULTS AND DISCUSSION

The results of sensory evaluation of tasted samples are shown in Figure 1.

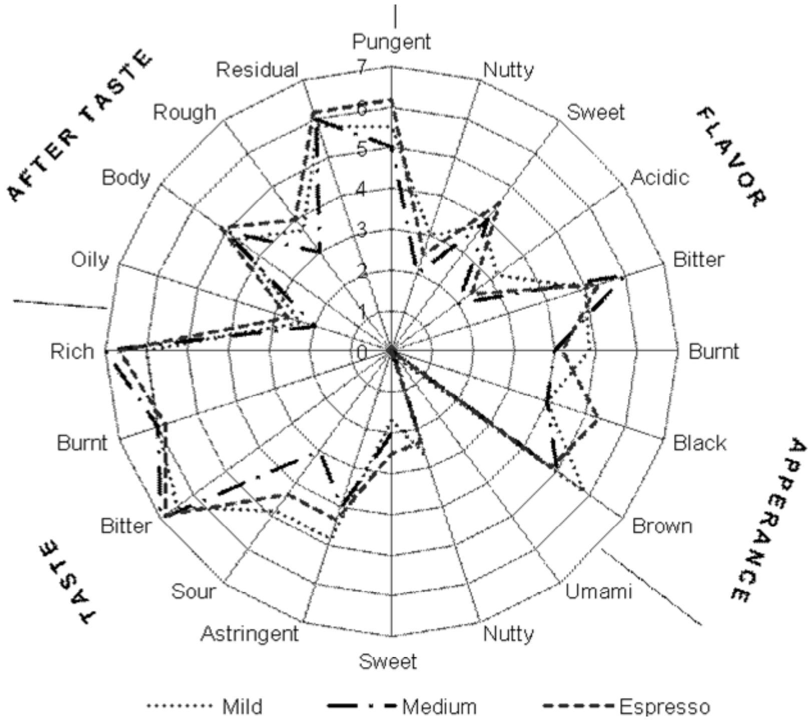

Fig. 1. Sensory evaluation of coffee beverage samples

It was found that the sensory characteristic of different samples of coffee vary and depend on the roasting degrees.

The average color descriptors evaluated at the level at 4.0 (slightly weak) 5.8 (weak nor strong). Brown color received the highest score for Mild coffee (5.8), and the lowest average characterized by the black color for samples of Mild and Medium coffee (4.0). The panelists noted a slight difference in the change in color between the tasted coffees. The black color was noted by panelist respectively from 5.3 for Espresso coffee to 4.0 for Medium and Mild coffee. Also for brown color the differences between samples of coffee was low and ranged respectively from 5.8 for Mild coffee to 4.8 for Espresso coffee. The results of Kruskal-Wallis test ($p = 0.05$) showed a statistically significant effect of roasting degree of coffee on black color of coffee brew ($KW\text{-}H(2;18) = 5.8$; $p = 0.05$) and did not showed a statistically significant effect of roasting degree of coffee on brown color of coffee brew ($KW\text{-}H(2;18) = 3.2$; $p = 0.2$).

Detection of flavor ranged from 2.0 (very weak) to 6.7 (slightly strong). The sample of Coffee Mild and Espresso roasted were characterized by a similar assessment of pungent smell - respectively 5.5 and 6.2. Top-ranked parameter at a comparable level was the bitter smell. Ratings fit in the range from 5.0 – for Mild coffee to 5.3 for Espresso coffee. Flavor of the infusions were characterized by „neither weak nor strong". Espresso Coffee, roasted at high temperature, has received the highest rating of pungent odor – 6.2, while medium coffee received the lowest score of – 2.0 indicating a very faint smell of bitter aromatic.

Given analyzed differentiators, the highest received ratings was the bitter taste. The umami taste for Medium and Espresso coffee was undetectable. Results presented in Figure 1 indicate that the nutty taste was evaluated on a comparable level from 2.3 (Medium) to 2.7 (Mild). Coffee stoned at the highest temperature received the lowest rating for the burnt taste (5.8), while roasted coffee burnt in 192°C characterized a burnt flavor at 6.0. Based on the observed results, the increasing roasting temperature, resulted in a reduction in flavor and sour taste from 4.8 to 4.3. Sour taste was more noticeable in the sample of Mild coffee (4.8).

Our outcomes were very similar to the data presented by Bhumirantana et al. [2] and showed that the roasting of coffee from light to dark resulted in a substantial development of burnt, pungent, ashy and sour notes as well as an increase in the intensity of coffee and roasted attributes.

The one of the audited differentiator was the feeling in the mouth after consuming the brew. The greasy coating feeling evaluator pointed to the level of 1.5 – (Very weak) for coffee and 2.7 Mild – (moderately weak) for Espresso. Rough parameter specifying the thick and muddy feeling in the mouth fluctuated within a range of from 3.7 to 4.0. The highest score of the fleshy features that remains in mouth was reported for medium coffee. Medium coffee was characterized by a slightly strong feeling – 5.7. Given analyzed differentiators, it was not possible to determine the feeling that remains after consuming the brew.

The result of coffee brew color parameters (*L, a*, b**) of tasted samples are shown in Table 2.

Table 2. The average values of color parameters in investigated samples of coffee

Color parameters	Roasting degree		
	Mild	Medium	Espresso
L*	22.45 ±0.01	22.93 ±0.005	21.52 ±0.01
K-W test	KW-H(2;18) = 2.6048; p = 0.2719 (NS)		
a*	1.63 ±0.02	2.38 ±0.03	1.36 ±0.08
K-W test	KW-H(2;18) = 2.1711; p = 0.3377 (NS)		
b*	2.90 ±0.03	3.70 ±0.02	1.95 ±0.04
K-W test	KW-H(2;18) = 3.9017; p = 0.1422 (NS)		

* significant at p = 0.05; NS – not significant

The values of *L** parameter ranged from 21.1 to 22.9. The highest value was recorded for the Medium coffee brew, while the lowest value, and therefore the darkest color, for the Espresso coffee. The parameter a* for infusion received positive values for all the tested coffees. The highest value of the parameter a* was detected in Medium coffee (2.4), while the lowest in Espresso coffee (1.4). The parameter b* for infusion also received positive values. Coffee Medium (3.7) was characterized by the highest score, while coffee Espresso (1.9) the lowest.
The results of Kruskal–Wallis test ($p = 0.05$) did not show a statistically significant difference between the roasting degree of coffee and color parameter *L*, a*, b**.
Corelation analysis (Tab. 3) showed that the values of color parameters (*L*, a*, b*) are not very strongly correlated with selected sensory features (brown and black color of coffee brew).

Table 3. The correlation between the selected sensory parameters and color parameters in investigated samples of coffee brew

Color of coffee brew	Color parameters CIE *L*, a*, b*		
	*L**	*a**	*b*
brown	0.536	0.315	0.476
black	-0.345	-0.346	-0.359

CONCLUSIONS

The result of this study indicated that color and aroma characters of coffee detected by the descriptive panel were insignificantly affected by degrees of roasting. In our study, it was observed that light roast generally yielded pungent, sweet aromatic, and burnt aroma notes while dark roast (Espresso) yielded burnt/acrid, bitter, rich and roasted aromatics. The flavor profiles of the brewed coffee could be examined to understand how the changes in aroma in coffee and degree of roasting affect the perceived flavor characteristics of the brewed coffee. Consumer evaluations would be necessary to identify the key attributes that might impact acceptability.

Based on the results of our studies, in the future, it will be also possible to assess the optimal roast level for the stages of roasted beans. In the study it was observed that the light and dark roasted ground coffee, respectively Mild and Espresso coffee were more preferred that medium roasted coffee. The light and dark roast appeared to be the optimal roast level for all consumers, yielding the most complex aroma attributes or achieving distinctive bitter, brown, and rich and burnt aromas.

Our data do not show the significant correlation between selected sensory features and color parameters *L*, a*, b*.

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