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Review Article

# Coffee Cultivation, Processing and Aroma: A Detailed Review

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## Abstract

Coffee is a popular beverage which is enjoyed around the world both as hot and cold drink, consumed for its stimulating and refreshing quality. Coffee is known as a brewed drink which is hot water extraction process carried out for plant materials. For coffee processing, ripe and red coffee berries are harvested and beans are extracted by separating the pulpy berry part. The greenish-grey seeds or beans of the berries are further cleaned to remove the thin film adhering to the seeds, to get the final seeds. The seeds are sun dried to remove moisture followed by roasting and grinding. Roasted coffee beans develops characteristic coffee flavor due to a series of changes in physical and chemical properties of coffee beans during roasting process. The roasted, grinded and brewed coffee extract is known popularly to be consumed with milk, sugar and other additives in both cold and hot conditions. Characteristic coffee flavor is due to development of a number of aromatic compounds which are formed during the roasting process. This review paper presents detailed information about the scientific aspect of coffee processing, which would be helpful for the coffee cultivars, processers and the consumers to have a better understanding about the world famous beverage "The Coffee".

**Keywords:** Coffee Processing; Composition; Roasting; Changes During Processing; Aroma Chemistry

## Introduction

Coffee is a brewed drink which is prepared from roasted and grinded coffee beans with or without the addition of water, milk, sugar and other ingredients. Coffee beans or seeds are obtained from coffee berries, which grow in coffee plants. Coffee plants are ever-green small shrubs that are native to Asia and Africa. Different species of coffee plants are available, out of which *Coffea robusta*, *Coffee arabica* and *Coffea liberrica* enjoys economic importance. Out of the three, in southern part of India, *Coffea arabica* is cultivated. *Coffea robusta* is also cultivated in India but cultivation of Coffea liberica hasn't been so much popular since it gets too much affected by diseases. *Coffea robusta* yields lower quality beans than *Coffea arabica*, which is known for best quality coffee beans [1]. Top ten coffee producing countries are Brazil, Vietnam, Colombia, Indonesia, India, Ethiopia, Mexico, Guatemala, Honduras and Peru. The names of countries are listed in descending order according to coffee production, i.e., Brazil is the leading coffee producing country and India ranks fifth in coffee production [1,2].

According to Coffee Board of India [3], India produced 316000 MT coffee as per crop harvest data, out of which 95000 MT and 221000 MT were *Coffea arabica* and *Coffea robusta* respectively, in year 2017-18. In India, top coffee producing states are Karnataka, Kerala and Tamil Nadu. These states coffee production status is presented in table 1.

| State of India | *Coffea arabica* (in MT) | *Coffea robusta* (in MT) | Total (in MT) |
|---|---|---|---|
| Karnataka | 69025.00 | 153275.00 | 222300.00 |
| Kerala | 2160.00 | 63575.00 | 65735.00 |
| Tamil Nadu | 13400.00 | 4040.00 | 17440.00 |
| North-Eastern India | 95.00 | 90.00 | 185.00 |
| Other states* | 10320.00 | 20.00 | 10340.00 |
| Total coffee production | 95000.00 | 221000.00 | 316000.00 |

**Table 1**: Major coffee producing states of India and coffee production 2017-18.

*Other states: Andhra Pradesh, Orissa etc.

India is one of the global coffee exporters and top ten leading countries where India exported coffee in the year 2017-18 are Italy, Germany, Russian Federation, Belgium, Turkey, USA, Poland, Libya, Spain and Indonesia. The names of countries are arranged in descending order, i.e. largest coffee importing country from India was Italy of amount 51545 MT. There are 45 different countries name listed where India exported 267510 MT coffee of unit value Rs. 157248/ Tonne. Hence it can be understood that coffee as a cash crop is quite a lucrative sector of economic importance [3]. This review paper aims to explore the cultivation and processing aspect as well as scientific edge of coffee aroma science.

## Coffee cultivation

Coffee seeds can be planted in moistened soil and with regular care, it can be grown as seedling. This conversion of seed to seedling is usually done in nurseries. Beside seed propagation, vegetative propagation by cutting method can also be opted, where high yield and disease free matured plant varieties are usually selected. Once the seedling is big enough, then it is moved from nursery to the coffee field. This transfer of seedling from nursery to field is usually done during rainy season when the soil is naturally wet, so that the roots may grow and make a stronger grip in the soil [4]. A typical coffee plantation is shown in figure 1.

**Figure 1:** Coffee plantation in Chikmangalur district, Karnataka.

Climate plays important role in coffee plant cultivation, which requires evenly distributed annual rainfall. Too much rainfall is hazardous for the coffee plant to survive since over rainfall may cause plant fungal diseases and rotting of plant leaves. Once matured enough, the coffee plant bears white flowers, as shown in figure 2. *Coffea arabica* flowers emerges after rain and *Coffea robusta* flowering time is quite irregular [4,5].

**Figure 2:** Coffee flowers.

Coffee berries in unripe condition, are green in colour, but when ripe they turns red as shown in Figure 3(a) and 3(b) respectively. Once the coffee berries are ripe, they are manually harvested followed by other post harvest operations. Inside each coffee berry, there are two coffee seeds, adhering to each other [5].

**Figure 3(a):** Green coffee berries.

**Figure 3(b):** Ripe and red coffee berries.

Diseased coffee leaves from coffee plantations located in Chikmangalur, which is also known as the "Coffee land of Karnataka", located in Karnataka, a southern state of India, is shown in figure 4(a). Using standard method, diseased leaf microscopic slides were prepared and their microstructures were observed using "Foldscope", the paper based inexpensive microscope. This microscope is light in weight and so compact in size that it can be carried to the fields in cloth pockets. Although this microscope might look small in size and low in cost, but it has magnification of 140X and its spherical lens enables us to view particle size till 2 micrometer in dimension. Foldscope enables to record the microstructure photographs or videos via smart phone camera [6,7]. Using a smart phone equipped with a digital camera of 13 MPa and a foldscope, the sample slides were viewed and microstructures observed were shown in figure 4(b) and 4(c).

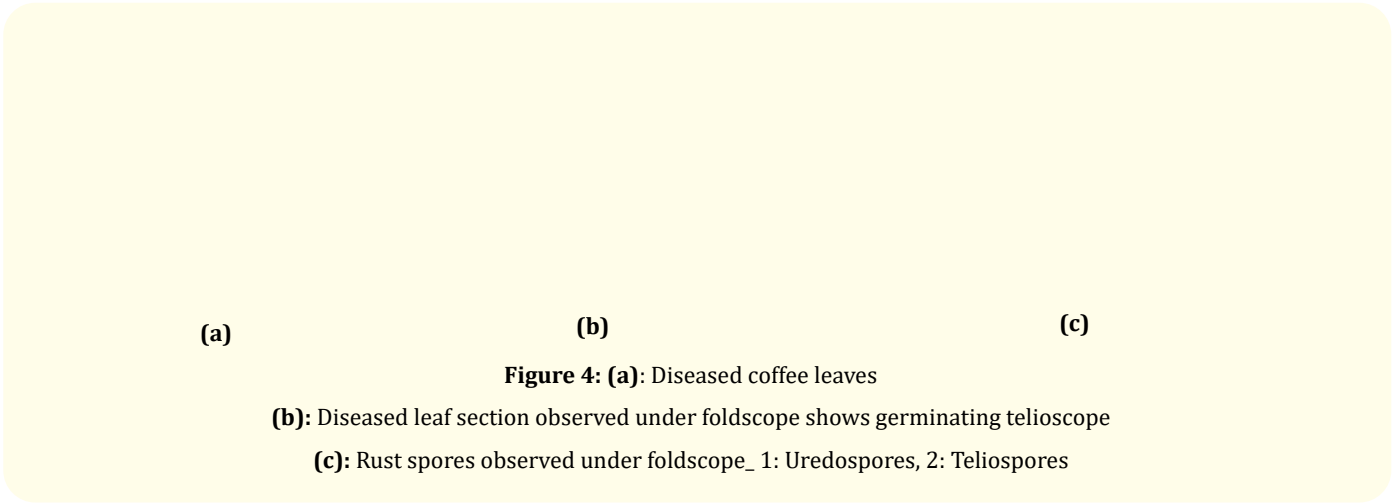


**Figure 4: (a)**: Diseased coffee leaves

**(b):** Diseased leaf section observed under foldscope shows germinating telioscope

**(c):** Rust spores observed under foldscope_ 1: Uredospores, 2: Teliospores

Based on morphological characteristics of the spores, the causative agent of fungal infection in the leaves were identified and informed to the coffee estate workers and others [8].

## Post-harvest processing of coffee

Harvested ripe coffee berries contain parchment hull and pulp, which are to be removed to get the coffee beans or the seeds. This can be done in two methods, i.e. dry or wet method. In dry method, the berries are dried and the covering over the dried seed is removed by hulling. By wet method, initially for removing the pulp, ripe coffee berries are passed through coffee pulping machine. De-pulped coffee berries contain mucilaginous coatings which are removed by different methods, i.e., microbial fermentation, pectin-digestion enzymes, different water washing treatments. The obtained beans after pulp and mucilaginous coating removal, contains another other hull, which are removed after drying of coffee beans. Coffee beans are generally dried under the sun, as shown in figure 5, where drying may take 4-5 days depending on the weather condition.

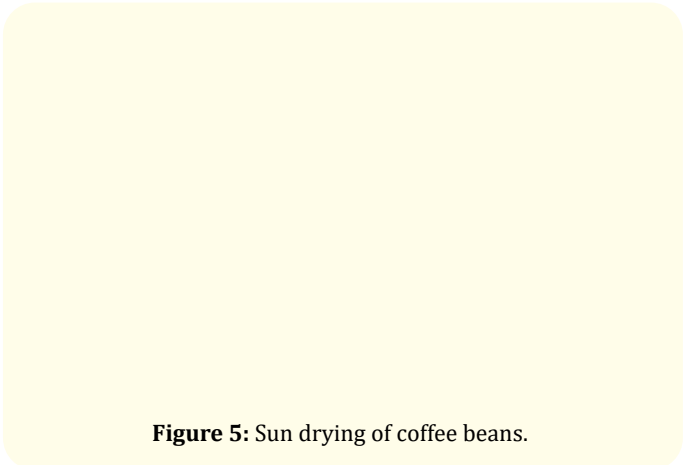

**Figure 5:** Sun drying of coffee beans.

During this drying operation significant moisture reduction from 53% to about 12% was reported. Electric dryers can be used where temperature control is more precise and drying time can be reduced, but chances of over-drying or un-uniform temperature distribution inside dryer, may affect the final produced coffee quality. Dried coffee seeds are passed through the hulling machine to remove the hull and by mechanical aspiration the hulls are separated from the seeds. Hulled coffee seeds are manually inspected and defected/discolored seeds are removed from the whole lot. Electronic colour sorters may also be used to eliminate defective seeds, as alternate to manual sorting. Sorted good quality beans are graded based on seed size, colour, and other standard tests to estimate the brewing quality of the finished coffee. Out of wet and dry processing method, wet processing of coffee seeds results in better quality green coffee [1,9].

After dehulling the coffee beans, the dehulled beans are roasted during which the distinctive coffee aroma originates due to a number of physico-chemical changes. Coffee roasters can be batch or continuous type and with development of technologies, now roasters are available which has temperature controls along with humidity, roaster gas recirculation facilities, precise roasting time control etc. Roaster temperature is maintained around 260°C and the temperature of the coffee beans may rise to 200 °C. During the roasting operation, the coffee beans losses all the moisture and some other volatiles. There is change in volume and colour during the roasting operation. Colour of the bean changes from dull-green to brown colour and the bean texture also becomes brittle after roasting. Roasted coffee beans are cooled and grinded. Size of grounded coffee beans depends on its end use, where the particle size and particle size distribution of coffee powder impacts the turbidity, brewing time and other properties. Coffee powder af-

ter grinding is recommended to be kept under air-tight, vacuum or in presence of inert gases, since the presence of oxygen affects the quality to a much extent. Open packaging of coffee powder results in losses of volatiles in atmosphere. Coffee are brewed in hot water under different conditions like coffee to hot water ratio, particle characteristics of the coffee powder, hot water temperature, type of mixing, brewing time etc. All this factors affects the brewed coffee getting extracted which can be measure with standard hydrometer, calibrated by authorized coffee agencies [1,9].

## Coffee flavour science

Coffee is mainly consumed for its stimulating effect, is caused by the presence of caffeine, whose composition varies from coffee species to species. For example *Coffee robusta* contains 1.5-2.5 per cent, whereas *Coffea arabica* contains 1.0-1.2 per cent. Although caffeine is known for their stimulating effects but studies have suggested over-consumption may result adverse mental and physical health effects. According to Wealth of India, 2nd Volume, CSIR-New Delhi, India (1988), composition wise green *Coffea arabica*, before roasting contains 8.98% moisture, 9.87% protein, 12.60% fat, caffeine 1.08% and others. After roasting the composition of the same *Coffea arabica* changes to 0.63% moisture, 11.23% protein, 13.59% fat, along with reducing in 1.08% caffeine to 0.82%. Chlorogenic acid content had also been reported to decrease after roasting from 8.46% to 4.74%. *C. robusta* coffee beans produce lesser acidic coffee than *C. arabica*. During coffee roasting, more than 600 volatile compounds are developed whose presence have been detected in roasted coffee beans out of which low temperature boiling point sulphur compounds are considered to have primary roles in flavor contribution in roasted coffee. Chlorogenic acid is responsible for astringency in coffee beverage and its decomposition results in coffee aroma. Decomposition of carbohydrate and protein also adds to coffee aroma. Polyphenolic compounds like tannin results in desired bitter taste in coffee. De Maria., *et al*. [10] reports about the complicated reactions involved in coffee aroma formation, namely Maillard and Strecker reaction and decomposition of carbohydatem trigonelline, chloregenic acid, polysaccharides, proteins etc. Development of a number of volatile compounds were identified using gas chromatography, mass spectrometry, and olfactometry during hot air roasting of coffee at six different hot air temperature conditions were reported. Trugo and Macrae [11] reported their findings on detection of high molecular weight materials during roasting operation for green coffee beans which degraded with roasting time, using high performance gel filtration chromatography for monitoring the molecular weight changes as a rapid analytical method. Cheetham [12] reviewed about presence of hundreds of flavor and aroma chemicals in roasted coffee responsible for characteristic flavor. Similar to others, the author reports about thermal decomposition of carbohydrates and phenols responsible for the flavor development. The author further reviewed presence of few particular compounds responsible for a particular kind of flavour related to coffee, as shown in Table 2.

| Compounds | Characteristic flavour |
|---|---|
| 2-furfurylthio | Roasted coffee-sulphur flavour note |
| 3-methyl-2-butenethio | |
| 3-thio-3-methylbutylformate | |
| Guaiacol | Phenol-smoky note |
| 4-vinylguaiacol | |
| Pyrazines with other volatile acids | Earthy roast |
| Furanones with other volatile acids | Caramel odours |

**Table 2**: Some compounds and their characteristic flavour*

*Cheetham [12].

## Decaffeinated Coffee

The effects of over-consumption of caffeine have already been reported. For removing the caffeine content from coffee, the green coffee beans are given a steam treatment, and then water extraction before roasting. Some specific organic solvents also find their application in decaffeination process to extract caffeine, but efficient removal and recovery of organic solvent residue remains a challenge. Recent advancement with super critical $CO_2$ extraction finds its wonderful application without any fear of left behind solvent traces used for the extraction purpose [9].

## Soluble "instant" coffee

This are called solubilized coffee, made by drying of water soluble brewed coffee. They are manufactured by vacuum spray drying of coffee brew received from the percolation method. Freeze drying can also be employed for preparation of this instant coffee, where the strong brewed coffee, have to be pre-freeze before final freeze drying [1,13,14].

## Conclusion

Coffee is a favorite beverage for many people, although many of us are not much aware of how the coffee is cultivated, processed and the science behind the characteristic coffee flavour development from the coffee seeds. This paper in brief reviewed about the processing aspect of coffee from harvest of berries to the manufacturing of coffee powder. The characteristic coffee aroma and flavour was reported to be the combined effects of 100's of

compounds originated during the roasting of coffee beans. It is understood that roasting is a very important aspect for good quality coffee production. After process, proper care needs to be taken for package and storage of hygroscopic coffee powder to prevent volatile loss and other undesirable chemical changes.

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