**“RECENT ADVANCES IN PROCESSING AND VALUE ADDITION IN**

**COFFEE (*Coffea*)”**

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**1. Introduction**

Coffee is a beverage brewed from the roasted and ground seeds of the evergreen coffee plants. Coffee is one of the three most popular beverages in the world (alongside water and tea). The history of coffee begins in Ethiopia where local people have been drinking coffee from many centuries. At the beginning of the 18th century, visiting Arab traders also found the drink agreeable and from then on, coffee was shipped to the Arabian peninsular. A demand for coffee quickly developed amongst the peoples of Arabia and coffee plantations were established in Yemen. Later, during the 18th and 19th centuries, there was a steady expansion of coffee drinking throughout the world and arabica coffee was exported to many countries, with the source planting material originating from either Ethiopia or Yemen. *Coffea canephoru* var. robusta was identified later on from more diverse origins in the forests of tropical central Africa and was later transferred to many lowland areas of Africa as well as to tropical countries of Asia and the Americas (Jean, 2004).

Major Coffee growing countries have been distinguished under four regions: Africa, Asia and Oceana, Mexico and Central America and South America with total production of 175.35 million bags (60 kg/bag). Across these regions, Brazil (41.8%), Vietnam (17.57%), Colombia (8.54%), Indonesia (7.33%), Honduras (3.7%), Ethiopia (4.47%), India (3.45%), Uganda (3.4%), Peru (2.3%) and Mexico (2.42%) are being recognized as top 10 coffee growing countries ([www.ico.org](http://www.ico.org)).

The first record of coffee growing in India is following the introduction of coffee beans from Yemen by Baba Budan to the hills of Chikmagalur, Karnataka in 1670. Since then, coffee plantations have become established in the region, extending south to Kodagu. Coffee growing areas in India are classified as traditional coffee-growing areas mostly consisting of Western Ghats of Karnataka, Kerala and Tamil Nadu, the non-traditional area consisting of Andhra Pradesh and Orissa and the North Eastern region consisting of all the north eastern states. The total area under coffee is about 4.65 lakh ha with a production of about 3,34,000 MT, comprising of 99,000 MT of Arabica and 2,35,000 MT of Robusta. Among different states, Karnataka produces about 71.4%, followed by Kerala (19.8%), Tamil Nadu (5.2%), Andhra Pradesh and Orissa (3.5%) and the North-Eastern region ([www.indiacoffee.org](http://www.indiacoffee.org)).

Botanically, coffee belongs to genus *Coffea* of the family *Rubiaceae.* The genus *Coffea* comprises of about 100 species, most of which are native to Africa. Of these, only two species *viz.,* *Coffea arabica* and *Coffea canephora var. Robusta* are cultivated commercially in India and many other countries. Another species, *C. liberica* is grown to a small extent in a few countries. Central Coffee Research Institute, Chikkamagaluru, Karnataka has developed 13 Arabica and 3 Robusta selections for commercial cultivation of which, seven selections of Arabica *viz.,* Sln.13 (Chandragiri), Sln.12 (Cauvery), Sln.5B, Sln.10, Sln.9, Sln.6 (S.2828), Sln.3 (S795) and 2 selections of Robusta *viz.,* Sln.1R (S274) and Sln.3R (CxR) are popular among the growers and cultivated on commercial scale (Anon., 2014).

With a view to protect and promote the unique Regional and Specialty Coffees of India, Coffee Board has obtained Geographical Indications registration for five coffees (www.pib.gov.in).

|  |  |  |  |  |
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|  |  |  | **Details | Geographical Indications | Intellectual Property India** | **Details | Geographical Indications | Intellectual Property India** |

**Fig. 1. GI certified five varieties of Indian coffee**

Geographical parameters like elevation, aspect and environmental factors like rainfall, temperature and atmospheric humidity can influence economic production of coffee much more than soil factors (Anon., 2014).

**Table 1. Soil and climatic requirements for Arabica and Robusta coffee**

|  |  |  |  |
| --- | --- | --- | --- |
| Sl. No. | Factors | Arabica | Robusta |
| 1 | Elevation | 1000 to 1500 m | 500 to 1000 m |
| 2 | Soils | Deep, rich in organic matter, well drained and slightly acidic in reaction (6 to 6.5 pH) | |
| 3 | Slopes | Gentle to moderate slopes | Gentle slopes to fairly level fields |
| 4 | Temperature | 15oC to 25oC | 20oC to 30oC |
| 5 | Relative humidity | 70 to 80% | 80 to 90% |
| 6 | Annual rainfall | 1600 to 2500 mm | 1000 to 2000 mm |
| 7 | Blossom showers | March-April (25 to 30 mm) | February-March (25 to 40 mm) |
| 8 | Backing showers | April-May (50 to 75 mm) | March-April (50 to 75 mm) |

**2. Primary processing of coffee**

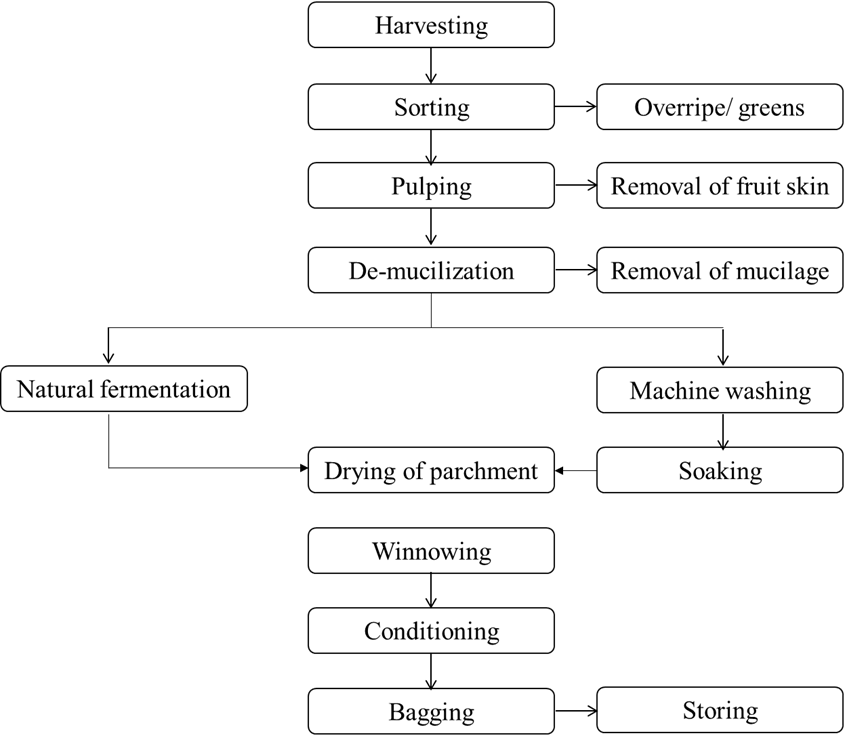
The period between November to January is the main harvest season of for Arabica, while Robusta harvesting takes place during December to February. For preparation of parchment by wet method, Arabica coffee is harvested manually in 2 to 3 rounds while in case of Robusta only 1 to 2 rounds of manual harvesting are common. For preparation of cherry coffee, fruits are harvested when about 90% of fruits are ripe.

Coffee after harvesting at the estate is processed by two methods *viz.,* dry (Fig.2). and wet (Fig.3) method.



**Fig. 2 Steps involved in dry method of processing of coffee**

In dry method of processing, the harvesting is done when 90% of fruits are ripe. Before subjecting the fruits for drying, all unripe, tree dried fruits and damaged cherries are sorted out and dried separately. After sorting, the remaining sound/ healthy fruits are spread evenly to thickness of about 7 to 8 cm on concrete or tiled drying yards. The coffee fruits put up for drying are stirred at least once in an hour. The coffee is heaped and covered every day in the evening and spread again in the next morning after mist clears up. The coffee will be fully dry (11-12% w.b.) at the end of 12 to 15 days under bright sunny weather conditions. The dry cherry is winnowed to remove dried leaves, twigs, dirt etc. before packing and storage. Coffee obtained by dry processing is called cherry coffee.



**Fig. 3 Steps involved in wet method of processing of coffee**

In the wet method, the harvested coffee cherries undergo a series of processing steps *viz*., pulping (removes the outer skin of the fruit) followed by fermentation and washing (to removes the pectinaceous mucilage adhering to the coffee bean) and sun drying for about 6 to 8 days (Fig.3). The coffee resulting from wet processing is known as parchment coffee. The cup quality of parchment coffee will be superior compared to cherry coffee. In India, most arabica coffee is processed by the wet method, while most robusta is processed by the dry method (Anon., 2014).

**3. Secondary processing**

The various steps involved in the secondary processing of coffee are as follows

**Receipt of raw coffee from the planters**

Immediately on receipt of coffee from the planters, the moisture content is checked using moisture meters in the curing works.

**Drying**

If the coffees received from the planters are found to be under dried, the same will be dried at the curing works to bring down the moisture content to the standard moisture percentage. The floor area required for drying coffee equivalent to one tonne of clean coffee is 7.273 sq. ft. Floor space required for spreading uncured coffee equivalent to one tonne of clean coffee is taken as 1200 sq. ft. The average drying time is taken as 1 day and total number of drying days available in a year is taken as 165 days. The flooring could be made of cement / concrete, bricks, tile or Cuddapah stone.

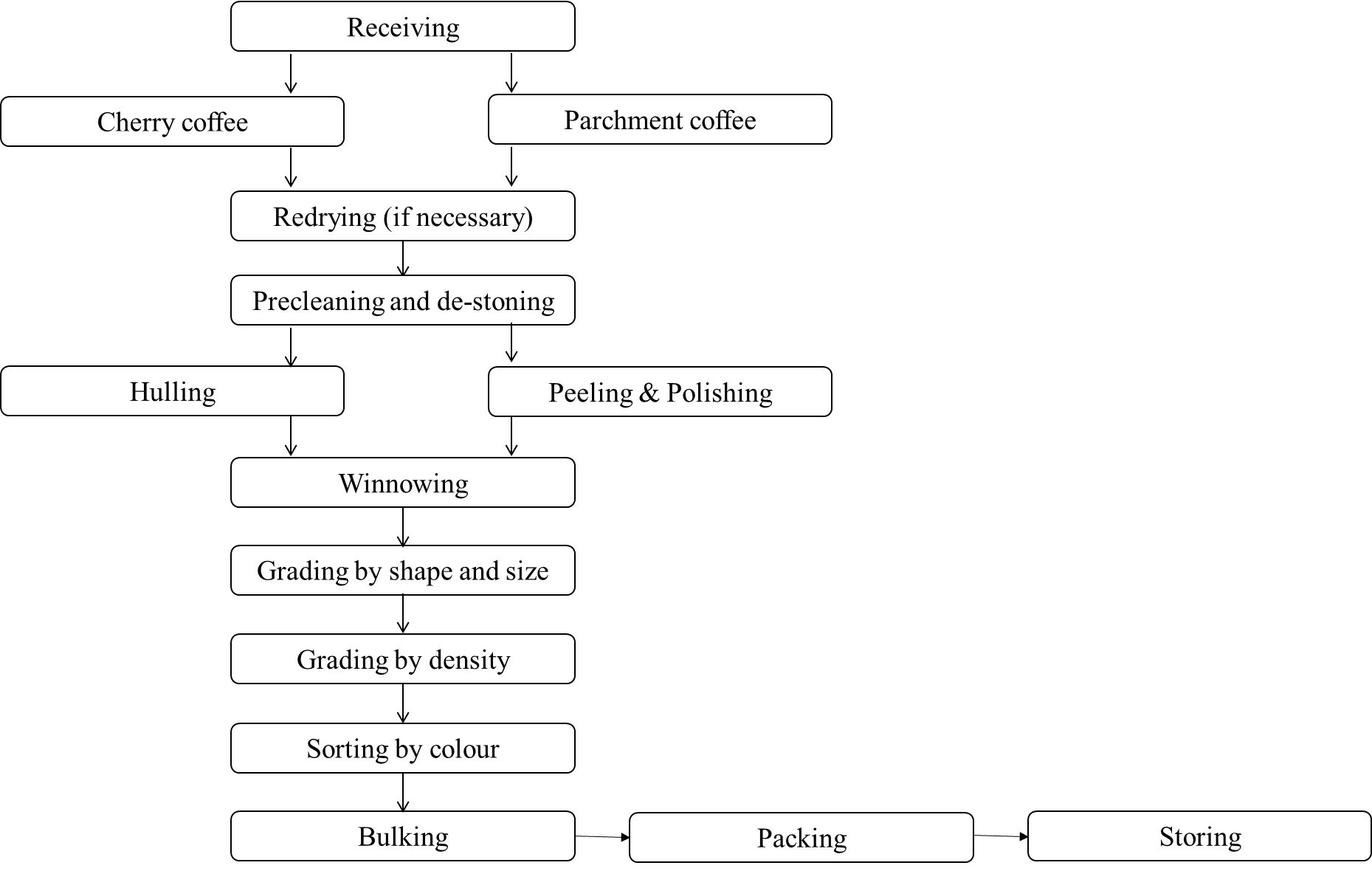
**Hulling, grading and garbling**

The machinery installed at the curing factory for the various curing operations are as follows:

1. Dust / Twig / Stone separator
2. Huller
3. Peeler-cum-polisher
4. Winnower
5. Unpeeled coffee separator
6. Grader
7. Catador
8. Specific gravity separator
9. Pneumatic separator
10. PB band separator
11. Bucket elevators
12. Electronic colour sorting machine

**Steps in hulling and grading of coffee**

The raw coffee is first passed through a stone/stick eliminator, where foreign materials like stones, sticks, twigs etc., are removed. The coffee is then passed into the huller / Peeler-cum-polisher and from there on to the horizontal or vertical winnower. The coffee is next allowed into pre-grader, where the bits are separated. It then passes through the sizes (graders), where the different grades of coffees such as PB, A, B & C are separated. In case, a pre-grader is not installed, the coffee may be directly passed on to the sizes, where bits could also be separated. Thereafter, the coffee is subjected to garbling/sorting, out-turning, bulking etc.



**Fig. 4 Secondary processing of coffee in curing works**

**Hulling and peeling**

The cherry coffees are hulled using 'hullers'. The parchment coffees are peeled using 'peelers', and then subjected to polishing.

**Grading**

Primary grading is carried out based on the size of beans. This is carried out on a rotary grader. Secondary grading is done based on densimetric classification of the individual graders. Catadors and gravity separators are used for the densimetric classification of coffee.

**Garbling / Sorting**

The sorting of defective beans and discoloured beans is carried out manually by women garblers. In many of the curing factories, electronic colour sorting machines are also used for the sorting of discoloured beans *viz.,* blacks, browns. The electronic colour sorting machine is complementary to the manual garbling process.

**Out turn**

After the garbling process, the coffee lot is out turned and the quantity of each of the grades weighed and recorded.

**Packing**

Double gunny bags are used for the packing of cured coffee. The type of gunny bag used is of the "B-Twill" of "DW" quality. The coffee is packed in quantity of 75kg / bag.

**Storage of coffee**

The drying capacity, machine capacity and storage capacity are the important requisites, which determine the curing capacity of a curing factory. The storage capacity of a curing factory is calculated based on certain norms fixed by the Board which are as follows: The floor area required for storing raw coffee (uncured) equivalent to one tonne of clean coffee is 13.5 Sq.ft., when the height of the godown is 15ft. In terms of volume the space required for storing raw coffee equivalent to one tonne of clean coffee is 202.5 cubic feet. The floor area required for storing one tonne of clean coffee is 7.5 sq. ft., for a wall height of 14 ft.

The following guidelines have been laid down for the proper storage of coffee in the godowns.

* There should be a clear demarcation between the different lots of raw coffee stored to maintain the identity of the individual lots in respect of quality and quantity.
* The coffee stacks should not lean against the walls of the godown.
* The stacks of raw coffee should be provided with dunnage made of parchment husk filled in gunny bags.
* The clean coffee stacks should be provided with wooden dunnage.
* Both the raw coffee and clean coffee godowns should be rodent proof.
* Materials like fertilizers, pesticides etc. should not be stored inside or near coffee godowns.

**4. Cup quality evaluation**

Cupping or cup tasting is developed as a means of consistency and impartially evaluating a coffee. It requires a tremendous investment in time and extensive knowledge of stages of coffee production and processing. Obviously the art and science of cup tasting is the prerogative of the cup taster who is trained to distinguish or identify subtle differences in taste and aroma, a sensory method which is most effective. Cup tasting is crucial in the commercial market. The exporters normally find it helpful in evaluating his coffee before sale or for the price paid to the grower. While the importer uses it to maintain uniformity and the standard set by the particular company linked to prices of the consumer’s satisfaction.

The cup quality relies on various factors. The intrinsic quality of coffee is influenced by the plant material, cultural practices and processing techniques. In fact the processing of coffee both at the estate and at the curing works is also important. Delayed pulping, over fermentation, improper washing, storing of coffee near pesticides, packing coffee in inferior quality gunny bags, improper drying causes off-taste in the coffee which can be evaluated during cupping.

Cupping is a method of systematically evaluating the aroma and taste characteristics of a sample of coffee beans. A prescribed manner of brewing and a specific series of steps lead to a complete sensory evaluation through olfaction, gestation and a mouthful sensation. Because cupping is usually associated with some economic purpose such as buying or blending of coffees (Anon., 2014).

**The cupping procedure**

**Sampling roasting**

Roasting is a dynamic complex process. The development of flavour is quite important during the process. Around 50-100 g of coffee sample is roasted light to medium degree at an optimum temperature of 205oC in the roasting machine, until a golden brown colour is obtained. The beans are roasted until the pop sound is produced.

**Grinding**

The roasted sample is ground to medium to coarse powder using the grinder. This grinder releases more fatty acids, oils and proteins into the extract and there is a good retention of volatile aromatics in the cup.

**Brewing**

Fresh coffee powder of standard roast with correct proportion of powder to water is necessary. 10 g of powder is taken in a porcelain cup and brewed with 250 ml of boiling water (temperature of water is not less than 95oC) and allowed to stand for five minutes and the floats are removed. The liquor is allowed to cool to a palatable temperature i.e., 45-50oC. Likewise, 5-7 cups are tasted per sample.

**Tasting**

Taste is a complex perception; it is carried out by a panel of tasters. A spoonful of brew is sucked into the mouth with a deep inhalation of air so that the brew is sprayed over the upper palate. This helps in the aroma rising into the nostrils. The brew is rolled over around the tongue and the taste impressions are determined. The brew is later discarded into the spittoon. Likewise, the number of cups tasted by the taster is restricted to a fixed number.

Thus, the tasters judge the quality of the liquor precisely and rate them into five categories *i.e*., fine, good, FAQ, falling off and poor depending on important characteristics namely, body, acidity, flavour and off flavours.

**Acidity:** It is a desirable characteristic in coffee. It is the sensation of dryness that the coffee produces under the edges of your tongue and on the back of your palate.

**Aroma**: It is a sensation which is difficult to separate from flavour. The aroma contributes to the flavour which we discern on our palate, subtle nuances, such as floral or winey characteristics are derived from the aroma of the brewed coffee.

**Body**: It is the mouth feel sensation of coffee brew *i.e*., viscosity, heaviness, thickness that is perceived on the tongue.

**Flavour**: It is the complex sensation encomposing taste and smell together with the sense of feeling.

**Some of the desirable flavour characteristics**

1. Caramelly - candy like or syrupy
2. Chocolaty - An after taste similar to unsweetened chocolate or vanilla.
3. Delicate - A subtle flavour perceived on the tip of the tongue.
4. Earthy - A soily characteristic
5. Fragrant - An aromatic characteristics ranging from floral to spicy.
6. Fruity - An aromatic characteristic reminiscent of berries or citrus.
7. Mellow - A round, smooth taste typically lacking acid
8. Nutty - An after taste similar to roasted nuts.
9. Spicy - A flavour and aroma reminiscent of spices
10. Sweet -Free of harshness
11. Winey - An after taste reminiscent of well matured wine.

**Some of the undesirable flavour characteristics**

1. Bitter -Perceived on the back of the tongue usually the result of over roasting.
2. Bland -Neutral in flavour
3. Carbony -Burnt charcoaly over toned - lack of acidity, aroma and aftertaste.
4. Dirty –mustiness reminiscent of eating dirt.
5. Grassy -An aroma and flavour reminiscent of freshly cut law
6. Harsh -A caustic, clawing, raspy characteristic
7. Muddy -A thick and dull
8. Musty -A slight stuffy or mouldy smell
9. Rioy -A starchy texture similar to water which pasta has been cooked.
10. Rubbery -An aroma and flavour reminiscent of burnt rubber
11. Soft -Neutral in flavour
12. Sour -Taste flavour reminiscent of unripe fruit
13. Thin -Lacking acidity, typically a result of under brewing
14. Turpeny -Turpentine like in flavour.
15. Watery -A lack of body or viscosity in the mouth.

Cupping is a great way to become familiar with different coffee varietals and blends. Based on this information, it will be possible to correct certain defects of the marketable products either by additional processing, drying or sorting, or by improved cultural techniques, planting method, marketing or transporting systems. Cupping conceives better knowledge so that the production could be reoriented in the quality direction.

**5. Coffee quality standards**

Grading of Indian coffee is based on the size of the coffee beans and percentage of defects. (Anon., 2014). The quality specification for Indian coffee are as follows:

**Table 2. Moisture standard for the different types of coffee**

|  |  |  |  |
| --- | --- | --- | --- |
| **Types of coffee** | | **Moisture content (%) w.b.** | |
| Arabica parchment (Washed/ Plantation) | 10.5 | |
| Arabica cherry | 11.5 | |
| Robusta parchment (Washed Robusta) | 10.5 | |
| Robusta cherry | 11.5 | |
| Mysore nuggets EB | 9.0 to 10.5 | |
| Robusta kaapi royale | 9.0 to 10.5 | |
| Monsooned malabar coffees | 13.0 to 14.5 | |

**Grading and garbling standards**

Based on grading, the washed and unwashed arabica and robusta are broadly categorized as commercial grades, premium grades, specialty grades and miscellaneous grades.

**I. Commercial Grades**

|  |  |  |  |
| --- | --- | --- | --- |
| **Washed Arabica (Plantation)** | **Unwashed Arabica (Arabica Cherry)** | **Washed Robusta (Robusta Parchment)** | **Unwashed Robusta (Robusta Cherry)** |
| Plantation PB | Arabica Cherry PB | Robusta Parchment PB | Robusta Cherry PB |
| Plantation A | Arabica Cherry AB | Robusta Parchment AB | Robusta Cherry AB |
| Plantation B | Arabica Cherry C | Robusta Parchment C | Robusta Cherry C |
| Plantation C | Arabica Cherry Blacks | Robusta Parchment Blacks | Robusta Cherry Blacks |
| Plantation Blacks | Arabica Cherry Bits | Robusta Parchment Browns | Robusta Cherry Browns |
| Plantation Bits | Arabica Cherry Browns | Robusta Parchment Bits | Robusta Cherry Bits |
| Plantation Bulk | Arabica Cherry Bulk | Robusta Parchment Bulk | Robusta Cherry Bulk |
|  |  |  | Robusta Cherry Clean Bulk |

**II. Premium Grades**

|  |  |  |  |
| --- | --- | --- | --- |
| **Washed Arabica (Plantation)** | **Unwashed Arabica (Arabica Cherry)** | **Washed Robusta (Robusta Parchment)** | **Unwashed Robusta (Robusta Cherry)** |
| Plantation AA | Arabica Cherry AA | Robusta Parchment A | Robusta Cherry AA |
| Plantation PB Bold | Arabica Cherry A | Robusta Parchment PB Bold | Robusta Cherry A |
|  | Arabica Cherry PB Bold |  | Robusta Cherry PB Bold |

**III. Specialty Coffees**

1. Mysore Nuggets Extra Bold
2. Robusta Kaapi Royale
3. Monsooned Malabar Coffees
4. Monsoonedd Malabar Arabica Coffees
5. Monsooned Malabar AAA
6. Monsooned Malabar AA
7. Monsooned Malabar A
8. Monsooned Malabar Arabica Triage
9. Monsooned Malabar Robusta Coffees
10. Monsooned Malabar Robusta RR
11. Monsooned Malabar Robusta Triage

**IV. Miscellaneous Grades**

1.Liberia Bulk (Bulk coffee from Liberica)

2. Excesia Bulk (Bulk coffee from Exceisa)

**FSSAI standards and additives of coffee**

The Food Safety Standards Authority of India has specified the limits of heavy metal contamination and pesticide residues as given in table 3, 4 & 5 (www.fssai.gov.in).

**Table 3. Maximum permissible limits of contaminants/toxin/residue in coffee beans**

|  |  |
| --- | --- |
| **Name of the metal contaminant/ toxin/ residue** | **Maximum**  **permissible limits** |
| Copper | 30.0 ppb |
| Monocrotophos | 0.10 ppm |
| Ethephon | 0.10 ppm |

**Table 4. Standards and additives of roast and ground coffee powder**

|  |  |  |
| --- | --- | --- |
| **Parameters** | **Roasted & ground coffee** | **Decaffeinated roast and ground coffee** |
| Moisture Content (m/m) | <5% (d.b.) | <5% (d.b.) |
| Total Ash (m/m) | 3-6% (d.b.) | 3-6% (d.b.) |
| Acid insoluble ash (m/m) | <0.1% (d.b.) | <0.1% (d.b.) |
| Water soluble ash (m/m) | ≥65% (d.b.) | ≥65% (d.b.) |
| Alkalinity of soluble ash (m/m) | 3.5-5 ml 0.1 N HCl (d.b.) | 3.5-5 ml 0.1 N HCl (d.b.) |
| Aqueous extracts (m/m) | 26-35% (d.b.) | 26-35% (d.b.) |
| Caffeine (m/m) | ≥1% (d.b.) | ≤0.1% (d.b.) |

**Table 5. Standards and additives of soluble coffee powder**

|  |  |  |
| --- | --- | --- |
| **Parameters** | **Soluble coffee powder** | **Decaffeinated soluble coffee powder** |
| Moisture Content (m/m) | ≤4% (d.b.) | ≤4% (d.b.) |
| Total Ash (m/m) | ≤12% (d.b.) | ≤12% (d.b.) |
| Caffeine (m/m) | ≥2.8% (d.b.) | ≤0.3% (d.b.) |
| Solubility in boiling water | Dissolves in 30 sec | Dissolves in 30 sec |
| Solubility in cold water (16±2oC) | Dissolves in 3 min | Dissolves in 3 min |

Aspergillus and Penicillium are the commonly seen moulds in coffee. Ochratoxin-A (OTA) is the main toxin produced by Penicillium and Aspergillus. OTA is reported to have nephrotoxic (causing damage to kidney) effect both in animals and human. The coffee importing countries have prescribed maximum permissible limits for Ochratoxin-A (OTA) in green beans, roast and ground coffee and instant coffee (www.ico.org).

**Table 6. Maximum permissible limits for OTA (ppb)**

|  |  |  |  |
| --- | --- | --- | --- |
| **Country** | **Maximum limits for OTA (ppb)** | | |
| **Green Bean** | **Roasted** | **Instant** |
| Czech Republic | 10 | 10 | 10 |
| Finland | 5 | 5 | 5 |
| Germany | - | 3 | 6 |
| Greece | 20 | - | - |
| Hungary | 15 | 10 | 10 |
| Italy | 8 | 4 | 4 |
| Netherlands | - | 10 | 10 |
| Portugal | 8 | 4 | 4 |
| Spain | 8 | 4 | 4 |
| Switzerland | 5 | 5 | 5 |

**6. Value addition**

**Roast and ground coffee**

**Roasting**

It is a time-temperature dependent process, whereby chemical changes are induced by pyrolysis within the coffee beans, together with marked physical changes in their internal structure. The required change takes place with a bean temperature from 190oC upwards; bean temperature up to 240oC may be reached in less than 12 minutes. Batch operated horizontal rotating drum roaster with either solid or perforated walls, in which hot air from a furnace/burner passes through the tumbling green coffee beans. Green coffee beans under movement are subjected to heat by conduction from hot metal surfaces, or convection from hot air, or more generally a mixture of both methods of heat transfer, together with contribution by radiation (www.niftem.com).

**Physico-chemical changes in coffee**

**Chemical changes**

The chemical changes include Maillard type reactions and caramelization of sucrose. The composition of roasted coffee is furnished. Volatile complex comprising of furan derivatives, pyrazines, pyridines, benzenoid aromatics, aliphatics, alicyclics and various sulphur compounds. These are important for the flavour/aroma in medium-roast Arabica coffee. Some compounds are generated by straight pyrolysis of single compounds e.g. chlorogenic acids in generating phenols; there is overall 40% residual content for a medium roast. The change in chlorogenic acid content is used as analytical measure of degree of roast. Similarly, coffee oil leads to formation of small amounts of aldehydes and hyrdrocarbons. The coffee oil is practically unaffected, as is the caffeine content. Newly formed residuum of ~ 25% by weight of roasted coffee is melanoidins/humic acids. The loss of mass is 2-3% on dry basis for Light roast, whereas it is up to 12% on dry basis for Very dark roast. The beans lose 15-20% of their weight but increases up to 25% in size.

**Physical changes**

The physical changes that occur include:

* Change in colour
* Formation of cavities/cracking of surface
* Void volume is 47% of medium roast bean vs. 0% in Cooling

**Cooling**

In batch operation, the roasted beans have to be quickly discharged at the end of required roasting period into a cooling car, or vessel, allowing upward passage of cold air. In addition, water may be sprayed from within the rotating drum, just before the end of the roast so called Water quenching. Assists in necessary cooling. Adds a small percentage of water by weight to roasted beans, thereby assists uniformity of particle size in subsequent grinding.

**Grinding**

Multistage twin horizontal rollers up to 4 stages may be used to ensure more uniform particle size distribution. 1st and 2nd stages Essentially performs cracking or crushing the beans into smaller units. 3rd and 4th stages leads to progressively finer grinding. The grind size required is related to subsequent method of brewing to be adopted and whether for home use or subsequent large scale extraction i.e. coarse, medium, fine, very fine.

**Packaging**

Roasted and ground (R & G) coffee releases substantial quantities of entrapped CO2 gas which develops high internal pressure, leading to bursting of package. The usual packaging material is laminates. Packaging under vacuum allows a low percentage of oxygen content in headspace to be established within the package and accommodate release of CO2. Alternatively, CO2 scavenger may be used.

**Brewing**

Brewing is extraction of soluble substances contributing to the basic taste plus of volatile substances for overall flavour. Roast coffee must be ground before brewing.

**Coffee brewing methods**

**Expresso method**

Coffee, an espresso machine has to be used. This machine is passing hot water through the ground coffee at a pressure of around 9 bar. The coffee is particularly finely ground. The result is a spicy coffee with a closed cream layer.

**Fresh brew method**

It is based on a quick filter method. With a fresh brew machine, the extraction process is accelerated and a stainless steel permanent filter is used.

**Instant**

Instant coffee is produced by so-called freeze-drying freshly brewed strong coffee. Coffee is quick and easy to prepare, simply by adding hot water. This gives you a cup of coffee in no time.

**Percolation**

The coffee is placed in a metal filter at the top of percolator. The hot water underneath rises through a tube and seeps through the coffee. Longer percolation time gives strong coffee.

**Quick filter**

Classic way of making coffee. Used for making small and large amounts of coffee.

**Filter**

Choice of grind. South Indian Coffee, also known as Filter Coffee is a sweet milky coffee made from dark roasted coffee beans (70-80%) and chicory (20-30%), especially popular in the southern states of Tamil Nadu and Karnataka. The most commonly used coffee beans are Arabica and Robusta. Outside India, a coffee drink prepared using a filter may be known as Filter Coffee or as Drip Coffee as the water passes through the grounds solely by gravity and not under pressure or in longer-term contact.

**Instant coffee**

Instant coffee, also called soluble coffee and coffee powder, is a beverage derived from brewed coffee beans. It is the dried soluble portion of roasted coffee, which can be presented to the consumer in either powder or granule form for immediate make-up in hot water. Instant coffee is commercially prepared by either freeze-drying or spray drying, after which it can be rehydrated. Advantages of instant coffee include speed of preparation (instant coffee dissolves instantly in hot water), lower shipping weight and volume than beans or ground coffee (to prepare the same amount of beverage), and long shelf life. About 20% of all processed coffee beans are used for making Instant coffee. The capacity of the plant available is up to 500 kg of Instant coffee per hour.

**Classification of instant coffee powder**

**Non-agglomerated instant coffee powder**

This type of powder consists of individual spherical bead-like particles giving the powder its free-flowability and good solubility in hot water. It is most economically produced in spray dryers with tower drying chambers. Powder bulk density is adjusted through inert gas injection into the concentrated coffee extract prior to high pressure atomization.

**Agglomerated instant coffee powder**

This type of powder consists of either medium-sized or large agglomerates with a minimum of fines, giving the powder superior free-flowability and solubility in hot and cold water. Medium sized agglomerates are most economically produced in spray bed dryers incorporating fluid bed agglomeration within the drying chamber. Large agglomerates are produced in a powder agglomerator where spray dried instant coffee is rewetted and dried, under strictly controlled conditions.

**Granulated instant coffee powder**

This type of powder consists of large granules, free from fine particles that gives the powder excellent free-flowability and solubility in hot water. It is most economically produced in freeze dryers, where the low temperature drying environment maximizes aroma retention. The size of the granules is determined by the degree of size reduction and size classification applied to the frozen extract.

**Production method for instant coffee**

As with regular coffee, the green coffee bean itself is first roasted to bring out flavour and aroma. Rotating cylinders containing the green beans and hot combustion gases are used in most roasting plants. When the bean temperature reaches 165◦C the roasting begins, accompanied by a popping sound. These batch cylinders take about 8◦C 15 min to complete roasting with about 25- 75% efficiency. Coffee roasting using a fluidized bed only takes from 30 sec to 4 min, and it operates at lower temperatures which allow greater retention of the coffee bean aroma and flavor. The beans are then ground finely. Grinding reduces the beans to 0.5-1.1mm (0.020-0.043 in) pieces in order to allow the coffee to be put in solution with water for the drying stage. Sets of scored rollers designed to crush the beans. Once roasted and ground, the coffee is dissolved in water, referred to as extraction. Water is added in 5-10 percolation columns at temperatures of 155-180◦C; this concentrates the coffee solution to about 15-30% coffee by mass. This may be further concentrated before the drying process begins by either vacuum evaporation or freeze concentration.

**Drying techniques**

**Spray drying**

Spray drying is the most economic method to obtain soluble coffee which is free-flowing and agglomerated/granulated powders. The dried powder has about 3.0% moisture. Spray drying features the spraying (atomization) of concentrated extract into hot drying air. The spray droplets dry to form a non-agglomerated, free-flowing powder consisting of large individual spherical bead-shaped particles. An agglomerated powder with low fines content can be produced by combining spray drying with powder fluidization in an integrated fluid bed built into the spray drying cone base. Powders consisting of very large agglomerates are produced in a separate agglomeration process, in which spray dried powder is rewetted by steam, agglomerated, and dried using fluidization and cascading powder principles. Spray drying produces spherical particles about 300 micrometre (0.012 in) size with a density of 0.22 g/cm. To achieve this, nozzle atomization is used. High speed rotating wheels operating at speeds of about 20,000 rpm may be used. The use of spray wheels requires that the drying towers have a wide radius to avoid the atomized droplets collecting onto the drying chamber walls. The drying is completed in 5-30 sec. (dependent on factors such as heat, size of particle, and diameter of chamber). The inlet and outlet air temperature are typically 270◦C and 110◦C respectively. The moisture content of the feed and powder is 75-85% and 3-3.5% respectively. Spray drying is preferred to freeze drying in some cases because of its economy, short drying time, usefulness when dealing with heat sensitive product, and the fine, rounded particles it produces. One drawback with spray drying is that the particles it produces are too fine to be used effectively by the consumer; they must first be either steam-fused in towers similar to spray dryers or by belt agglomeration to produce particles of suitable size.

**Freeze drying**

Freeze drying gives a premium product. It preserves all the desirable aspects of the concentrated coffee extract. Actual freezing can take place on a continuous Air blast belt freezer or for smaller capacities on Rota drum freezer. Granulation of frozen coffee slabs is done to get the right granule size and size distribution. Quality parameters include colour, density and solubility. Freeze drying includes pre-freezing, foaming and freezing of the concentrated extract followed by granulation - sieving of the frozen granules, which are dried in trays (batch processing) or on a moving conveyer belt (continuous processing). On freezing, the water in the concentrated extract forms ice crystals, which sublime under the influence of vacuum and applied heat to leave a dry granular product. Sublimation is the direct phase transition from solid state (ice) to gas phase (vapour). The conveyer belt permits much shorter drying times, promoting improved aroma retention as the coffee granules are exposed only for a relatively short time, to the vacuum conditions inside the freeze drying sublimation chamber.

**Decaffeinated coffee**

The degree of required caffeine reduction for coffee to be labeled “decaffeinated” is not consistent throughout the world. Most European laws restrict coffee products marketed as “decaffeinated” to a maximum of 0.1 wt. % anhydrous caffeine based on dry matter in green and roasted coffee and a maximum of 0.3 wt. % (basis dry matter) in solid, pasty, or liquid coffee extracts. Although during the past century various ideas and solvents have been used for decaffeination, four extraction solvents are in operation today: dichloromethane (DCM), water, ethyl acetate (EA), and carbon dioxide in its supercritical (scCO2) and liquid (liCO2) states (Britta, 2017).

**Extraction with organic solvents**

A variety of organic solvents have been found to be suitable, but only two are commonly used: DCM (methylene chloride; CH2Cl2) and ethyl acetate (ethyl ethanoate; CH3-COO-CH2-CH3).

With organic solvent decaffeination, beans are first contacted with steam and water to increase their moisture content from roughly 10 to 25 or even 40 wt.%. The beans are then decaffeinated by extraction with the organic solvent, either in fixed beds (e.g., percolation column batteries, carousel extractors) or in agitated systems (e.g., rotating drums). The diffusion of caffeine in the beans is rather slow and thereby rate controlling, and thus intense bean agitation, is not imperative. The limited solvation capacity enforces multiple extractions with fresh organic solvent or a vessel sequence operating in counter current mode. After completion the residual organic solvent is drained and stripped with steam. Finally, the initial moisture content is re-established by drying with air (often a sequence of different drying technologies, *e.g.,* fluidized beds, vibrating belts, vacuum dryers). Low air temperatures, oxygen exclusion, and completion by cooling can be helpful to minimize aroma decomposition. The used organic solvent is recycled via distillation (e.g., continuous natural circulation evaporator) producing a solid residue (w60% caffeine, w40% others, mostly lipids). Caffeine is separated from the residue and refined, with the remains named coffee waxes due to their appearance, although triglycerides are predominant.

**Extraction with water**

The bed of green beans is extracted with fresh water. The extract stream containing caffeine as well as various other coffee solubles passes an absorber bed of activated carbon (AC). A special type of AC displays a high selectivity for caffeine so that most other substances stay in the water phase. The now nearly caffeine-free solution is concentrated (e.g., up to 30%) for later addition to the green beans and thereby recycles most of the previously extracted noncaffeine substances. To make the decaffeinated beans absorb the concentrate they need a marked drying step. The processed concentrate waits approximately 1-1.5 h before being added back to the appendant bean charge. After adding back the concentrate, final bean drying completes the process.

**Extraction with pressurized carbon dioxide CO2**

Although commonly known as a gas, carbon dioxide exists at elevated pressures either as liquid or a so-called supercritical fluid. In the liquid and even more so in the supercritical state (T > 31oC, p > 7.39 MPa), CO2 is able to dissolve some caffeine but less than other solvents. Its advantage is a superior selectivity. Decaffeination with scCO2 operates at around 25 MPa and 100oC. CO2 is readily available, physiologically harmless, and nonflammable. This allows for a decaffeination process without any of the other drawbacks but requires costly installation and maintenance and the use of rather special high pressure technology. The general process sequence is like in the other processes: beans are swollen with water and then extracted in percolation columns, which are in this case massive high pressure vessels rated to pressures such as 30 MPa. Several regeneration methods for the caffeine loaded CO2 flow have been proposed, like the use of membranes to separate caffeine from the scCO2 (Gehrig, 1984). Two methods are used today: either adsorption with AC or stripping in a high-pressure wash-column with water.

**Packaging of coffee powder**

**Metal cans**

Packaging coffee powder in metal cans has been highly popular for a long time, particularly for retail packaging. For example, cans are commercially available with capacities of 400, 900, 1800, and 2500 g. The main reason for using metal cans is their excellent physical strength, durability, absolute barrier properties to moisture, O2, and light, absence of flavour or odour, and rigidity.

**Multilayer pouches**

In recent years, aluminium foil/plastic film laminates have been introduced as a replacement for the tinplate can. The laminates can be formed, filled, gas-flushed, and sealed on a single machine from reel stock. Such flexible pouches or sachets are well positioned to exploit the opportunities for convenience food markets. Flexible packages reduce the volume of traditional packaging such as metal cans, reduce transport costs, reduce the cost of the packaging, and require less material, thus minimizing postconsumer waste. Commonly, a laminated multilayer pouch for coffee powder must comprise a barrier to water vapor, O2 (at least for WMP products), and light. Aluminium foil is capable of providing such a barrier provided the foil does not have pin holes in it. Aluminium foil built into a flexible material provides a close-to-absolute barrier. Building into a flexible material is essential because the foil does not have any mechanical strength by itself and therefore needs protection from mechanical damage.

A sandwich construction with two plastic layers—one on the inside, such as low density polyethylene (LDPE), so that the pouch can be sealed and one on the outside, such as biaxially oriented polypropylene (BOPP) or poly (ethylene terephthalate) (PET), to provide mechanical protection and also carry information—is common practice. Sachets with larger capacity (in excess of 250 g) comprising a high-barrier plastic layer sandwiched between LDPE and BOPP or PET would be able to achieve a similar shelf life to an alufoil-sandwiched portion pack pouch.

**Coffee consumption**

A cup (150 ml) of brewed coffee contains 80-120 mg of caffeine and instant coffee 50-65 mg. Caffeine stimulates the central nervous system and induces physiological dependence. Generally, low doses (20-200 mg) of caffeine produce mild positive effects like a feeling of well-being, alertness and being energetic. Higher doses (>200 mg) can produce negative effects like nervousness and anxiety, especially in people who do not usually consume caffeine-containing beverages. Tannin is also present in coffee and is known to interfere with iron absorption. Hence, coffee should be avoided at least for one hour before and after meals (www.nin.res.in).

**Coffee as a food additive and nutraceutical**

As a nutraceutical, coffee has anti-inflammatory, anti-oxidant, anti-obesity activity, type-2 diabetes mellitus, cardiovascular diseases. As a food additive, coffee has antimicrobial activity, inhibits lipid peroxidation and can function as a prebiotic (Saeed *et al.,* 2019).

**Innovative coffee products**

Coffee-leaf tea is a [herbal tea](https://en.wikipedia.org/wiki/Herbal_tea) prepared from the [leaves](https://en.wikipedia.org/wiki/Leaf) of the [coffee plant](https://en.wikipedia.org/wiki/Coffea) (either [*Coffea robusta*](https://en.wikipedia.org/wiki/Coffea_robusta) or [*Coffea arabica*](https://en.wikipedia.org/wiki/Coffea_arabica)). The leaves are roaste and grounded, then brewed or steeped in hot water in a form similar to [tea](https://en.wikipedia.org/wiki/Tea). The resulting beverage is similar in taste to [green tea](https://en.wikipedia.org/wiki/Green_tea), but with less caffeine content than either regular tea or coffee. In Ethiopia, coffee-leaf tea is called kuti and has been consumed for hundreds of years (www.wikipedia.org).

Coffee cherry tea is a [herbal tea](https://en.wikipedia.org/wiki/Herbal_tea) made from the dried skins of the coffee fruit. Often it is more than the skins that are used and include the dried berries (or "cherries") of the [coffee plant](https://en.wikipedia.org/wiki/Coffea) that remain after the coffee beans have been collected from within. It is also known as cascara, from the Spanish [*cascara*](https://en.wiktionary.org/wiki/c%C3%A1scara), meaning "[husk](https://en.wikipedia.org/wiki/Husk)". Coffee cherry tea is a common drink in [Bolivia](https://en.wikipedia.org/wiki/Bolivia), as well as in [Yemen](https://en.wikipedia.org/wiki/Yemen) (where it is called [*qishr*](https://en.wikipedia.org/wiki/Qishr)) and [Somalia](https://en.wikipedia.org/wiki/Somalia) (where it is called *bun*) (Amaia *et al.,* 2020). There are several innovative coffee products like instant coffee cubes, probiotic cold coffee and beverages from green coffee ([www.cftri.res.in](http://www.cftri.res.in)). The other commercially available coffee-based products are Coca-Cola with coffee, cold coffee, coffee almonds, coffee cookies, chocolates, coffee paste, coffee fills, cosmetics etc.

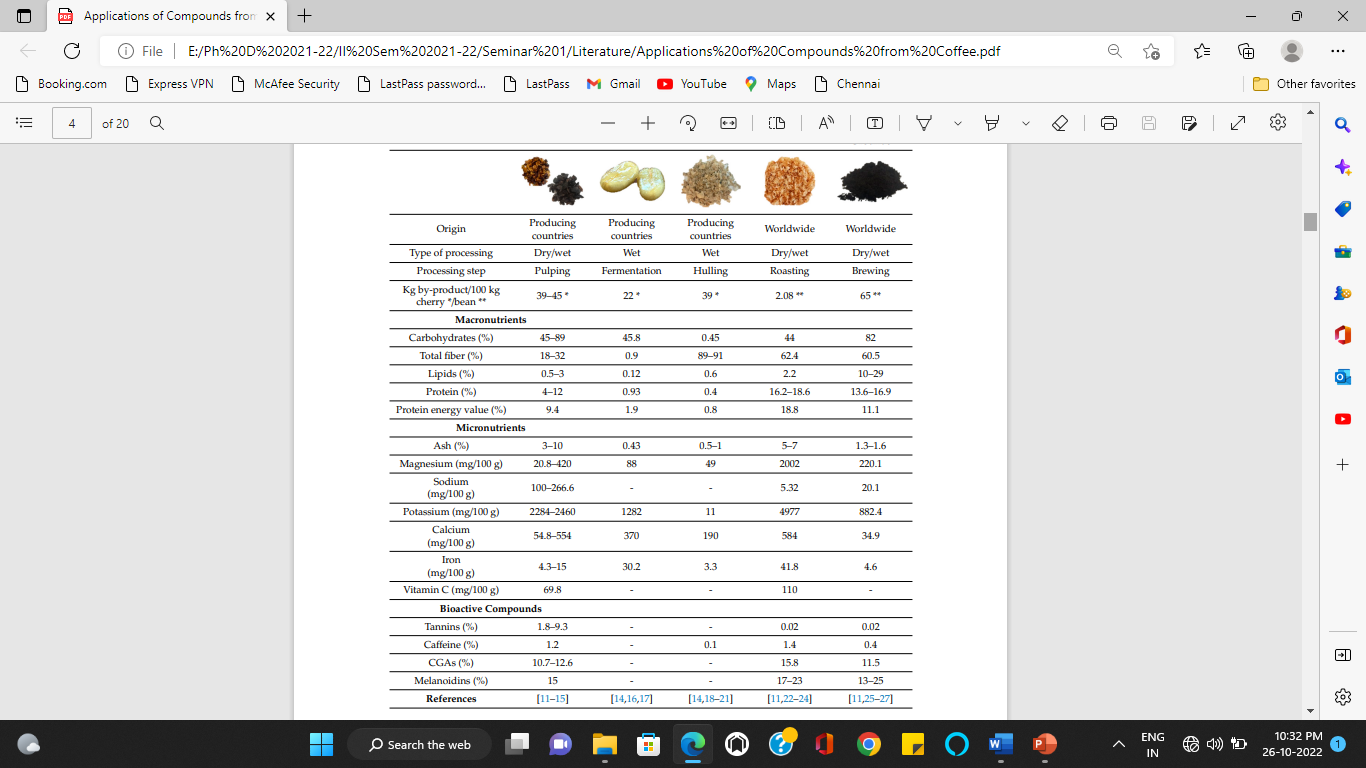
**7. Coffee by-products utilization**

The coffee cherry consists of an outer skin, usually green in unripe and red in ripe fruits, that covers a soft and sweet pulp. This is followed by a viscous and highly hydrated layer of mucilage (pectin layer), a thin yellowish endocarp, the parchment and, finally, the silver skin that covers each hemisphere of the green coffee bean. The first by-product generated during coffee processing is cascara. The definition and composition of this by-product depends on the type of processing employed: the wet or dry method. The dry method, commonly used in Robusta producing countries, is technologically simpler. The freshly harvested cherries are spread evenly and dried for 2–4 weeks under the sun until moisture is below 12%. Then, the cherries are mechanically de-husked and the skin, pulp, mucilage, parchment and part of the silver skin are removed from the bean. Coffee cascara obtained from the dry method comprises nearly 45% of the coffee cherry.

The wet processing is commonly used for Arabica, which is commercially more appreciated and requires the use of different instruments to obtain the green bean. First, the skin and pulp covering the beans are removed by a depulper. In Colombia, one of the first producers of Arabica coffee, in 100 kg of mature coffee cherries, 39 kg corresponds to skin and pulp. Then, the mucilage is eliminated by fermentation for 24 to 72 h and from 100 kg of fresh coffee cherries, 22 kg of mucilage is generated. Next, the bean covered by the parchment is washed, drained and dried until moisture reaches around 10%. Finally, the parchment is removed using hulling machinery. In Colombia, 39 kg of parchment is generated during processing from 100 kg of fresh coffee cherries.

By-products generated until the obtainment of the green coffee bean are generated in coffee producing countries. Green beans are then exported to coffee-consuming countries and stored until roasting. During the roasting process, the silver skin (CS, the thin tegument that covers the bean) is detached and represents the only by-product of the coffee roasting industry. In Spain, the roasting of 120 kg of coffee generates 2.5 kg of CS. Finally, roasted beans are ground, and the coffee beverage is prepared at home or processed for soluble/instant coffee leading to the generation of the last coffee by-product, spent coffee grounds (SCGs). About 2 kg of wet SCGs are obtained for each kilogram of soluble coffee produced. Table 7 shows the origin, type of processing, processing step and the nutritional and bioactive compound composition of all coffee by-products (Amaia *et al.,* 2020).

**Table 7. Origin, type of processing, processing step and the nutritional and bioactive compound composition of coffee by-products**



**Food applications of coffee processing by-products**

Based on their nutritional composition, dietary fiber is the main component in all coffee by-products. The dietary fiber present in by-products is of different nature (soluble and insoluble), lacks allergenic proteins and could be easily extracted for use as an ingredient within the concept of a healthy diet. The second main component in coffee by-products is protein, which could also be isolated and employed as an ingredient.

**Table 8. Food applications of coffee processing by-products**

| **By-product** | **Applications** | **Reference** |
| --- | --- | --- |
| Cascara | Biofuel  Enzymes  Bio-sorbents  Particle board  Animal feed | Gouvea *et al*. (2009)  Murthy *et al*. (2009)  Oliveira *et al*. (2008)  Bekalo and Reinhardt (2010)  Mazzafera (2002) |
| Extraction of honey  High fibre salty cookies  Anthocyanin-food colour | Ramirez and Jaramillo (2015)  Moreno *et al*. (2019)  Hartati *et al*. (2012) |
| Mucilage | Source of pectin, antioxidants and flavanoids | Rathinavelu and Graziosi (2005) |
| Parchment | Functional ingredient  Gluten free bread (6.25%)  Cookies (2%)  Cellulose as a source of packaging material | Benitez (2019)  Cubero (2017)  Apuzzo (2018) |
| Silver skin | Breads  Biscuit  Cake | Pourfarzad (2013)  Garcia (2014)  Ates and Elmac (2019) |
| Spent Coffee Ground | Nutraceuticals-anti inflammatory  Food Ingredient- bakery products  Novel beverages with coffee aroma  Food preservative  Skincare products-oil extracted from SCG  Animal feed  Biodiesel and Bio ethanol  Solid biofuel  Composting  Material for construction  Bioplastics  Adsorbent of contaminants | Lopez (2016)  Oseguera (2019)  Sampaio (2013)  Jimenez (2015)  Marto (2016)  Seo (2015)  Rocha (2014)  Limousy (2015)  Ronga (2016)  Arulrajah (2017)  Williamson (2019)  Macnutt (2019) |

Cascara and silver skin are also a potential source of micronutrients, vitamins and minerals, such as ascorbic acid and potassium. The main phenolic compounds found in coffee by-products are chlorogenic acids, with potential health-promoting properties, such as antioxidant, anti-diabetic and anti-obesity. Studies carried out to date indicate that by adequately controlling food safety in terms of biological contaminants (fungi and mycotoxins) and chemicals (pesticides and acrylamide), coffee by-products could be used as food ingredients due to their interesting content in nutrients and non-nutrient health-promoting compounds. Due to their particular composition and safety, botanical extracts obtained from coffee cascara and silver skin can be employed in nutritional, health and cosmetic applications.

**Nutritional value and health promoting properties**

**Table 9. Nutrition value and health promoting properties of coffee by-products**

|  |  |  |
| --- | --- | --- |
| **By product** | **Nutrition claims** | **Health promoting properties** |
| Cascara | High in fibre  Low in fat  Source of potassium, calcium, magnesium and vitamin C | Anti-diabetic  Anti-oxidant  Anti-inflammatory |
| Mucilage | Low in fat  Source of potassium, calcium and magnesium | Anti-oxidant |
| Parchment | High in fibre  Low in fat  Source of calcium and magnesium | Hypoglycemic  Hypolipidemic |
| Silverskin | High in fibre  Low in fat  Source of proteins, potassium, calcium, magnesium and vitamin C | Prebiotic  Anti-obesity; Anti-diabetic  Antioxidant  Anti-inflammatory; Skin health |
| Spent coffee grounds | High in fiber  Source of proteins  Source of potassium and magnesium | Prebiotic ; Anti-diabetic  Antioxidant; Anti-inflammatory |

Coffee by-products have been proposed as a potential sustainable source of macro-, micro- and non-nutrient bioactive compounds. Table 9 summarizes the nutrition claims that can be attributed to each coffee by-product based on their nutritional composition and their health-promoting properties. Despite the fact that with the data taken from the literature, certain nutritional claims are not reached, depending on the composition of each specific sample, a particular by-product could reach a certain nutritional claim. For instance, in some cases cascara, spent coffee grounds and the ingredients obtained from them may be considered as source of proteins. This macronutrient is the second most abundant component found in both raw materials (Table 7).

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