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# Study on the effect of solvents in extraction of green coffee beans and its decaffeination

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## ABSTRACT

Coffee is the most important food commodity worldwide. Coffee is internationally traded as green coffee (the coffee bean covered or not with the silver skin), which is produced by either dry or wet processing. The active components of green coffee are chlorogenic acid and caffeine. Caffeine contributes taste, act as a stimulant and other benefits include mood enhancement, better exercise performance and reaction time, and reduction of symptoms associated with Parkinson's disease and tremors. But, it has some negative effects such as sleeplessness and mild addiction, anxiety, restlessness, tension, nervousness, and psychomotor agitation. CGA have so many valuable health properties, such as hepatoprotective, Anti obesity, hypoglycaemic, anticarcinogenic and antiviral activities. The objective of the study is to determine the chlorogenic acid and caffeine percentage in green coffee extract and to decaffeinate it. The experiment is conducted on flaked green coffee bean. The solvents used in the trail for the extraction are alcohol, aqueous alcohol, acetone and aqueous acetone. To decaffeinate, the pooled extract is circulated through a 6 cm activated carbon filter column and the activated carbon will act as an adsorbent. The decaffeinated extract is loaded to a rotavapor at 60 °C under reduced pressure to remove the solvents from the green coffee extract. The chlorogenic acid and caffeine percentage were determined by HPLC analysis. The study shows that the solvent have influence on the extraction efficiency,

chlorogenic acid and caffeine percentage. And also showed that decaffeination is possible by passing the green coffee extract through activated carbon.

**Keywords**: Decaffeination, Extraction, Activated Carbon

## 1. INTRODUCTION

Coffee is the most important food commodity worldwide and ranks second, after crude oil, among all the other commodities. Coffee is produced extensively as a main agricultural export product in almost 60 tropical and subtropical countries (Lashermes et al., 2008 and Vieira, 2008). Coffee consumption has greatly increased all around the world. In 2010, coffee production reached 8.1 million tons worldwide (International coffee organisation report, 2011). The reasons for this continuous increase in coffee consumption include improved cup quality through selection of varieties and breeding, better agricultural practices, the creation of specialty shops, and a change in coffee's image through the dissemination of information on the health benefits of long-term coffee consumption.

### Biology

All coffee plants are classified in the large family Rubiaceae. They are ever green shrubs or small trees that may grow 5 m (15 ft) tall. The leaves are dark green and glossy, usually 10–15 cm (4–6 in) long and 6 cm (2.4 in) wide, simple, entire, and opposite. Petioles of opposite leaves fuse at base to form interpetiolar stipules, characteristic of Rubiaceae. The flowers are axillary, and clusters of fragrant white flowers bloom simultaneously. Gynoecium consists of inferior ovary, also characteristic of Rubiaceae. Flowers followed by oval berries of about 1.5 cm (0.6 in), (James et.al 1983).

The two main species commercially important spices are Coffeacanephora (predominantly a form known as 'robusta') and C.arabica (Dagoon, 2005). C. Arabica, the most highly regarded species, is native to the south-western highlands of Ethiopia and the Boma Plateau in southeastern Sudan and possibly Mount Marsabit in northern Kenya (Berthaud et.al 1988). C. canephora is native to western and central Subsaharan Africa, from Guinea to the Uganda and southern Sudan (Van der Vossen et.al 1985). Less popular species are C. Liberica, C. Stenophylla, C. Mauritiana, and C. Racemosa.

### Green coffee and processing

Green coffee beans have a mild, green bean-like aroma (Naidu et.al, 2008). The active components of green coffee bean are chlorogenic acid (upto 12%) and caffeine (1 to 4% (dry basis).

It is composed of insoluble polysaccharides like cellulose and hemicelluloses (ca. 50% w/w). They contain also soluble carbohydrates, such as the monosaccharide fructose, glucose, galactose and arabinose, the oligosaccharides sucrose (accounting for over 90% of the oligosaccharides), raffinose and stachyose, and polymers of galactose, mannose, arabinose and glucose. Soluble carbohydrates act by binding aroma, stabilizing foam, sedimenting and increasing viscosity of the extract. In addition, non-volatile aliphatic acids (such as citric, malic and quinic acids) and volatile acids are also present (such as acetic, propanoic, butanoic, isovaleric, hexanoic and decanoic acids). Oils and waxes are also important constituents, accounting for 8 to 18% of the dry mass, together with proteins and free amino acids (9–12% w/w) and minerals (3–5% w/w) (Arya and Rao, 2007, Belitz et al., 2009, Clifford, 1985a and González-Ríos et al., 2007). The lipid fraction of green coffee beans is mainly composed of triacylglycerols, sterols, tocopherols, and diterpenes of the kaurene family, the latter comprising up to 20% of the total lipids (Speer et al., 2006).

Good harvesting methods are important to produce good-quality coffee. Coffee fruits are harvested in three ways: picking, stripping, or mechanical harvest. In the first method, the cherries are picked one at a time. This method is time-consuming because coffee fruits do not usually ripen simultaneously and therefore expensive .However, picking tends to produce better-quality coffee seeds, in terms of both taste and health, than other methods. Mechanical harvesting is performed by shaking the trees or by stripping the branches with an apparatus similar to a flexible comb. This method collects immature, ripe, and overripe seeds along with leaves.

After harvest, coffee fruits undergo pulp extraction. The most common methods are wet and dry methods. In the dry processing method, seeds are exposed to the air dryers or sun until the moisture content is approximately 10%–12 % (Cirilo et al., 2003). After drying, the fruits are cleaned and dehulled, and then the dried skin and pulp are removed, leaving a mucilaginous material (silver skin). The seeds are mechanically and electronically sorted to separate defective seeds from the high quality seeds.

The wet-processing technique produces a higher quality brew but is more sophisticated than dry method. Before dehulling and separating the seeds, cherry selection takes place in flotation tanks, followed by soaking and fermentation. During fermentation, enzymes may be added, the silver skin is removed and acidity increases; the pH is reduced to 4.5 (Toci et al., 2008). The seeds (parchment coffee) are then extensively washed, polished, and sun-dried and/or air-dried.

After the seeds are dried, coffee is graded, sized and mechanically/manually /or electronically sorted to eliminate defective seeds (Bee et al., 2004). The green coffee seeds are then ready for roasting. Alternatively, they may be decaffeinated, steam-treated, or stored before roasting.

**Caffeine**

Caffeine is a bitter, white crystalline purine, a methylxanthine alkaloid, accounting for 1 to 4% (dry basis), with large variation within spices (Belitz et al., 2009, Dessalegn et al., 2008 and Mazzafera and Silvarolla, 2010). Because it contributes taste, they are strongly related to the quality of coffee beverages (Farah et al., 2006). It is well-known for increasing alertness through, stimulation of the central nervous system, rising blood circulation and respiration, being probably the main reason for coffee popularity (Belitz et al., 2009 and Reich et al., 2008). Other benefits of caffeine include mood enhancement, better exercise performance and reaction time, and reduction of symptoms associated with Parkinson's disease and tremors (Heckmanet al., 2010, Glade, 2010).

But, caffeine has some negative effects such as sleeplessness and mild addiction, which has prompted development of a decaffeinated coffee industry (estimated for around 10–15% of the total amount of coffee consumed in the world) (DuFrene & Rubinstein, 2010), which might also benefit from naturally decaffeinated coffee genotypes (Silvarolla, Mazzafera, & Fazuoli, 2004). High doses of caffeine also cause anxiety, restlessness, tension, nervousness, and psychomotor agitation (Daly & Fredholm, 1998), while long-term use of this , may increase the risk of cardiovascular diseases (Yang, Palmer, & de Wit, 2010), (Dórea & da Costa, 2005).

**Chlorogenic acid**

Chlorogenic acid (CGA) is a natural chemical compound which is the ester of caffeic acid and quinic acid. It is an important biosynthetic intermediate and antioxidant (Boerjan et al., 2003), (Johnston et al., 2003).

CGA found in green coffee beans(up to 12% of solids) include caffeoylquinic, feruloylquinic, p-coumaroylquinic, dimethoxy cinnamoylquinic, dicaffeoylquinic, diferuloylquinic, di-p-coumaroylquinic, feruloylcaffeoylquinic, dimethoxy cinnamoylcaffeoylquinic, dimethoxy cinnamoylferuloylquinic, p-coumaroylcaffeoylquinic, p-coumaroylferuloylquinic and p-coumaroyl dimethoxy cinnamoylquinic acids (Alonso-Salces et al., 2009, Alonso-Salces, et al., 2009 and Belitz et al., 2009).

CGA have valuable health properties, such as hepatoprotective, Anti obesity, hypoglycemic, anticarcinogenic and antiviral activities. Other phenolic compounds, such as tannins, lignans and anthocyanins are found in lower contents in the coffee seeds (Farah & Donangelo, 2006) (Iwai, et al., 2004).

**The reason to use green coffee bean**

Roasting coffee transforms the chemical and physical properties of green coffee beans into roasted coffee products. The roasting process of coffee beans reduces amounts of the chemical chlorogenic acid. Because the high temperature of the roasting process causes a breakage of the carbon -carbon bonds of CGA, resulting in isomerization and degradation. After 5min of roasting, the levels of 5-CQA had decreased substantially, while the levels of 3-CQA and 4-CQA had increased to twice their original values. In addition, it is possible that partial hydrolysis of diCQA to monoester derivatives occurs in addition to isomerization. An initial rise in the total CGA amount was observed at 5 min of roast. This could be a result of the loss of other compounds that are more sensitive to heat, causing a relative increase in levels of the remaining ones (Shahrzad et al., 1996). Longer periods of roasting resulted in a loss of total CGA. Besides isomerization and degradation, other chemical transformations may occur, the dominant being dehydration of the quinic acid moiety and formation of a lactone ring. Because the elimination of a water molecule from the six-membered ring of the quinic acid requires a syn-1, 3-diaxial configuration of the hydroxyl and carboxyl groups to form lactones, only those isomers that lack a cinnamoyl substituent in the 5-position of the quinic acid (i.e., 3-CQA and 4-CQA) are able to form a 1,5-quinide during roasting (Clifford et.al, 2000). The rate at which all these changes occur depends on both temperature and the amount of beans inside the roaster.

**Green coffee extract**

The roasting process will causes a series of changes in the composition of the coffee beans, because some compounds are degraded or modified (Alves et al., 2010), resulting in the development of characteristic aroma, flavour and colour (Buffo & Cardelli-Freire,

2004). To avoid loss of some beneficial compounds during this process, green coffee can be also used to obtain the "green coffee extract", Extraction can be done with either hot water (Suzukiet al., 2002), alcohol (Thom, 2007) or their mixture (Naidu et al., 2008). Green coffee extracts have been investigated for their antioxidant potential (Naidu et al., 2008), body weight control properties (Shimoda et al., 2006), blood pressure-lowering effect (Watanabe et al., 2006), antibacterial activity (Arora et al., 2009) and antihypertensive effect (Kozuma et al., 2005 and Ochiai et al., 2004). Some green coffee extracts can be commercially found, which contain most secondary metabolites from the green coffee beans, particularly CGA, but lower levels of caffeine, cafestol and kahweol. Cafestol and kahweol have been related to increased levels of serum cholesterol (Farah et al., 2008, Speer and Kölling-Speer, 2006 and Thom, 2007) but, at the same time, might have some anticarcinogenic effects (Cavin et al., 2002), (Rubayiza and Meurens, 2005 and Speer and Kölling-Speer, 2006).

## 2. MATERIALS AND METHOD

### Materials

The green coffee beans were purchased from the local market of Kerala. The solvent used for extraction is alcohol, acetone, aqueous acetone, and aqueous alcohol. Acetonitrile (HPLC grade), Formic acid (AR grade) Water (HPLC), 5-caffeoylquninic acid (sigma standard, purity 99.1%), Caffeine (sigma standard, purity 99.1%).

### Pre-treatment for extraction

The green coffee beans obtained were first cleaned to remove the external mattes such as dirt and other impurities. In trial 1 the green coffee bean is grinded in a wet grinder and sieved through mesh no: 10, no: 20 and no: 60. The particle size of mesh no: 20 is taken for extraction. And in trial 2 green coffee beans are flaked by passing through a roller mill to a thickness of 0.5–1.0 mm.

### Extraction from green coffee bean

The efficiency of solid/liquid extraction processes is affected by critical processing parameters, such as temperature, nature of solvent, structure of solid matrix (mainly particle size) and extraction time (Franco et. al).The grinded (500g) and flaked green coffee bean (500g) is taken in a 5 litre conical flask. 2.5 litre solvent is added to the conical flask and stirred well. Solvent to solid ratio is 1:5 and it was reported that the phenolic content is affected by the extraction solvent volume being used (Cacace et al., 2003; Maran & Priya, 2015). The solvents used in both the trials are alcohol, aqueous alcohol, acetone and aqueous acetone. Solid to solvent mix is kept for a contact period of 3hours; then filtered through a filter paper. To obtain the total concentration of caffeine and chlorogenic acid from green coffee bean, the feed was extracted 3 times.

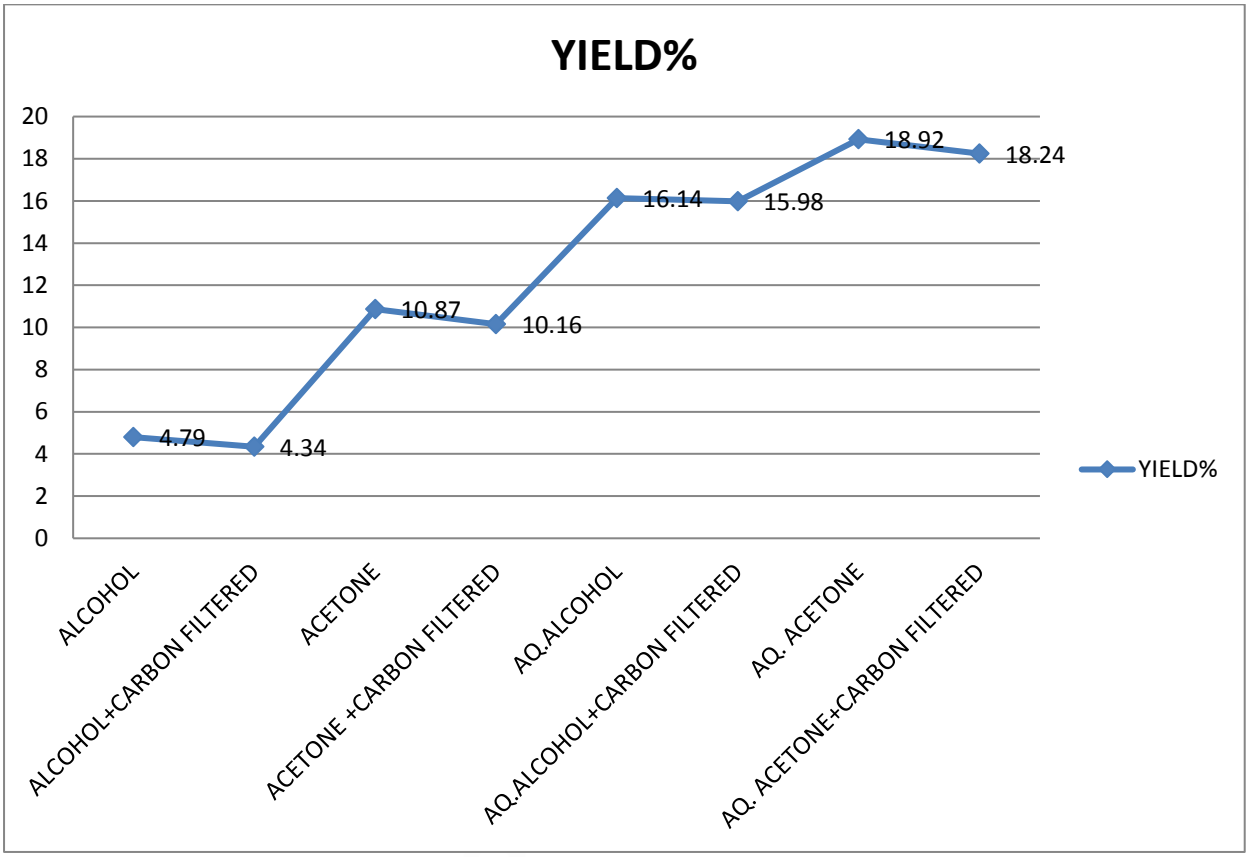
### Decaffeination

The pooled extract is circulated through an 6 cm activated carbon filter column .Activated carbon, is also called activated charcoal, activated coal, or carbo activates. It is a form of carbon, processed to have small, low-volume pores that increase the surface area available for adsorption. Activated carbon is used as a adsorbent to selectively remove the caffeine from the green coffee extract. The decaffeinated extract is added to a round bottom flask and then it is loaded to a arotavapor (Buchi R-3) at 60 °C under reduced pressure to remove the solvents from the green coffee extract. The yield, chlorogenic acid % and %of caffeine were computed.

## 3. RESULTS AND DISCUSSION

### The yield percentage of extraction

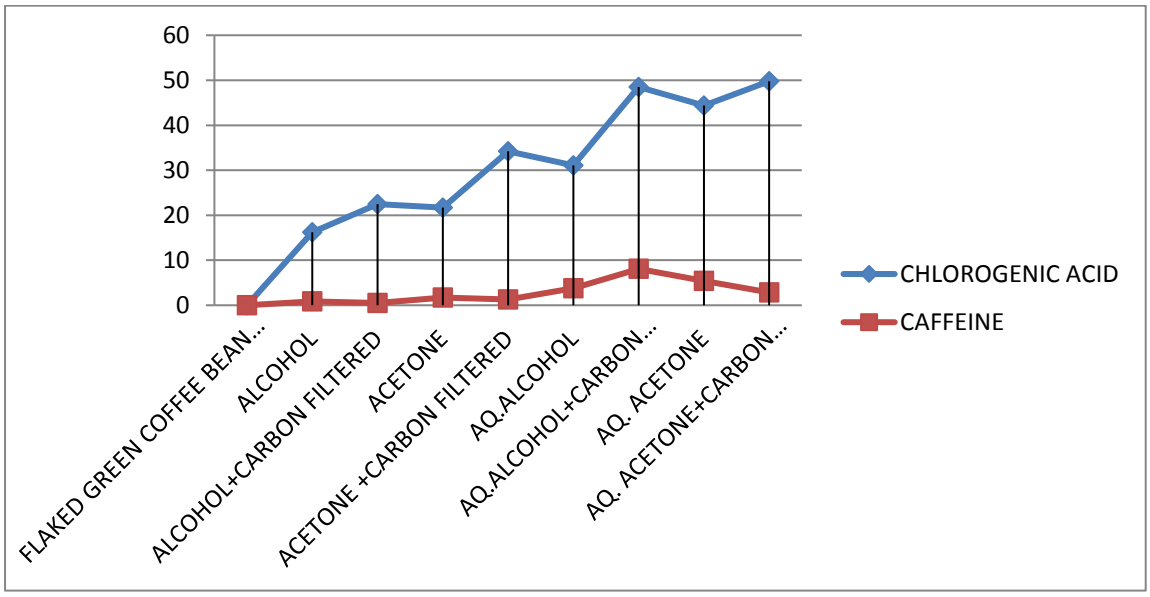
- The highest chlorogenic acid percentage is found in aqueous acetone extracted carbon filtered green coffee extract.
- This is because activated carbon will purify and isolate chlorogenic acid from the green coffee extract.
- The maximum caffeine of 5.42% is extracted with aqueous acetone of flaked coffee bean and when it is passed through activated carbon the caffeine content is reduced to 2.84%.This is because the carbon will act as an adsorbent and remove caffeine.
- Extraction efficiency of solvent is directly proportional to polarity index .Aqueous solvents have higher polarity index followed by acetone of 5.1 and alcohol of 3.9 polarity index. This is the reason why aqueous acetone have highest yield (up to 18.24%), followed by aqueous alcohol, acetone and alcohol the least.




Yield of flaked green coffee bean

Flaked green coffee bean

| TRIALS | YIELD% |
|---|---|
| ALCOHOL | 4.79 |
| ALCOHOL+CARBON FILTERED | 4.34 |
| ACETONE | 10.87 |
| ACETONE +CARBON FILTERED | 10.16 |
| AQ.ALCOHOL | 16.14 |
| AQ.ALCOHOL+CARBON FILTERED | 15.98 |
| AQ. ACETONE | 18.92 |
| AQ. ACETONE+CARBON FILTERED | 18.24 |




Flaked green coffee bean trials

| FLAKED GREEN COFFEE BEAN TRIALS | CHLOROGENIC ACID | CAFFEINE |
|---|---|---|
| ALCOHOL | 16.23 | 0.88 |
| ALCOHOL+CARBON FILTERED | 22.51 | 0.51 |
| ACETONE | 21.67 | 1.72 |
| ACETONE +CARBON FILTERED | 34.22 | 1.29 |
| AQ.ALCOHOL | 31.06 | 3.80 |
| AQ.ALCOHOL+CARBON FILTERED | 48.48 | 8.08 |
| AQ. ACETONE | 44.38 | 5.42 |
| AQ. ACETONE+CARBON FILTERED | 49.77 | 2.84 |

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