DEVELOPMENT OF HOT AND COLD BEVERAGES FROM COFFEE (C*offea arabica* L.) HUSK

M.Sc. THESIS

BY

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DEVELOPMENT OF HOT AND COLD BEVERAGES FROM COFFEE (*Coffea arabica* L.) HUSK

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By

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DEDICATION

This thesis manuscript is dedicated to my family and my grandfather ZEPERA SHEKURE for all the sacrifices, wishes and praiseworthy to my success in all my endeavors.

STATEMENT OF THE AUTHOR

I, the undersigned, declare that this Thesis is my work and is not submitted to any institution elsewhere for the award of any academic degree, diploma or certificate and all sources of materials used for this Thesis have been duly acknowledged. This Thesis has been submitted in partial fulfillment of the requirements for M.Sc. degree at Jimma University, College of Agriculture and Veterinary Medicine and is deposited at the University's library to be made available to borrowers under the rules of the library.

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BIOGRAPHICAL SKETCH

The author Woinshet Tizazu Abate was born at Gumer woreda, Gurage zone of SNNPRS region on June 1987 G.C. She attended her elementary and junior secondary school at Arekete elementary and junior school and High school at Ayertena senior secondary school and preparatory at Higher 23 senior secondary and preparatory school in Addis Ababa 1992 to 2006 G.C. She joined Jimma University College of Agriculture and Veterinary Medicine in 2007 and graduated in 2009 with B.Sc. degree in Horticulture. Then she was employed by Ethiopian Conformity Assessment Enterprise as quality inspector two from 2010 - 2011G.C. She got the opportunity to rejoin Jimma University College of Agriculture and Veterinary Medicine to pursue her postgraduate study in September 2011/12 in Postharvest Management; specializing in Perishables.

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LIST OF ABBREVIATIONS AND ACRONYMS

AOAC	Association of Official Analytical Chemists
CBD	Coffee Berry Disease
CGA	Chlorogenic Acid
CGL	Chlorogenic Acid Lactones
CRD	Completely Randomized Design
EARO	Ethiopian Agricultural Research Organization
ECAE	Ethiopian Conformity Assessment Enterprise
ECX	Ethiopian Commodity Exchange
GLM	General Linear Model
HDPE	High Density Polyethylene
HPLC	High Performance Liquid Chromatography
ICO	International Coffee Organization
IPGRI	International Plant Genetic Resource Institute
ITC	International Trade Centre
JUCAVM	Jimma University College of Agriculture and Veterinary Medicine
LSCPDE	Limmu Suntu Coffee Plantation Development Enterprise
LSD	Least Significant Difference
MCTD	Ministry of Coffee and Tea Development
ppm	Parts per million
SAS	Statistical Analysis System
SNNPRS	Southern Nation Nationalities and Peoples' Regional State
UK	United Kingdom
US	United States
USA	United States of America

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ABESTRACT

Coffee husk is the most abundantly available agricultural waste in many coffee-producing areas of the tropics including Ethiopia. To date, it does not have much commercial or industrial value other than, becoming the major polluting agent of rivers and lakes. It contains caffeine and other chemicals which could be extracted and incorporated in to beverages in the process of brewing. This potential of the coffee husk to be utilized as a raw material for making a beverage could be among the solutions for the problem of it being a waste coming out of coffee bean processing operations. Thus, this study was conducted to investigate the possibilities of developing hot and cold beverages of acceptable sensory quality from the dry coffee husk. The study, comprised of three roasting temperatures, roasting times and different levels of dose, laid out in 3x3x3 factorial arrangement for the sensory evaluation and 3x3 *factorial arrangement for proximate analysis in CRD. Data were collected on physicochemical characteristics and sensorial response variables and analyzed using SAS version 9.2 Software. The results of the study revealed that almost all of the response variables were significantly affected by the interaction of roasting temperature, roasting time and dose. As a result, the caffeine content of roasted coffee husk was higher in samples subjected to 140^{0}C for 3, minute than in the rest of the samples compared. Carbohydrate content is higher in row coffee husk than in the roasted ones and lowest in samples roasted at 160^{0}C for 5 minutes. Coffee husk hot beverage produced from 160^{0}C roasting temperature, 3 minute roasting time with 24g/l dose was more accepted by consumers for all sensory attributes except color, which was favored for the same dose of coffee husk roasted at 140^{0}C for 5 minutes. More than 50% of the treatment combinations resulted in overall acceptability score of 4 and above showing various degrees of liking of the hot beverage. Cold beverage produced from 24g of coffee husk roasted at 140^{0}C for 3 minutes and brewed in a liter of water was more accepted by the consumers for most of the attributes investigated than the others cold beverage produced by different combination of the treatments. It is possible to produce cold beverages of acceptable sensory quality with a number of treatment combinations of 140 and 150^{0}C roasting temperatures and 3 and 5 minutes of roasting time at doses of 20 and 24 g/l. Correlation analysis among the response variables indicated that moisture content was negatively and very highly significantly ($P<0.01$) correlated with fiber, ash and protein contents of the roasted husk. However, it had no significant ($P<0.05$) correlation with caffeine. Fiber content showed very highly significant ($P<0.01$) and negative association with carbohydrate. Caffeine had significant correlation with protein. The relationship between sensory quality attributes of both hot and cold beverages of the coffee husk is very highly significant ($P<0.01$) and positive with each other. It can be concluded that the chemical composition of coffee husk and consumer likings of the beverage are significantly affected by roasting temperatures, roasting times and doses. The findings from this study could promote the consumption of coffee husk in the form of hot and cold beverages which, with no doubt, can be considered as one of mitigation strategy against environmental pollution which otherwise would be debilitating to our coffee industry. However, additional studies need to be done using more number of varieties to come up with a comprehensive recommendation.*

Key Words: Coffee Husk; Beverage; Caffeine; Roasting

1. INTRODUCTION

Coffee belongs to the family *Rubiaceae* and genus *Coffea* comprised 104 species native to forests and scrublands of tropical Africa, Madagascar and the Mascarene Islands in the Indian Ocean (Davis *et al*., 2006, 2010) based on a pre-phylogenetic circumscription. As a consequence of evolutionary studies, Davis *et al*. (2011) recently subsumed psilanthus Hook. F. into *Coffea* which increases the number of *Coffea* species to 124, with the geographic distribution considerably extended to tropical Asia and Australasia. The economically most important species of the genus are *C. arabica* L. with more than 70 % of the world's coffee production and *C. canephora* pierre ex A. Froehner with nearly 35% (ICO, 2013). Out of the two major crop species better quality coffee with low content of caffeine and fine aroma are associated with C. *arabica* (Raina *et al.,* 1998). All *Coffea* species are diploid (2n=2x=22) and generally self-incompatible, except for *C. arabica*, which is tetraploid (2n=4x=44) and self-compatible (Lashermes *et al.,* 1997; Carneiro, 1999; Anthony *et al.,* 2002; Steiger *et al.,* 2002 and Tadesse, 2003).

Coffee is one of the most valuable commodities in the international agricultural trade (Chaves *et al*., 2008). For many years, it has been the second highest commodity following oil as a source of foreign exchange and a major employer globally. It is reported that over US$ 90 billion was generated from coffee international trade each year (Chaves *et al*., 2008). It also provides job opportunities for more than 500 million people employed in all activities from cultivation to the final product for consumption across the world (DaMatta and Ramalho, 2006; Chaves *et al*., 2008).

Ethiopia is the only center of origin and diversity of *Coffea arabica* L. and thus is an important source of *Coffea* genetic resources of the world *Coffea* industry (Tadesse, 2003). The crop is also a source of foreign currency for many developing countries in the tropics. For instance, Ethiopia obtained over 35% of its income from foreign exchange (ICO, 2012). About 25%, 15 million of Ethiopia's population depends on coffee for their livelihood directly or indirectly (Tadesse, 2003). Ethiopia is currently the fifth largest Arabica coffee producer in the world and the first in Africa with a production of 390,000 tons during the crop year 2011/12 (ICO, 2012).

Commonly there are two methods of coffee processing known as sun dried (natural) and wet (washed) processing. Very recently semi-washed processing method introduced to Ethiopia. It is a method of processing coffee by washing before fermentation. In Ethiopia, washed coffee accounts for 35%, while natural (sun dried) accounts for 65% of all the coffee produced (Musebe *et al.,* 2009). In the dry processing, fruits are dried naturally (sun-dried) or artificially (in furnaces), to obtain dry beans from which the exocarp, mesocarp and endocarp of the cherry coffee have to be removed by hulling, that give husk as byproduct. In the wet processing procedure the fresh fruits are pulped, fermented, washed and sun or furnace dried. The pulping procedure removes the exocarp and most of the mesocarp, resulting in coffee pulp by product. The dried coffee in the wet processing procedure is called dry parchment coffee, because the endocarp (parchment) is still on the beans. Hulling the dry parchment coffee leads to hulls by product. Exocarp plus mesocarp and endocarp represent 60% of the dried fruit mass. Therefore, a considerable volume of husk and hulls are produced when the coffee fruits are processed (Fan *et al.,* 2003).

It is estimated that, for a single kilogram of coffee beans produced, about one kg husks are generated (Fransa and Olivera, 2009) which becomes a serious problem due to the presence of toxic material such as caffeine, free phenols (monomers) and polyphenols (tannins). The outer skin and a part of mucilage from the coffee pulp, produced during the wet processing; whereas all parts except the bean form the coffee husk, produced by dry processing (Fan *et al.,* 2003). After processing the pulp and hull are largely dumped or disposed into arable land and surface water. Nowadays the main alternative uses of coffee by-products include the production of soil conditioner, fertilizer, mulch, animal feed, alcohol, biogas, sugar, pectin, charcoal, heat energy, wax, acids and caffeine (Fan *et al.,* 2003).

Coffee husk is the most abundantly available agricultural waste in many coffee-producing areas of the tropics including Ethiopia. In most coffee producing and processing areas of Ethiopia the husk does not have much commercial or other industrial value it is becoming the major polluting agent of rivers and lakes. The huge presence of proteins, sugars and minerals in coffee husk and its high humidity favors the rapid growth of microorganisms which can pose due environmental pollution (Roussos *et al*., 1995).

The use of coffee husk for making a drink is being practiced traditionally among the rural people in some places like the Hararghe region in Ethiopia and the same way in Yemen. With the spread of consumption of tea in Ethiopia the traditional use of the coffee husk for hot drink is being reduced specially among the young generation in towns. These days with the high rise in the price of coffee some people use other materials like barley grain or coffee husk for mixing with the roasted and ground coffee beans to make the coffee drink. According to Oliveira *et al.* (2009), the coffee husk has caffeine and other chemicals which could be extracted and transferred to the beverages in the process of brewing. In areas where the husk is being used for making drink, the people know that regular consumers are usually stimulated to the drink the same way the coffee consumers would.

This potential of the coffee husk as a raw material for making a beverage could be among the solutions for the problem of it being a waste coming out of green coffee bean processing operations. In addition it could make the cultivation and processing of coffee more economically important by widening the dimensions of its use for income generation to the producer. It could be an industrial raw material in the future thereby adding the number of beverages in the market. Furthermore the process may also make the husk to easily be degrade once it is gone through the brewing process that it could easily be decomposed and mixed with the soil as manure. Once the beverage is developed it can also create job opportunity for people who could be involved in the production, processing and marketing of the husk and its beverage in small or large scale. With this in mind this research was initiated and having the following objectives.

General objective

- To investigate the possibilities of developing hot and cold beverages from the dry coffee husk and assess acceptable sensory quality.

Specific objectives;

- To investigate the effects of coffee husk roasting temperature and time on the chemical properties from coffee husk
- To investigate sensory acceptability of hot and cold beverages to be brewed.
- To determine the husk dose level of the beverage for consumer acceptability

2. LITERATURE REVIEW

2.1. Coffee Production and Processing

Coffee is one of the international agricultural commodities and is cultivated all over the world. It represents an agricultural crop of economic significance to the coffee producing countries (Fujioka and Shibamoto, 2008). Coffee is nowadays produced in a large number of countries worldwide. Nevertheless, the ten largest coffee producing countries are responsible for approximately 80% of the world production. Brazil, Vietnam, Indonesia, Colombia and Ethiopia are respectively the first, second, third, fourth and fifth largest coffee producers. They are responsible for more than half of the world supply of coffee (ICO, 2011/12). The world total exports in 2012 reached to 113.1 million bags, 8.2% higher than 2011, and predominantly fuelled by a high volume of Robusta shipments (ICO, 2013). The global annual coffee production is estimated at 5.5 million tons of which 6.4% is produced in Ethiopia. The Ethiopian annual coffee production is estimated at 0.35 million tons of which 55%, 35% and 10% of which is from the western, southern and eastern part of the country respectively (Alemayehu *et al.,* 2007).

Coffee cherries are the raw fruit of the coffee plant, which are composed of two coffee beans covered by a thin parchment like hull and further surrounded by pulp. These cherries are usually harvested after 5 years of coffee trees plantation and when the bear fruit turns red (Arya and Rao, 2007). Green coffee berries ripen over several months and develop garnet red surface color when reaching harvesting stage. The exocarp is red outer skin of the red coffee berries. Beneath the pulp the mesocarp, each surrounded by a parchment like covering the endocarp or pectin layer, the two beans flat sides of which are facing each other. There is thin, slimy layer of mucilage surrounding the parchment in ripe coffee fruits. Silvery skin is thin membrane located between two coffee beans covered underneath the parchment (Mutua, 2000).

The aim of coffee processing (both dry and wet method) is isolation of coffee beans by removing the shell and mucilaginous part from the cherries. The solid residues obtained from wet and dry coffee processing is termed as coffee pulp and coffee husk, respectively (Pandey *et al.,* 2000). Dry coffee processing method is the oldest, simplest and requires little machinery. It involves drying the whole cherry and hulling. This is a natural process and the harvested cherries classified here are dried in their entirety, most usually in the sun (Clark, 1985) or the fruit is allowed to remain on the tree past the full ripe stage and is partially dried before harvesting (Sivetz and Desrosier, 1979). The dried coffee cherry when at about 12 percent moisture is then subjected to a milling operation (or 'hulling' or rather 'de husking') to separate out the green bean (Clark, 1985).

Wet coffee processing requires the use of specific equipment for removal of the pulp with the help of substantial quantities of water. In general, washed coffee carefully prepared and handled, is clean in flavor and free from undesirable element (Sivetz and Desrosier, 1979). Wet processed Arabica is aromatic with fine acidity and some astringency, while dry processed Arabica is less aromatic but with greater body (Clifford, 1985). The use of 'under water fermentation as opposed to 'dry' accentuates the formation of acids. Natural coffee, since it is always dried in contact with its mucilage, has a better body and due to this fact under ideal condition natural coffee may be of excellent quality, clean tasting and full bodied and while different, fully as desirable as washed coffee (Clark, 1985).

2.2. Coffee Production Systems in Ethiopia

Coffee grows in Ethiopia in almost all administrative regions. However, the major coffee growers of the country are, Oromia and Southern regions (Suseela *et al*., 2001). Coffee production systems in Ethiopia are grouped into four broad categories namely, forest coffee, semi-forest coffee, garden coffee and coffee plantations (MCTD, 1992). They account 10, 34, 35 and 21% of the total production, respectively. The most important cultivation areas are southwestern and southern parts of the country. Ethiopia is the only country in the world where coffee grows wild as an understory shrub or small tree in the Afro-montane rainforests (Paulos and Demil, 2000).

Coffee grows under diverse environmental conditions ranging from 550 m to 2600 m above sea level, with annual rainfall varying from 1000-2000 mm, and minimum and maximum temperature of 8-15 ^{0}C and 24-31 ^{0}C, respectively, requiring deep, well drained, loamy and slightly acidic soils (Paulos and Tesfaye, 2000). The estimated area of land covered by coffee is about 600,000 hectares and the estimated annual national production of clean coffee is about 350,000 tons. Coffee is limited to only a single slashing of the broad-leaved weeds at the beginning of the cropping season followed by harvesting (Alemayehu *et al*., 2008).

Coffee production throughout Ethiopia can be put in to two categories based on its level of production as major and minor coffee growing regions. Iluababor, Wellega, Keffa, Sidamo, Gedeo and Harrage are the major coffee growing regions in Ethiopia. They contribution is 95% of the total coffee production in Ethiopia. Arssi, Shoa, Gojjam, Gonder and Wollo are where coffee is not produced as major production but it only satisfies the local consumption. These are considered minor coffee growing regions. Wild animals and birds disseminating seeds within the forest community assist spontaneous regeneration (Paulos and Demel, 2000). The forest is also covered by heterogeneous species of overhead shade trees. The occurrence of wild coffee types with distinct phenotypic differences in the forests extends around Sheka, Tepi and Bebeka; Gewata and Geisha in Kefa, Obacherko in Gera, Geba-Doggi valley near Yayu in Illubabor and Eba forest in Anfillo, all in Southwest Ethiopia while the average yield of forest coffee has been estimated to be in the order of 200-250 kg/ha (Paulos and Demel, 2000).

Semi-forest coffee production system is commonly found in Iluababor, Jimma, Keffa-Sheka, Benchi-Maji and west Wellega zones. Forest coffee lands of considerable sizes that are located near the main roads, rural towns or peasant villages are covered with coffee trees standing in scattered manner and are managed with little cultural practices such as weeding and shade regulation (Workafes and Kassu, 2000). These types of plantations are known traditionally as semi-forest type and are believed to have evolved from forest coffee production system. The farmers slash the weeds and shrubs in the relatively light forests and fill in the open spaces with local seedlings. In the coffee improvement weredas of Sidamo, Gedeo, West Hararghe and West Wellega, the observed coffee production system is garden type, located near the residence houses and with an area of less than 0.5 hectares (Workafes and Kassu, 2000). Improved management of row planted coffee in Hararghe, in South and Southwestern part of the country has been used as intensive coffee production system. Spacing, planting pattern and tree density depends on the type of selections planted. The coffee plantation development enterprise runs highly intensified plantations. These large plantations (state coffee farms) of about 21,000 hectares are distributed into seven different farms in Limu, Tepi and Bebeka.

2.3. Importance of Coffee

Today, coffee is one of the most important non-alcoholic beverage crops grown in over 80 countries in the tropical and subtropical regions of the world, exported in different forms to more than 165 nations, and provides a livelihood for some 25 million coffee farming families around the world (Labuschagne *et al*., 2008).

Arabica coffee still grows wild in the forests of the south-western part of Ethiopia, which remains an important source of genetic resources for the world coffee industry (Tadesse, 2003). Ethiopian coffee is an important source of coffee genetic resources for the world coffee industry. As a matter of fact, Ethiopia is the only center of origin and diversity of Arabica coffee (*C. arabica*) (Anthony *et al*., 2001). It is cultivated in most parts of the tropics, accounting for 80 percent of the world coffee market, and about 70 percent of the production (Tadesse *et al*., 2002). It is also an important source of income and employment in developing countries of Latin America, Africa and Asia (Anthony *et al*., 2001). Coffee is the major source of foreign currency for Ethiopia and contributes more than 35% of the total export earnings (ICO, 2012).

Coffee in Ethiopia has a defining feature of the national culture and identity, with 44% of the production consumed domestically (Mayne, 2002) and the country is the leading coffee consumer among all African coffee producers. Coffee beans have been used as stimulant beverage in almost all administrative regions of the country. Even in some places in the country, people use it as a special entertainment; they boiled the dried cherry or beans in butter and use it as a ceremonial food for special days (Raina *et al.*, 1998).

Coffee is also found to be high in health-giving antioxidants. It is considered, as a health drink following a study showing coffee is a surprisingly rich source of anti-cancer agents. A study has found that coffee contributes more antioxidants which have been linked with fighting heart disease and cancer to the diet than cranberries, apples or tomatoes. Anti-oxidants help to rid the body off harmful free radicals and destructive molecules. Recent studies showed that daily intake of coffee were associated with a 50 percent reduction in risk of liver cancer additionally, there was a clear relationship in men between amounts of coffee used daily and risk of liver cancer (Tavani, 1997). Those drinking five or more cup a day had a 76% reduced risk. Studies on the effect of coffee also showed that coffee contains four times the amount of cancer fighting antioxidants as green tea (Davids, 2001). The other study from the Harvard-based Nurses' Health study and Health professionals following study examined the role of coffee in risk of bowel cancer among about 170,000 male and female participants. During a long follow up period 1,177 cases of bowel cancer were found, plus 261 cases of cancer of the lowest part of the bowel, the rectum (Davids, 2001). There was no relation between caffeinated coffee (or tea) intake and cancers of the colon or rectum. However, consumption of as little as one-quarter cup of decaffeinated coffee a day reduced rectal cancer risk by 50 per cent, though it had no influence on colon cancer (Tavani, 1997).

2.4. Coffee Husk

The generation of residues and by-products is inherent in any productive sector. The agro-industrial and the food sectors produce large quantities of waste, both liquid and solid. Coffee is the second largest traded commodity in the world, after petroleum, and therefore, the coffee industry is responsible for the generation of large amount of residues (Nabais *et al.,* 2008). The processing of coffee generates huge amount of agricultural residues such as coffee cherry skin and pulp or husk. In the wet processing method, coffee cherries are pulped to remove the skin (exocarp) and the pulp (outer mesocarp). The skin is separated by pulping and is led away by washing from the vats into collection pits. These coffee pulps forms the most abundant waste produced during the pulping operation of the coffee. It represents around 43% of the weight of the coffee fruit on a fresh weight basis, or approximately 28% (26-30 %) of the coffee fruit on a dry weight basis. The other by-products of coffee fruit processing are the mucilage, about 5% (5-14%) of the dry weight of the fruit and coffee hulls, representing 12% (10-12%) of the weight of the fruit on a dry weight basis (Pushpa *et al*., 2012).

Coffee pulp, also identified as coffee fruit without seeds, is an abundant agricultural waste that causes serious environmental pollution problems. According to Gezahegn *et al.* (2012), coffee husk is the most abundantly available agro-industrial waste produced during the pulping action on the coffee cherries to obtain coffee beans in many coffee-producing areas of the tropics including Ethiopia. It is estimated that, for 1 kilogram of coffee beans produced, about 1 kg husk is generated, whereas in the dry process 0.18 kg coffee husk is generated for every kilogram of (fresh) dry coffee cherries. In most coffee producing and processing areas of Ethiopia the husk does not have much agricultural, commercial or industrial uses, it is becoming the major polluting agent of rivers and lakes. The huge presence of proteins, sugars and minerals in coffee husk and its high humidity favors the rapid growth of microorganisms which can cause environmental pollution. So municipalities where coffee processing industries are found should pioneer various initiatives for improving the environmental performance of the coffee industries.

2.4.1. Coffee Husk as Waste Product

The tropical agro-industrial residues such as coffee pulp and coffee husk are generated in large amounts during the processing and their disposal causes serious environmental problems. In recent years, there has been an increasing trend towards efficient utilization and value addition of agro-industrial residues such as coffee pulp and husk. The processing of coffee generates two types of waste. The first is the pulp produced during wet milling processing of the coffee in which the cherry is separated from the bean. This pulp is available only at dispersed coffee factories located close to the areas of cultivation and already (in use) as fertilizer and animal feed. The second waste is the coffee husk separated during the dry milling process. Coffee husk is fibrous, low in moisture, uniform in size and low in ash. This makes it well suited to carbonized fuel production. It is also used as mulch, poultry bedding or cooking fuel. Application of these agro-industrial residues in bioprocesses on one hand provides alternative substrates for solid-state fermentation (SSF) and on the other side helps solving pollution problem (Shankaranand and Lonsane, 1994; Martinez *et al.*, 2000; Pandey *et al.*, 2000; Soccol and Vandenberghe, 2003).

Coffee processing industries, are posing environmental hazard due to large-scale disposal of coffee pulp, husk, and effluents from wet processing. This practice poses a great threat to water and land quality around the wet coffee processing units. Presence of toxic compounds like phenols in these byproducts restricts their direct use in agriculture. In addition, the indiscriminate use of fresh coffee pulp also affects crop (plants) through acid formation and local heat generation in the process of its fermentation. In order to restrain from the possibility of adverse effect of the disposal of coffee wastes, there is a need to find a healthier and productive way of utilizing these wastes. Scientific method of preparing enriched compost using decomposition technique and fortification technique can render this waste fit for agricultural use (Preethu *et al.*, 2007). Coffee pulp can also form an excellent substrate for production of value added products.

2.4.2. Uses of Coffee Husk

Proposed alternative uses for coffee husks include employing this solid residue as a supplement for animal feed, direct use as fuel and fermentation for the production of a diversity of products (enzymes, citric acid and flavouring substances), use as a substrate for cultivation of mushrooms, use as adsorbents, production of soil conditioner, fertilizer, mulch, alcohol, biogas, caffeine, sugar, pectines, charcoal, heat energy, wax and acids. Such residue consists mainly of the pulp and hull of the coffee fruit; it presents a high concentration of carbohydrates and thus can be viewed as a potential raw material for bio-ethanol production (Franca and Oliveira, 2009).

Coffee husks have been widely used as (green) manure in coffee and banana plantations. However, with the emergence of the coffee wilt disease, this utilization option has been discouraged as it accelerates the spread of the disease (Serani *et al.*, 2007). The reduction in use of coffee husks as manure therefore implies that large quantities of the coffee husks pose serious disposal problems. Small quantities are also used as litter in poultry houses. Loose coffee husk could be used as (heat) energy source; however, its use is limited due to the low energy density (Samson *et al.*, 2005). Other characteristics such as the unevenness, fluffiness and dustiness make it expensive to store, transport and utilize this biomass material (Li and Liu, 2000). These problems, however, have been resolved by densification of the husk through briquetting. Charcoal produced from coffee husks after briquetting has been in use in Kenya for long time. Studies have also shown that burning of crop residues in conventional burners is inefficient and leads to excessive pollution due to excessive particulate emissions (Grover and Mishra, 1996; Tripathi *et al.*, 1998).

For environmental protection and economic gain, attempts have been made in the past to utilize coffee pulp as an animal feed. However, such attempts (ended up) with limited success because of the presence of anti-physiological factors such as caffeine, tannins, chlorogenic acid and high levels of potassium (Bressani, 1979; Adams and Dougan, 1981; Roussos *et al.*, 1995).

2.4.3. Chemical Composition of Coffee Husk

Coffee is one of the most widely consumed psychoactive beverages in our society. It is a well-known and extensively utilized psychotropic agent with effects on mood, cognitive performance, and motor activity (Mayumi *et al.,* 2004). Coffee is a complex mixture of potential "neutriceuticals". Coffee's chemical composition is determined by a complex interaction of agricultural factors, roasting, blending and brewing processes. Of the main constituents of coffee, typical values for the water soluble ones in order of their abundance are phenolic polymers (pulp) 8%, polysaccharides 6%, chlorogenic acids 4%, minerals 3 %, water 2%, caffeine 1%, organic acids 0.5%, sugars 0.3%, lipids 0.2%, and aroma 0.1% (Isabel, 2004).

Chemical composition of coffee husk is essentially rich in carbohydrates, amino acids, proteins and minerals; especially potassium. It also contains appreciable amounts of tannins, polyphenols and caffeine (Bressani, 1979). Whereas coffee husk is a by-product obtained after drying and de-hulling coffee cherries in dry process method, it contains 10% crude protein, 16% lignin and 57 and 52% neutral and acid detergent fiber respectively indicating that it is fibrous and rather poor roughage (Pandey *et al.,* 2000).

According to Oliveira *et al.* (2009) the proximate composition of the coffee husks was determined as 15.0% moisture, 5.4% ash, 7.0% protein, 0.3% lipids and 72.3% carbohydrates. The high contents of carbohydrates are expected, given the origin of such solid residue, i.e., fruit pulp and outer skin. Cellulose, hemi-cellulose and lignin contents were 16, 11 and 9% dry basis, respectively.

2.5. Roasting

Roasting is primarily intended to cause chemical changes in the coffee bean resulting in the formation of desirable flavor compounds. Physical changes in coffee during roasting include reduction in mass due to loss of moisture and decomposition of carbohydrates, increase in volume of coffee beans, lowering of density due to puffing and increase in brittleness (Mwithiga and Jindal, 2003). Green coffee must be roasted in order to give the final beverage with its unique sensory characteristics (ITC, 2002). Coffee can be roasted to various degrees, from very light to very dark. The degree of roast has direct impact on the sensory profile of the coffee cup, which is a matter of consumer preference. Therefore, the roasting process guarantees the consistent sensory quality of the finished produce (Prodolliet, 2004).

At the start of coffee roasting process, evaporative cooling declines, so the bean temperature rises and an exothermic pyrolysis begins in the temperature ranges of 140–160 ^{0}C, and leads to the formation of the well known color, aroma and taste of roasted coffee product. The acceptable dry matter loss ranges from some 35 for a very pale roast to some 14 % for a very dark roast. The corresponding figures for total roasting loss (dry matter and water) are some 10 percent and 25 percent, respectively (Clifford, 1985). Uneven roast results in poor quality liquor, and dark roast enhances the body, while light roast emphasizes acidity (ITC, 2002). A large quantity of carbon dioxide is produced; its expansion generates internal pressure in the range from 5.5 to 8.0 atmospheres and accounts for the swelling of the bean by some 170–230 percent during commercial roast (Clifford, 1985).

Roasting is the most important process in the coffee technology. Coffee bean is a very complex system which during roasting changes its physical and chemical properties. It is well known that during roasting, coffee beans lose their strength and toughness and become brittle and fragile (Pittia *et al.*, 2007). Thermally induced coffee aroma development is accompanied by several physical changes including color, weight loss, volume, density and texture (Frisullo *et al.*, 2010).

Time and temperature of thermal processing have an impact on formation of individual components of aroma and also on their retention in roasted coffee (Nebesny *et al.*, 2007). According to them application of microwaves, particularly coupled with convective heating increased total amounts of volatile substances of roasted coffee. A study by Garcia *et al.* (2008) indicated that medium roast coffee gives better means value of aroma, flavor and acidity, which are reduced in darker roast and finally concluded that as roasting time increased bitterness will increase and astringency will decrease.

The overall sensory quality of coffee depends up on roasting duration and temperature (Mwithiga and Jindal, 2007). In addition, they reported that acidity and overall quality of coffee brew initially increased and then declined with further roast duration. Coffee roasted for shorter period of time had distinctive flavor resembling to cereals taste and dark roasted coffee gives more bitter taste (Boeneke *et al.*, 2007). According to Moura *et al.* (2007), linear increase of time and temperature on the coffee roast presents significant negative effect on aroma, characteristic flavor, chocolate flavor, sweetness, as well as significant positive effects on bitterness.

Coffee roasting process is responsible for the products characteristics and final quality. In this process, several substances such as chlorogenic acid (CGA), chlorogenic acid lactones (CGL) and caffeine are formed or eliminated, providing flavor, acidity and body (Tfouni *et al.*, 2012). According to Farah, *et al.* (2005), during initial time of roasting rise of total CGA and CGL amount observed; in addition for longer time of roasting (10 min) the amounts of total CGA and CGL decreased to less than 5.2 and 20%, respectively. Slight decrease in caffeine content of *Coffea arabica* under strong roasting conditions was reported (Casal *et al.*, 2000). Chlorogenic acid lactones (CGL) were found to contribute considerably to the bitterness of the coffee beverage (Ginz and Enhelhardt, 1995).

2.6 Sensory Evaluation

Sensory evaluation is a scientific method used to evoke, measure, analyze and interpret those responses to products as perceived through the senses of sight, smell, touch, taste and hearing (Stone and Sidel, 2004). It is one of the methods used in identifying the market acceptability especially in food or drink based products. A palatable food is one considered to be both acceptable and agreeable to ones' taste. Hence, various sensory impressions or sensations, including, odor (aroma/flavor), taste, appearance, mouth-feel, touch /texture, are all involved in our judgment of acceptability, palatability, and quality of food (Lazim and Suriani, 2009).

According to Linda *et al.* (1991) sensory analysis panel can be grouped in to four types;- highly trained experts, trained laboratory panels, laboratory acceptance panels and large consumer panels. Highly trained experts (1-3 people) evaluate quality with a very high acuity and reproducibility;- example wine, tea, and coffee experts. Evaluation by experts and trained laboratory panels can be useful for control purposes, for guiding product development, improvement and for evaluating quality. The trained panel (10-20 people) can be particularly useful in assessing product attribute changes for which there is no adequate instrumentation. Sensory analyses performed by laboratory acceptance panels (25-50 people) are valuable in predicting consumer reactions to a product. Large consumer panels (more than 100 people) are used to determine consumer reaction to the product.

3. MATERIALS AND METHODS

The study material coffee husk was obtained from Limmu Suntu Coffee Plantation Development Enterprise (LSCPDE). The husk was roasted at Ethiopian Commodity Exchange (ECX) laboratory located in Jimma. Three roasting temperatures, roasting times and levels of husk dose were used which gave 27 observations. Chemical Analysis was undertaken at Ethiopian Conformity Assessment Enterprise (ECAE) laboratory following standard tests recommended by AOAC and others. The details of materials and analytical methods used are indicated below.

3.1. Experimental Location

The proximate composition analysis and caffeine content of the coffee husk were analyzed at Ethiopian Conformity Assessment Enterprise (ECAE) laboratory located in Addis Ababa. The room temperature of the laboratory was between 20 and 25^0C. Beverage preparation and sensory evaluation was conducted in Postharvest Management laboratory of the College of Agriculture and Veterinary Medicine of Jimma University (JUCAVM). JUCAVM is geographically located 346 Km southwest of Addis Ababa at about $7^0$41'04.08"N latitude and 36^0, 49' 50.42" E longitude at an altitude of 1710 m.a.s.l. The temperature and relative humidity at post harvest management laboratory was in a range of 24-27^0C and 57-60% respectively.

3.2. Experimental Materials

The basic raw material for production of beverage was dry coffee husk. The coffee fruits needed for the production of husk was of variety 74110 obtained from Limmu Suntu Coffee Plantation Development Enterprise (LSCPDE). The variety was selected for its wide range of adaptability, better quality and yield performance (Behailu *et al.,* 2008; Taye *et al.,* 2011). Then red ripe cheery was sun dried immediately after harvesting to moisture content of 12 percent (wet basis) and shelled manually to obtain the husk. The husk was packed with moisture proof and air tight high density polyethylene bag (HDPE) until needed for the experiment.

3.3. Experimental Design

The experiment was laid out in a 3x3x3 factorial arrangement for sensory evaluation and a 3x3 factorial arrangement for chemical analyses in Completely Randomized Design (CRD) with three replications. Factors considered for assessing sensory acceptability of the beverage product were roasting temperature, roasting time and dose of coffee husk each in 3 levels. For analysis of proximate composition and caffeine content of the roasted husk, the former two factors were considered. Randomization was held separately and independently for each of the replications where the treatments were assigned completely at random as described in (Montgomery, 2009).

The linear statistical model for the treatment factors is shown below.

$\mathbf{Y_{ijkl} = \mu + T_i + t_j + D_k + (Tt)_{ij} + (tD)_{jk} + (TD)_{ik} + (TtD)_{ijk} + \varepsilon_{ijkl}}$ .... for sensory evaluation

$\mathbf{Y_{ijk} = \mu + T_i + t_j + (Tt)_{ij} + \varepsilon_{ijk}}$ ....for chemical analysis

$\mathbf{Y}_{ijkl}$ = the response

μ = the overall mean effect

$\mathbf{T_i}$ = the effect of i^{th} level of roasting temperature

$\mathbf{t_j}$ = the effect of j^{th} level of roasting time.

$\mathbf{D_k}$ = the effect of k^{th} level of husk application dose.

$\mathbf{(Tt)_{ij}}$ = the interaction between i^{th} level of roasting temperature and j^{th} level of roasting time.

$\mathbf{(tD)_{jk}}$ = the interaction between j^{th} level of roasting time and k^{th} level of husk dose.

$\mathbf{(TD)_{ik}}$ = the interaction between i^{th} level of roasting temperature and k^{th} level of husk dose.

$\mathbf{(TtD)_{ijk}}$ = the interaction between i^{th} level of roasting temperature, j^{th} level of roasting time and $\mathbf{k^{th}}$ level of husk dose.

ε_{ijk} and ε_{ijkl} = are the error effects

Table 1. Treatment combinations of roasting time, temperature and husk dose

	T_1			T_2			T_3		
	t_1	t_2	t_3	t_1	t_2	t_3	t_1	t_2	t_3
D_1	D_1 t_1 T_1	D_1 t_2 T_1	D_1 t_3 T_1	D_1 t_1 T_2	D_1 t_2 T_2	D_1 t_3 T_2	D_1 t_1 T_3	D_1 t_2 T_3	D_1 t_3 T_3
D_2	D_2 t_1 T_1	D_2 t_2 T_1	D_2 t_3 T_1	D_2 t_1 T_2	D_2 t_2 T_2	D_2 t_3 T_2	D_2 t_1 T_3	D_2 t_2 T_3	D_2 t_3 T_3
D_3	D_3 t_1 T_1	D_3 t_2 T_1	D_3 t_3 T_1	D_3 t_1 T_2	D_3 t_2 T_2	D_3 t_3 T_2	D_3 t_1 T_3	D_3 t_2 T_3	D_3 t_3 T_3

Where: T_1, T_2 and T_3 represent roasting temperatures of 140, 150 and 160^0C respectively.
t_1, t_2 and t_3 represent roasting times of 3, 5 and 7 minutes respectively.
D_1, D_2 and D_3 represent application dose of roasted coffee husk of 16, 20 and 24 grams, respectively, per litter of water.

Table 2. Treatment combinations of roasting time and temperature

	T_1	T_2	T_3
t_1	T_1 t_1	T_2 t_1	T_3 t_1
t_2	T_1 t_2	T_2 t_2	T_3 t_2
t_3	T_1 t_3	T_2 t_3	T_3 t_3

Where:

T_1, T_2 and T_3 represent roasting temperatures of 140,150 and 160^{0}C respectively.

t_1, t_2 and t_3 represent roasting times of 3, 5 and 7 minutes respectively.

3.4. Sample Preparation

3.4.1. Coffee husk

The details of coffee husk preparation and subsequent procedures are given in Figure 1. Only the red ripe coffee cherries were harvested by hand picking individually. The freshly picked cherries were spread out on wire mesh for sun drying. In order to prevent the cherries from spoiling and for uniform drying they were raked and turned repeatedly. The drying fruits were covered at night and during rain to prevent absorption of moisture. When the moisture content of the cherries dropped to 12 percent drying was stopped. The dried cherries were hulled manually using mortar and pestle. The dry coffee husk was separated, cleaned and stored in airtight high density polyethylene (HDPE) plastic bag for subsequent works.

3.4.2. Beverage formulation

The husk was roasted (Probat BRZ6, Germany) at the prescribed temperature and duration (Table 2). The beverage was prepared by boiling the roasted coffee husk in water for 8 minutes. The time was determined by preliminary tests in order to extract its contents to form the beverage. The concentration of the soluble solids in the beverage was adjusted by limiting the weight of the roasted coffee husk used for unit volume of hot water. The different level of temperatures, times and doses were determined after a series of preliminary works (Table 1 and 2).

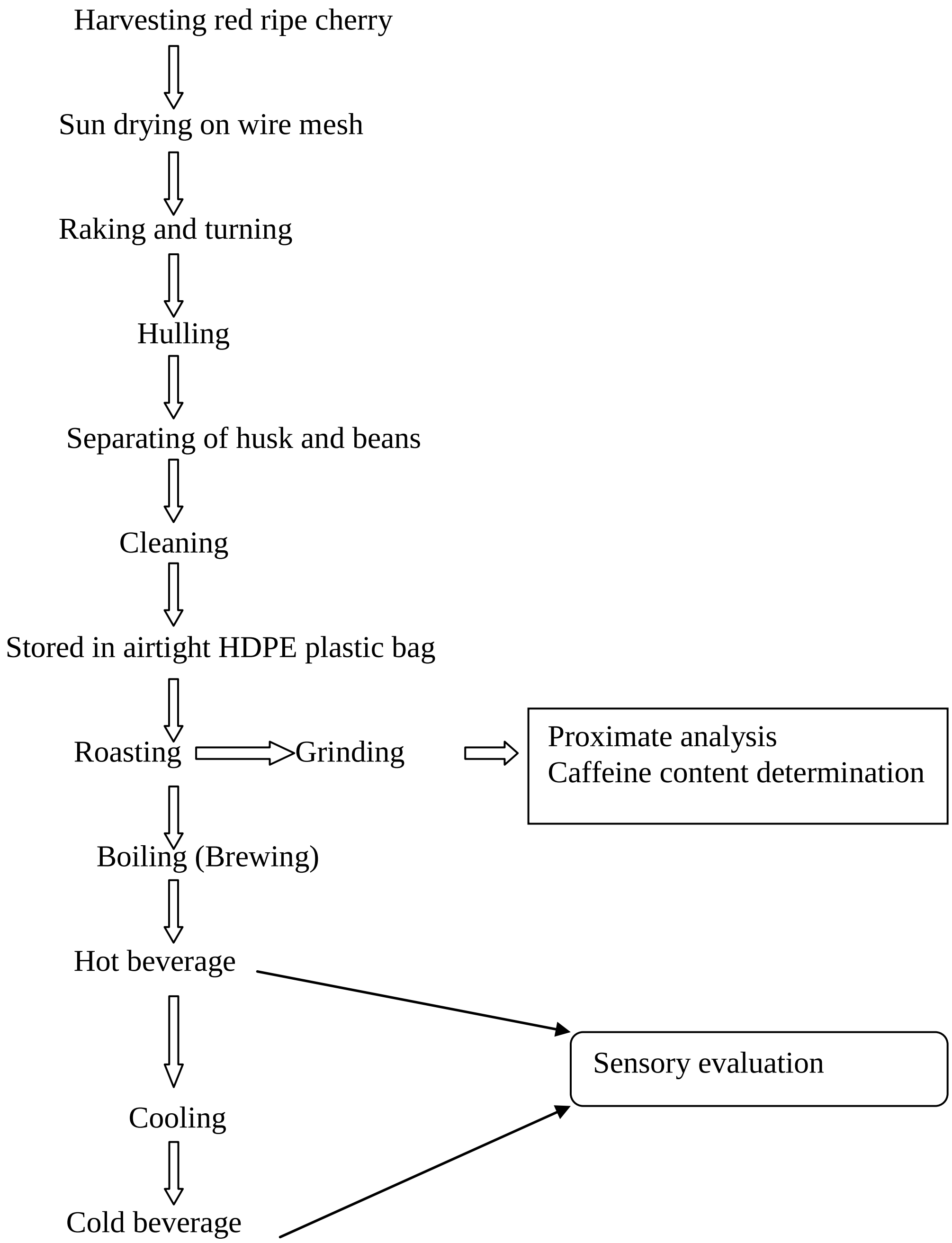

Figure 1. Flow chart showing coffee husk preparation and brewing of beverage

3.5. Data Collection

3.5.1. Proximate composition

3.5.1.1. Determination of moisture content

The moisture content of the ground coffee husk sample was determined according to (AOAC, 2000). Three grams ground coffee husk sample was taken into a previously dried (at105^{o}C) moisture analysis dish and the weight of the sample was determined as M_i. The sample was then dried for 1 hr in an oven (Cintex, CLC-12, England) at 105^{o}C and cooled in a desiccator for about 30 minutes and weighed accurately and recorded as M_d. Finally, the difference in weight of the samples before and after drying was determined as percent moisture as indicated in Equation 1:

$$Moisture(\%) = \frac{M_i - M_d}{sample\ weight} \times 100\% \ldots\ldots (1)$$

Where:
M_i=Weight before drying (g)
M_d = Weight after drying (g)

3.5.1.2. Determination of total ash

The ash content was determined by gravimetric method (AOAC, 2000). A clean crucible was placed in a furnace and ignited at 550^{o}C for 1 hour to be weighed after cooling (m_1). Two grams of a well-mixed sample was placed in a crucible and reweighed (m_2). The sample was carbonized over a blue flame before igniting it in a muffle furnace (Model KLS 45-12-M, Germany) at 550^{o}C until ashing was completed over 12 hours. The sample was then be cooled to ambient temperature and weighed again (m_3). Finally the ash content was determined as follows (Equation 2):

$$Ash\ content(\%) = \frac{m_3 - m_1}{m_2 - m_1} \times 100 \ldots\ldots (2)$$

Where: m_3= mass of crucible and sample after ashing (g)
m_2 = mass of crucible and sample before ashing (g)
m_1= mass of crucible (g)
m_3-m_1= mass of sample after ashing (g)
m_2-m_1= mass of sample before ashing (g)

3.5.1.3. Determination of crude protein

Total nitrogen content of the samples was determined by micro-Kjeldahl method as indicated in AOAC (2000) method No. 979-09 using automatic digestion and distillation systems (Model TUR2-6300, Germany). About 0.5g of fresh sample was added to a tecator tube. Next 6ml of acid mixture (5 parts of concentrated ortho-phosphoric acid and 100 parts of concentrated sulfuric acid) was added and mixed. Then 3.5 ml of 30% hydrogen peroxide was added step by step. As soon as the violet reaction had ceased, the tubes were shaken and placed back to the rack. Subsequently, three grams of catalyst mixture (0.5 g of selenium metal with 100g of potassium sulphate) was added into each tube, and allowed to stand for about 10 minutes before digestion. When the temperature of the digester attained 370^0C, the tubes were lowered into the digester and digestion was continued until a clear solution was obtained. The tubes in the rake were cooled in a hood, then in digested samples, distilled water (30 mL) was added. Ammonia was distilled (TUR2-6300, nitrogen analyzer distillation device) off after adding 25 ml of NaOH (40%) into receiving flask (25 ml of boric acid with 10 drops of indicator solution). Finally, the distillate was titrated with standardized 0.1N hydrochloric acid until reddish color appeared. The crude protein content was estimated from % nitrogen using Equation 3 and 4:

$$Nitrogen(\%) = \frac{V\,HCl\,in\,L\,x\;N\,HCl\,x\,14}{Sample\ weight}\,x\,100 \quad \text{..3}$$

Where:
V is volume of HCl in L consumed to the end point of titration,
N is the normality of HCl used 0.1N and
14.00 is the molecular weight of nitrogen.

Finally, crude protein was obtained by multiplying total nitrogen with an appropriate correction factor.

$$Crude\ protein\ (\%) = Total\ nitrogen\ (\%)\ \times 6.25 \text{...4}$$

3.5.1.4. Determination of crude fat

Crude fat was determined using soxhlet method of fat extraction (AOAC 920.39, 2000). A clean and dried thimble containing about 3g of coffee husk sample and covered with fat free cotton was placed in the extraction chamber. The flask was rinsed for several times with the solvent hexane. The sample contained in the thimble was extracted with the solvent hexane in a soxhlet extraction apparatus (SZC-C Fat Determinate, China) for 6 hours at a condensation rate of at least 3-6 drops per second. Upon completion of the extraction, the solvent was then evaporated by heating on a steam bath. The flask containing the extracted fat was dried in an oven 100^{O}C for 30 minutes followed by cooling in desiccator.

Finally, the flask with its contents was weighed and the crude fat content was determined using Equation 5:

$$Crude\ fat(\%) = \frac{W_2 - W_1}{W} \quad \ldots\ldots 5$$

Where: W_1 *= weight of the extraction flask (g)*
W_2 *= weight of the extraction flask plus the dried crude fat (g)*
W = Weight of sample (g)

3.5.1.5. Determination of crude fiber

The crude fiber content of the samples was determined by the non-enzymatic gravimetric method (AOAC, 2000 962.09). Two grams of well defatted sample was placed into 500 mL flask and 200 mL of 1.25% H_2SO_4 and 2 g pre weighed boiling chips was added. Next, the flask was placed on digestion apparatus and boiled exactly for 30 minutes, while shaking at 5 minute intervals. After boiling some cold water was added and the insoluble reside was separated using filter paper (541). Subsequently, the flask was washed with hot water (near boiling point) until the filtrate was substantially neutral to litmus paper. The insoluble residue was returned to the flask and 200 mL 1.25% of NaOH was added. It was then placed on digestion apparatus and boiled for 30 minutes while shaking at 5 minutes interval. The digested sample was filtered in filter paper (541) and washed with hot water. The residue was dried at 130^{o}C for 2 hrs and cooled in desiccators and weighed (m_1). The dried residue was ignited for 2 hrs at 600±15^{o}C until ashing completes and then cooled in desiccators and reweighed (m_2) Equation 6.

$$Crude\ Fiber(\%) = \frac{(M_1 - weight\ of\ filter\ paper) - M_2}{Weight\ of\ sample} x 100 \ldots\ldots (6)$$

Where: m_1 *= mass of crucible and residue before ignition*
m_2 *= mass of crucible and residue after ignition*

3.5.1.6. Determination of total carbohydrates

Total carbohydrate content of the samples was determined by difference considering the above tested parameters from 100% (Equation 7).

$$\mathbf{C}(\%) = \mathbf{100}\% - (\mathbf{M} + \mathbf{P} + \mathbf{F} + \mathbf{Fb} + \mathbf{A})\% \quad ....7$$

Where: C (%) – Carbohydrate content,
M (%) – Moisture content,
P (%) – Protein,
F (%) – Fat content,
Fb (%) – Fiber content and
A (%) – Ash content

3.5.2. Determination of caffeine content

Caffeine content was determined by Wanyika *et al.* (2010) method using HPLC using the following procedure.

Standard solutions

Caffeine stock solution of 1000 ppm was prepared by accurately weighing 100.00 mg of pure caffeine and quantitatively transferring it into 100 ml volumetric flask and making it to the mark with the mobile phase. Working standards of 0.5, 1, 2, 4, 8, 16 ppm were prepared by serial dilution of the stock solution using the mobile phase.

Sample preparation and caffeine determination

Samples of coffee husk each weighing 2.00 g were weighed in triplicate and put into 250 ml beakers. Next, 100 ml of boiling distilled water was added and left to stand for five minutes with stirring. Then the solution was cooled and filtered into conical flasks. Five mL of the filtrate were pipetted into clean 50 ml volumetric flasks and made to the mark with the mobile phase. The standards and samples were run in the HPLC (Model 1260 Agilent technologies, Germany) system. The following were the HPLC conditions: Column, reverse phase Zorbax Eclipse plus C_{18}, 150 × 4.6 mm × 5 µm, flow rate, 0.8 ml/min, detector, photodiode array set at 273 nm, pressure 111.7-112.1bar, mobile phase water- methanol mix (60, 40) and sample volume of 10 µl. A calibration curve, showing peak areas versus concentration of the standards, was plotted (appendix figure1). The caffeine level of the various samples was calculated using the regression equation of the best line of fit (Wanyika *et al*., 2010).

3.5.3. Sensory evaluation procedures

Hot and cold beverage prepared from coffee husk samples were coded with three digit numbers and subjected to sensory evaluation by fifty untrained panelists (Linda *et al.*, 1991) who were randomly selected from JUCAVM staff and students of Postharvest Management and ECX cuppers. The panelists were briefed on the 7-point hedonic scale and its use prior to sample tasting. The scores consisting of 7 (like extremely), 6 (like very much), 5 (like slightly), 4 (neither like nor dislike), 3 (dislike slightly), 2 (dislike very much) and 1 (dislike extremely) (appendix D). The same volume of coffee husk beverage without any flavoring or any preservatives was served in white cups coded with three-digit numbers. The order of presentation of the samples was randomized and all the samples were not presented at a time in order to reduce carelessness during tasting. A paper ballot comprising of five sensory attributes, namely; color, flavor, aroma, taste, and overall acceptability was given to each panelist (Isengard, 2001). Each individual tasted the sample using spoon and went through the ballot questions for each sample and recorded responses. During the evaluation panelists rinsed their mouth with water and expectorate just after tasting each sample before proceeding to the next. Then the score of all judges for each sample were summed up and divided by the number of panelists to find the average.

3.6. Data Analysis

Statistical analyses were conducted using SAS version 9.2 Software (SAS Institute Inc. 2008). Analysis of variance (ANOVA) was done with the general linear model (GLM) and differences between means were analyzed by the Least Significant Difference (LSD) test. Statistical significance was established at $P < 0.05$. The degree of correlation between two variables was associated by the use of correlation analysis methods as described in Montgomery (2009).

4. RESULTS AND DISCUSSION

4.1. Effect of Roasting Temperature and Time on Proximate Composition of Coffee Husk

The results obtained from the analysis of the data indicated that, the interaction effect of temperature and time was highly significant at ($P < 0.01$) for protein content (Table 3). The mean value of protein content of the samples was in the range of 7.96-9.70%. The highest value (9.70%) was observed in the coffee husk roasted at a temperature of 140^0C for 7 minutes. This was followed by the 9.26% of the samples roasted at 150^0C for 5 and 7 minutes each whereas the lowest value (7.96%) was recorded for the control (raw) coffee husk. The result obtained for the control was consistent with the findings of Oliveira *et al.* (2009) which ranged from 8 to 11%. No information is available to compare results of this study on proximate composition of coffee husk roasted at different temperature or times.

The effect of roasting temperature and time on crude fat content did not show significant difference. The mean value of crude fat content of the coffee husk was 0.02% for all treatments. This is may be due to the fact that lipids are relatively stable to roast, except when intensive roast is practiced where the lipids are expelled to the coffee bean surface (Farah, 2012; Cruz *et al.,* 2012). The crude fiber composition of coffee husk showed highly significant ($P < 0.01$) differences due to roasting temperature and time (Table 3). As indicated in Table 3 the crude fiber content of the samples was in the range of 33.92 - 49.73%. The highest values (49.73 and 49.25%) did occur to samples roasted at 160^0C for 5 and 7 minutes, respectively, with no significant difference between them. Apart from the raw husk the lowest crude fiber was recorded for sample roasted at 150^0C for 3 minute duration. No trend has been noticed the crude fiber data.

The interaction effect of roasting temperature and time on moisture content of coffee husk was highly significant ($P < 0.01$). The moisture content of the coffee husk was within the range of 3.02% to 7.40% (Table 3). The highest value (7.40%) was recorded from control (raw) coffee husk as it should naturally. Among those subjected to the treatments, the highest (3.92%) belonged to samples roasted at 160^0C for 3 minutes and the lowest (3.02%) to samples roasted at the same temperature for 7 minutes. Generally as the temperature and time increased the moisture content dropped. This finding is in agreement with Trugo and Macrae

(1984) and Farah (2012) who reported that the moisture content of roasted coffee (1.5%–5%) is much lower than that of green coffee and varied depending on the roasting degree.

The interaction of roasting temperature and time had significant effect ($P < 0.01$) on the carbohydrate content of coffee husk. As indicated in Table 3 values ranged from 32.48 to 47.33%. The highest value (47.33%) was observed in the unroasted coffee husk whereas, the lowest value (32.48%) in samples subjected to 160^0C for 5 minutes. According to Trugo (1985) and Farah (2012) carbohydrates are major constituents of coffee and may account for more than 50% of the dry weight. Polysaccharides (soluble and insoluble) account for approximately 44% of dry matter in *C. arabica* L. Sucrose is important for coffee flavor and quality; it accounts for up to 9% of *C. arabica* L dry weight. Higher sucrose content is one of the reasons for the superior aroma and overall flavor of Arabica coffee. The polysaccharide content was reduced during roasting due to degradation to low molecular weight carbohydrates (mono and oligosaccharide) and become more extractable (Mwithiga and Jindal, 2007).

The interaction effect of roasting temperature and time on ash content of coffee husk was highly significant ($P < 0.01$) as indicated in Table 3. The ash content of the samples was within the range of 3.37 to 5.54%. The highest value (5.54%) of ash content was observed in sample roasted at 160^0C for 5 minutes whereas lowest value (4.05%) among the treated samples belonged to samples treated at the same temperature for 7 minutes. The ash content of the control (raw husk) (3.37%) was the lowest of all and significantly different from the rest of the values.

Table 3. Proximate composition of coffee husk as affected by different roasting temperature and time

Temperature (^{0}C)	Time (minutes)	Moisture (%)	Ash (%)	Crude fat (%)	Crude fiber (%)	Protein (%)	Carbohydrate (%)
140	3	3.35^{de}	5.16^{bc}	0.02a	44.81^{bc}	8.60^{cde}	38.06^{d}
	5	3.58^{c}	5.25^{bc}	0.02a	42.18^{d}	8.15^{ef}	40.82^{c}
	7	3.37^{d}	5.29^{bc}	0.02a	44.96^{bc}	9.70^{a}	36.67^{e}
150	3	3.22^{e}	5.32^{bc}	0.02a	40.10^{e}	8.81^{bcd}	42.53^{b}
	5	3.30^{de}	5.20^{bc}	0.02a	43.88^{c}	9.26^{ab}	38.34^{d}
	7	3.23^{e}	5.37^{ab}	0.02a	45.86^{b}	9.26^{ab}	36.25^{e}
160	3	3.82^{b}	5.13^{c}	0.02a	41.34^{d}	8.57^{de}	41.03^{c}
	5	3.22^{e}	5.54^{a}	0.02a	49.73^{a}	9.02^{bcd}	32.48^{g}
	7	3.02^{f}	4.05^{d}	0.02a	49.25^{a}	9.06^{bc}	34.60^{f}
Raw coffee husk		7.40^{a}	3.37^{e}	0.02a	33.92^{f}	7.96^{f}	47.33^{a}
LSD (5%)		0.13	0.21	0	1.23	0.46	1.40
CV (%)		2.09	2.49	0	1.65	3.06	2.09

Mean values within a column followed by the same letter (s) are not significantly different at P<0.05

4.2. Effect of Roasting Temperature and Time on Caffeine Content of Coffee Husk

Figure 2 depicts the caffeine content of the husk roasted at the various temperatures and considered duration. The interaction effect of roasting temperature and time was highly significant ($P < 0.01$). The mean values were in the range of 0.82 % to 1.11 %. Statistically, the highest values (1.11%, 1.10%) occurred to sample roasted a 140^0C for 3 and 5 minutes, respectively, and to that roasted at 150^0C for 5 minutes (1.07%) however, the lowest value (0.82 %) was recorded in samples roasted at 140^0C for 7 minutes. According to Farah (2012) and Tfouni *et al.* (2012) caffeine is not significantly altered during coffee roasting, but small losses may occur due to sublimation. However, an increase in the proportion of caffeine may be observed due to the loss of other volatile compounds. Slight decrease in caffeine content of *Coffea arabica* under strong roasting conditions was reported (Casal *et al.*, 2000).

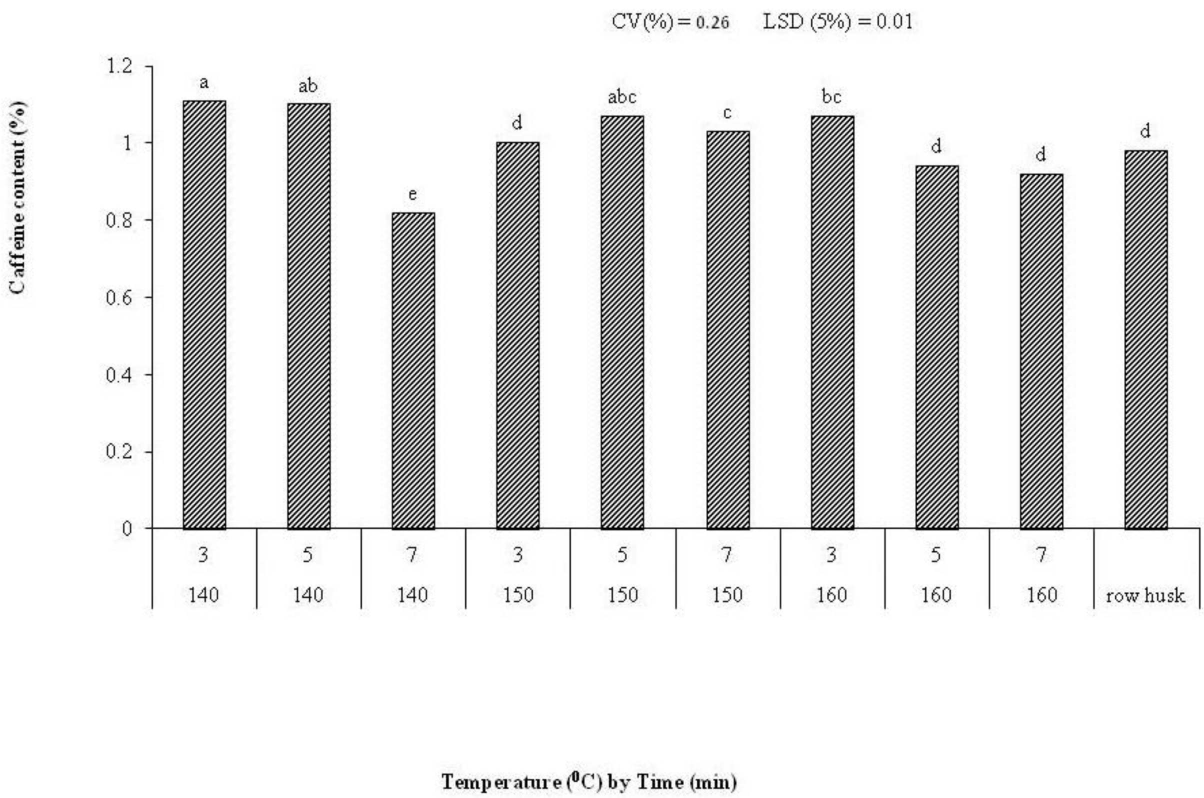

Figure 2. Interaction effect of temperature and time on caffeine content of coffee husk

Bars capped with the same letter(s) are not significantly different at $P < 0.05$

4.3. Effect of Roasting Temperature, Roasting Time and Dose of Husk on Sensory Acceptability of Hot Beverage

Table 4 shows sensory evaluation score of the hot beverage produced from the roasted coffee husk. The data exhibited highly significant variation at ($P < 0.01$) for color, aroma, flavor, taste and overall acceptability attributed to the different roasting temperature, roasting time and dose. Sensory mean scores of a 7- point hedonic scale resulted in highest mean value (6.68) for color of the hot beverage was recorded for coffee husk roasted at 140^0C for 5 minutes and a dose of 24 g/l, whereas, the lowest value (1.96) was for samples roasted at 160^0C for 7 minutes with a dose of 16 g/l. It appeared that the color scores of the hot beverages brewed from coffee husk roasted at 140^0C for 5 minutes and at 150^0C for 3 minutes at doses of 20 and 24 g/l in both cases resulted in scores ranging from 5.66 to 6.68 in a scale of 7. These combination of treatments resulted in most favorable colors of the hot beverage.

The acceptance score of flavor of the hot beverage varied between 5.50 and 3.00 in a scale of 7 (Table 4). The former (5.50) is for samples roasted at 140^0C for 7 minutes with a dose of 20 g/L. Those roasted at 160^0C for 3 minutes with a dose of 24 g/l on the higher side and the latter (3.00) is for samples roasted at 140^0C for 3 minutes and a dose of 16 g/l. In fact, only two more treatment combinations particularly 140^0C for 7 minutes with 24 g/l and 150^0C for 7 minutes with 24 g/l, resulted in hot beverage with flavor scores of above 5.00 with the majority scoring between 3.50 and 5.00 showing some degree of liking of the flavor of the beverage. All the scores did not fall below 3.00 indicating that the majority of the panelists did not reflect a disliking response. For a completely new product such a positive response is encouraging and could be a driving force for further improvement.

Regarding the scores of aroma the data showed significant effect due to the treatment combinations (Table 4). The highest mean value (5.66) happened to two treatment combinations namely 150^0C and 160^0C roasting temperatures combined with 3 minutes durations and a dose of 24 g/l in both cases. Thirteen out of 18 treatment combinations at roasting temperatures of 140^0C and 150^0C exhibited scores in the range of 4.5 and 5.5 showing favoring choices of the aromas. The lowest scores 3.34 and 3.36 happened to treatment combinations of 140^0C, 3 min and 16g/l; and 160^0C, 7 min and 16 g/l. The 16g/l dose resulted in the lowest scores in all their combination with the different roasting temperatures and times. Generally the scores of aroma exhibited acceptable scores of 4.5 and above in a scale of 7 point for the majority of treatment combinations showing degree of likings ranging from moderate to high.

Sensory scores for taste as presented in Table 4 exhibited highly significant ($P < 0.01$) differences attributed to the treatments. Statistically the highest scores (6.28 and 6.34) happened to treatment combinations of 150^0C and 160^0C roasting temperatures; for 7 and 3 minutes, respectively, at a dose level of 24 g/l in both cases. Five more treatment combinations resulted in taste scores of 5.00 to 5.98 showing acceptability levels of moderately like to like. Only three treatment combinations resulted in scores below 3.00 reflecting some degree of disliking.

The overall acceptability scores of the hot beverages made from coffee husks showed significant ($P < 0.05$) differences arising from the different treatment combinations. As shown in Table 4, the highest score (6.68 out of 7 points) was obtained from roasting at 160^0C combined with 3 minutes roasting time and a dose of 24 g/l. The next higher score (6.28) was attained at 140^0C roasting for 7 minutes and a similar dose of 24 g/l. Eight more treatment combinations resulted in overall acceptability scores of 5.00 to 5.98 showing degrees of liking above moderate liking. More than 50% of the treatment combinations resulted in overall acceptability score of 4 and above with various degrees of liking. Hot beverage produced from coffee husk roasted at 160^0C for 3 minute and brewed with 24 g/l dose showed superior results except color and also its caffeine content was the second. It can be concluded from these that acceptable hot beverages can be produced using more than one treatment combinations apart from those indicated above giving highest scores.

Table 4. Consumer liking of coffee husk hot beverage samples from different roast temperature, roasting time and dose

Treatments			Sensory attributes and scores at 7 point of scale				
Temperature (^{0}C)	Time (min)	Dose (g/l)	Color	Flavor	Aroma	Taste	Overall acceptability
140	3	16	4.00^{h}	3.00^{i}	3.34^{l}	2.66^{lm}	2.48^{no}
		20	5.02^{e}	4.32^{e}	4.60^{fgh}	4.00^{h}	4.42^{i}
		24	5.66^{c}	4.66^{d}	4.70^{efg}	4.32^{g}	5.26^{ef}
	5	16	5.00^{e}	3.64^{g}	3.98^{jk}	3.98^{h}	3.94^{j}
		20	5.68^{c}	4.32^{e}	4.98^{cde}	3.98^{h}	4.56^{hi}
		24	6.68^{a}	3.66^{g}	4.76^{ef}	5.32^{d}	5.54^{de}
	7	16	3.64^{i}	3.98^{f}	4.30^{hij}	4.32^{g}	3.90^{j}
		20	4.34^{g}	5.50^{a}	5.32^{abc}	5.66^{c}	5.68^{cd}
		24	4.34^{g}	5.18^{b}	5.22^{bcd}	5.98^{b}	6.28^{b}
150	3	16	5.32^{d}	4.32^{e}	4.94^{def}	4.66^{f}	3.92^{j}
		20	5.66^{c}	4.82^{cd}	5.32^{abc}	5.00^{e}	5.00^{fg}
		24	6.32^{b}	4.96^{bc}	5.66^{a}	4.68^{f}	5.60^{d}
	5	16	3.66^{i}	3.66^{g}	4.30^{hij}	3.66^{i}	3.56^{k}
		20	4.66^{f}	4.02^{f}	4.90^{def}	4.66^{f}	4.82^{gh}
		24	4.66^{f}	4.32^{e}	5.32^{abc}	5.04^{e}	5.72^{cd}
	7	16	3.00^{j}	4.32^{e}	4.32^{hij}	3.32^{j}	2.70^{n}
		20	3.02^{j}	4.88^{cd}	5.36^{ab}	4.00^{h}	4.72^{ghi}
		24	2.66^{kl}	5.04^{bc}	5.00^{cde}	6.28^{a}	5.98^{bc}
160	3	16	2.44^{l}	3.54^{gh}	3.92^{k}	2.92^{kl}	3.20^{lm}
		20	4.36^{g}	4.34^{e}	4.94^{def}	4.68^{f}	5.16^{f}
		24	5.00^{e}	5.50^{a}	5.66^{a}	6.34^{a}	6.68^{a}
	5	16	2.66^{kl}	3.48^{gh}	3.48^{l}	3.02^{k}	2.66^{n}
		20	3.68^{i}	3.34^{h}	4.02^{ijk}	3.32^{j}	3.08^{m}
		24	4.66^{f}	3.44^{gh}	4.22^{ijk}	3.34^{j}	3.98^{j}
	7	16	1.96^{m}	3.68^{g}	3.36^{l}	2.64^{m}	2.32^{o}
		20	2.68^{k}	3.66^{g}	4.04^{ijk}	4.02^{h}	3.38^{klm}
		24	3.02^{j}	3.98^{f}	4.36^{ghi}	3.68^{i}	3.50^{kl}
LSD (5%)			0.24	0.30	0.35	0.27	0.30
CV (%)			14.64	18.46	19.54	16.31	17.62

Values in a column followed by the same letters are not significantly different at $P < 0.05$

4. 4. Effect of Roasting Temperature, Time and Dose of Husk on Sensory Acceptability of Cold Beverage

Table 5 presents sensory acceptability evaluation result of the cold beverages produced from coffee husk by different treatment combinations. The result show highly significant ($P < 0.01$) differences among mean values of acceptability scores of the color of the beverage (Table 5). The highest scores (6.02) in a scale of 7 points occurred to the beverage produced from samples roasted at 140^{0}C for 3 minutes and brewed at a dose of 24 g/l. The next higher color scores of 5.43 and 5.22 with no statistical difference between them happened to beverages produced by roasting temperature of 140^0C for duration of 5 minutes and 24 g/l dose for the former; and same temperature at 3 and 5 minutes of durations at 20 g/l dose for the latter. The color acceptability of beverages produced by combining the three temperatures and three dose levels with 7 minutes roasting time resulted in scores below 4 indicating unacceptability. Generally the scores ranged from 1.98 for 160^0C roasting temperature combined with 7 minutes duration and a dose of 16 g/l to the highest score (6.02) of the above indicated treatment combination.

Flavor acceptability scores of the cold beverage produced from the coffee husk is given in Table 5. The highest values, (4.32, 4.20 and 4.14 in a scale of 7 points), belonged to those produced by roasting at 140^0C for 3 minutes and doses of 20 and 24 g/l for the former two; and the 5 minutes roasting time and the 24 g/l dose level for the last value. Of the total 27 treatment combinations, only 6 resulted in beverages with flavor acceptability score of 4.00 and above. This indicates that the cold beverage produced from the roasted coffee husks had poor flavor which was not accepted by panelist. The lowest average score recorded was 2.96 belonging to a roasting temperature of 160^0C for 7 minutes at a dose level of 24g/l.

Data of taste acceptability score of the cold beverage are given in Table 5. The highest score of taste (5.85) happened to the beverage produced from husk roasted at 140^0C for 3 minutes and concentrated at 24 g/l. The same beverage also had the highest scores for color (6.02) and flavor (4.20). The next higher scores (5.50 and 5.24) go to the beverages brewed from husks roasted at 150^0C for 5 minutes at a dose of 24g/l for the former and at 140^0C for 5 minutes at 24g/l for the latter.

The taste scores are highly influenced by the dose in all the combinations of roasting temperature and time, increasing as the dose of the husk increased. Furthermore, the 7 minute roasting time resulted in significantly lower average scores than the 5 and 3 minutes durations at all the three roasting temperatures. It can also be observed easily that the 160^0C roasting temperature resulted in lower score for all combinations of roasting time and dose than their counter parts conduct in the other two roasting temperatures. In general, five treatment combinations of 140 and 150^0C roasting temperatures resulted in taste acceptability scores of 5.00 and above, indicating that cold beverages of acceptable taste could be produced from coffee husk.

The overall acceptability scores of the cold beverage as presented in Table 5 indicated statistically different ($P < 0.01$) values attributed to the different treatments. The highest scores (5.42 and 5.62) happened to beverage produced at 140^0C roasting temperature and 3 minutes duration with doses of 20 and 24 g/l respectively. The next higher values (5.30 and 5.28) happened to the same roasting temperature but the 5 minute roasting time with doses of 20 and 24g/l, respectively. Another value of 5.30 was also recorded at 150^0C roasting temperature and 3 minutes duration combined with 24 g/l dose level. In overall acceptability scores the treatment combinations of the 140^0C roasting temperatures exhibited more number of scores greater than 5.00, than the other two temperatures. On the other hand most scores of the beverages produced by the roasting temperature 160^0C combined with all the three different roasting durations and three dose levels fall below 4 in a scale of 7 indicating that this temperature is not suited to produce beverage of acceptable quality. In general it is possible to produce cold beverages of acceptable sensory quality with a number of treatment combinations of 140 and 150^0C roasting temperatures and 3 and 5 minutes of roasting time at doses of 20 and 24g/l.

Sensory evaluation data in table 4 and 5 showed that:

- Hot beverage produced from a treatment combination of 160 ^{0}C, 3 minute, 24 g/L dose level exhibited better result.
- However, for cold beverage the superior results were from 140 ^{0}C, 3 minute, 24g/L dose.

  From these results we can concluded that a temperature was the main factor to determine sensorial property, even though these were variations in terms of time and dose level.

Table 5. Consumer liking of coffee husk cold beverage from different roasting temperature, roasting time and dose

Treatments			Sensory attributes and scores at 7 point of scale			
Temperature (^{0}C)	Time (min)	Dose (g/l)	Color	Flavor	Taste	Overall acceptability
140	3	16	3.82^{g}	3.74^{efg}	3.00^{h}	3.16^{j}
		20	5.22^{bc}	4.32^{a}	5.06^{c}	5.42^{ab}
		24	6.02^{a}	4.20^{ab}	5.88^{a}	5.62^{a}
	5	16	3.78^{g}	3.82^{def}	3.72^{fg}	3.16^{j}
		20	5.22^{bc}	4.00^{bcd}	4.48^{de}	5.30^{b}
		24	5.43^{b}	4.14^{abc}	5.24^{bc}	5.28^{b}
	7	16	3.06^{i}	3.80^{def}	2.32^{i}	2.46^{l}
		20	2.98^{i}	3.74^{efg}	2.98^{h}	2.82^{k}
		24	3.94^{g}	3.74^{efg}	4.38^{e}	4.48^{de}
150	3	16	3.86^{g}	3.86^{de}	3.76^{fg}	3.88^{ghi}
		20	4.86^{de}	3.90^{de}	4.70^{d}	4.74^{cd}
		24	5.12^{cd}	4.00^{bcd}	5.10^{c}	5.30^{b}
	5	16	3.82^{g}	3.10^{hi}	3.02^{h}	3.18^{j}
		20	4.64^{ef}	3.94^{cde}	4.72^{d}	4.82^{c}
		24	4.84^{de}	4.00^{bcd}	5.50^{b}	4.74^{cd}
	7	16	2.10^{j}	3.88^{de}	2.14^{ij}	2.20^{lm}
		20	3.94^{g}	3.12^{hi}	3.54^{g}	3.06^{jk}
		24	3.82^{g}	3.92^{cde}	3.82^{fg}	3.92^{gh}
160	3	16	3.46^{h}	3.16^{hi}	2.92^{h}	3.04^{jk}
		20	3.92^{g}	3.84^{de}	3.02^{h}	3.84^{hi}
		24	4.74^{ef}	3.76^{efg}	3.84^{f}	4.16^{fg}
	5	16	3.12^{i}	3.60^{fg}	2.86^{h}	3.62^{i}
		20	4.62^{ef}	3.82^{def}	3.78^{fg}	3.92^{gh}
		24	4.50^{f}	3.82^{def}	4.38^{e}	4.42^{ef}
	7	16	1.98^{j}	3.56^{g}	2.02^{j}	2.14^{m}
		20	3.06^{i}	3.24^{h}	2.20^{ij}	2.26^{lm}
		24	3.14^{i}	2.96^{i}	3.00^{h}	2.40^{lm}
LSD (5%)			0.29	0.22	0.30	0.28
CV (%)			18.48	15.32	20.29	18.60

Values in a column followed by the same letter are not significantly different at P < 0.05

4.5. Correlation Studies

4.5.1. Correlation analysis among coffee husk chemical composition

The relationship among moisture, ash, fiber, protein, carbohydrate and caffeine was assessed and presented in Table 6. The simple correlation analysis showed that moisture content had very highly significant ($P < 0.01$) and positive correlation with carbohydrate ($r = 0.75$). On the other hand it showed negative and very highly significant (P < 0.01) correlation with fiber (r = -0.79), ash (r = -0.76) and negative correlation with protein (r = -0.60). Contrary to these it had no correlation with caffeine (r = 0.00). Ash content had highly significant (P < 0.01) and negatively correlated with carbohydrate (r = -0.48). On the other hand it revealed significant (P < 0.05) and positive correlation with fiber (r = 0.45), protein (r = 0.44) and (r = 0.12) (Table 6).

Protein had very highly significant (P < 0.01) and positive correlation with fiber (r = 0.61) but is negatively correlated with carbohydrate (r = -0.67) (Table 6). It had highly significant (P < 0.01) but negative correlation with caffeine (r = -0.48). Fiber showed very highly significant (P < 0.01) but negative association with carbohydrate (r = -0.99). However it showed non-significant (P < 0.05) and negative association with caffeine (r = -0.18). Carbohydrate had non-significant (P < 0.05) positive association with caffeine (r = 0.24). Caffeine had only significant correlation with protein (Table 6).

Table 6. Simple Pearson correlation values among chemical composition of coffee husk

	Moisture	Ash	Protein	Fiber	Carbohydrate	Caffeine
Moisture	1.00					
Ash	-0.76^{***}	1.00				
Protein	-0.60^{***}	0.44^{*}	1.00			
Fiber	-0.79^{***}	0.45^{*}	0.61^{***}	1.00		
Carbohydrate	0.75^{***}	-0.48^{**}	-0.67^{***}	-0.99^{***}	1.00	
Caffeine	0.00^{ns}	0.12^{ns}	-0.48^{**}	-0.18^{ns}	0.24^{ns}	1.00

^{ns}, *, **, *** *indicates the correlation is non- significant, significant, highly significant and very highly significant respectively*

4.5.2. Correlation analysis among sensory attributes of coffee husk hot beverage

The simple Pearson correlation analysis (Table 7) showed that color had very highly significant (P < 0.01) and positive correlation with flavor (0.22) and positive correlation with aroma (0.38), taste (0.36), overall acceptability (0.46). Flavor had very highly significant (P < 0.01) and positive correlation with aroma (0.51), taste (0.64) and overall acceptability (0.55). Aroma had very highly significant (P < 0.01) and positive correlation with taste (0.52) and overall acceptability (0.55). Only taste was very highly significant (P < 0.01) and positive correlation with overall acceptability (0.72).

Table 7. Correlation values among sensory attributes of coffee husk hot beverage

	Color	Flavor	Aroma	Taste	Overall acceptability
Color	1.00				
Flavor	0.22***	1.00			
Aroma	0.38***	0.51***	1.00		
Taste	0.36***	0.64***	0.52***	1.00	
Overall acceptability	0.46***	0.55***	0.55***	0.72***	1.00

*** *indicates the correlation is very highly significant*

4.5.3. Correlation analysis among sensory attributes of coffee husk cold beverage

The simple correlation results (Table 8) depicted that color exhibited very highly significant ($P < 0.01$) and positive correlation with overall acceptability (0.74) and taste (0.73). It had positive correlation with flavor (0.48). Flavor had very highly significant ($P < 0.01$) and positive correlation with taste (0.53) and overall acceptability (0.54). Taste also displayed very highly significant ($P < 0.01$) and positive association with overall acceptability (0.83).

Table 8. Correlation values among sensory attributes of coffee husk cold beverage

	Color	Flavor	Taste	Overall acceptability
Color	1.00			
Flavor	0.48***	1.00		
Taste	0.73***	0.53***	1.00	
Overall acceptability	0.74***	0.54***	0.83***	1.00

*** *indicates the correlation is very highly significant*

5. SUMMARY AND CONCLUSION

Coffee husk is the most abundantly available agricultural waste in many coffee-producing areas of the tropics including Ethiopia. In most coffee producing and processing areas of Ethiopia the husk does not have much commercial or other industrial value other than becoming a major polluting agent of rivers and lakes. The huge presence of proteins, sugars and minerals in coffee husk with presence of moisture favors the rapid growth of microorganisms which can pose a threat of environmental pollution.

The use of coffee husk for making a drink is being practiced traditionally among the rural people in some places like Hararghe region in Ethiopia and in Yemen. This potential of the coffee husk to be utilized as a raw material for making a beverage could be among the solutions for the problem of it being a waste coming out of green coffee bean processing operations. The present study was conducted to investigate the possibilities of developing hot and cold beverages of acceptable sensory quality from dry coffee husk.

The effect of different roasting temperatures and times; and doses on physicochemical composition as well as consumer acceptability of the husk and its beverage were investigated. The findings indicated that coffee husk has a potential to be processed in to hot and cold beverage. Significant difference was observed in chemical properties and consumer acceptance of the beverages formed. The caffeine content of roasted coffee husk was higher when roasted at 140^0C for 3 minute than in the rest of the samples compared. Carbohydrate content is higher in raw coffee husk than in the roasted ones and lowest in samples roasted at 160^0C for 5 minutes. Hot beverage produced from husk roasted at 160^0C for 3 minutes and brewed from dose of 24 g/l was the most accepted by consumers for all attributes except color. Among the cold beverages the one produced by roasting at140^0C for 3 minute from dose of 24 g/l was the most accepted by the consumer oriented panels in most of the attributes investigated.

Correlation analysis indicated that moisture content was negatively and very highly significant ($P < 0.01$) correlated with fiber, ash and protein contents of the roasted husk. However, it had no significant difference ($P < 0.05$) and no correlation with caffeine. Fiber showed very highly significant ($P < 0.01$) and negative association with carbohydrate.

Caffeine had significant correlation with protein only. The relationship between sensory quality attributes of both hot and cold beverages of the roasted coffee husk is very highly significant ($P < 0.01$) and positive with each other. From the sensory evaluation results, the hot beverage was preferred by the panelists more than the cold one. It can be concluded that the chemical composition of coffee husk and consumer liking of the beverages are significantly affected by roasting temperatures, roasting times and doses. Further understanding on the relationships of the contents of coffee husk with roasting temperature, roasting time and dose is essential to improve coffee husk for beverage development.

6. FUTURE LINE OF WORK

As future line of work, further researches which involve the following are recommended**:**

- Evaluation of different coffee varieties for their suitability to produce beverage.
- Further analysis of other biochemical constituents of coffee husk under different roasting temperature and time.
- Investigations on the effect of brewing method and boiling duration on the beverage.
- Study on the shelf life and storage conditions of the husk and /or beverage.
- Development of appropriate packaging material for long shelf life or good keeping of the husk and the beverage.
- Development of a beverage by mixing it with other products like milk.

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8. APPENDIX

A. ANOVA Tables

Appendix Table 1. Mean square values for proximate composition and caffeine content of coffee husk as affected by roasting temperature, roasting time and interaction

Factors	Df	Mean Square Values of Coffee Husk Chemical Composition					
		Protein(%)	C.Fib(%)	CH(%)	Moisture(%)	Ash(%)	Caffeine(%)
Temp	2	0.22^{ns}	30.71***	23.17***	0.08***	0.40***	0.03*
Time	2	1.15***	50.10***	52.54***	0.19***	0.43***	0.37***
Temp x Time	4	0.59***	24.80***	25.52***	0.26***	0.69***	0.37***
CV(%)		3.06	1.65	2.09	2.09	2.49	0.26

,,***; significant, highly significant and very highly significant, respectively; ns=non-significant at $P<0.05$*
DF=degree of Freedom, Temp= Temperature, C.Fib= crude fiber, CH=carbohydrate

Appendix Table 2. Mean square values for sensory attributes of coffee husk hot beverage as affected by roasting temperature, roasting time, dose and interaction

Factors	DF	Mean Square Values of Sensory Attributes				
		Color	Flavor	Aroma	Taste	OA
Temp	2	272.80***	40.89***	70.65***	87.25***	120.90***
Time	2	366.07***	66.58***	13.63***	20.25***	23.97***
Dose	2	183.71***	77.97***	128.84***	267.35***	556.85***
Temp x Time	4	64.95***	23.80***	29.64***	87.63***	106.26***
Temp x Dose	4	16.88***	10.16***	3.54**	2.25**	1.79*
Time x Dose	4	17.83***	14.05***	2.93**	9.75***	12.90***
Temp x Time x Dose	8	2.71***	5.08***	2.18**	34.32***	13.14***
CV(%)		14.64	18.46	19.54	16.31	17.62

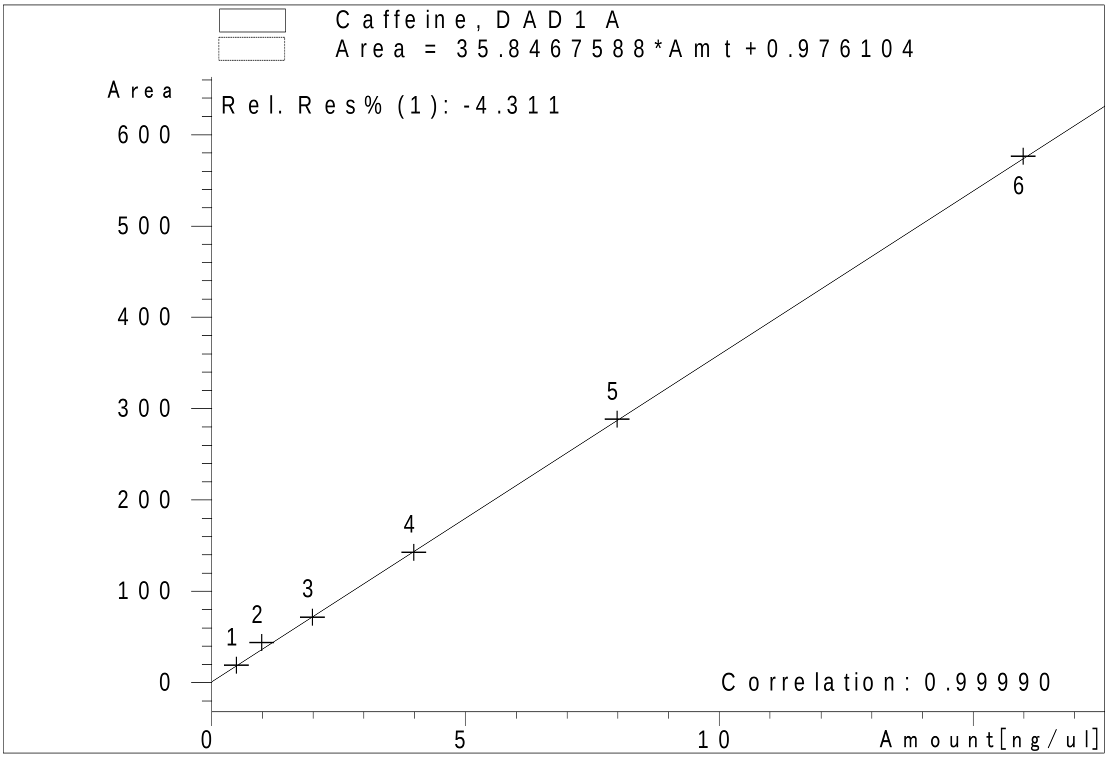
,,***; significant, highly significant and very highly significant, respectively at $P<0.05$*
DF=degree of Freedom, OA= Overall acceptability, Temp= Temperature

Appendix Table 3. Mean square values for sensory attributes of coffee husk cold beverage as affected by roasting temperature, roasting time, dose and interaction

Factors	DF	Mean Square Values of Sensory Attributes			
		Color	Flavor	Taste	OA
Temp	2	68.45***	19.41***	139.68***	96.67***
Time	2	289.62***	12.45***	228.00***	318.89***
Dose	2	237.33***	5.95***	330.50***	268.21***
Temp x Time	4	2.35**	2.35***	4.94***	5.13***
Temp x Dose	4	3.20***	2.06***	14.60**	23.79***
Time x Dose	4	3.25***	9.18***	1.57*	10.72***
Temp x Time x Dose	8	8.13***	3.23***	7.92***	6.10***
CV(%)		18.48	15.32	20.29	18.60

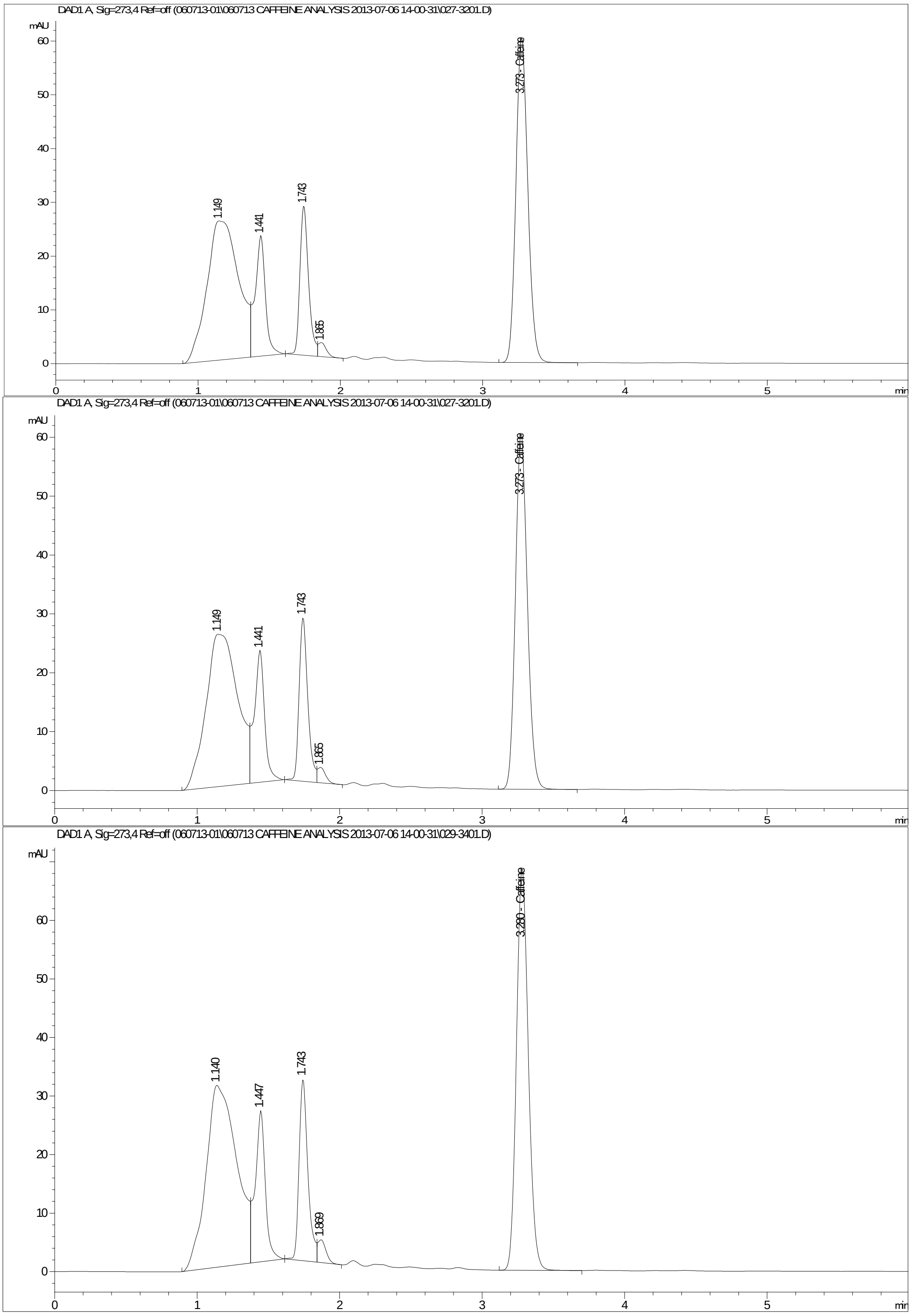
,,***; significant, highly significant and very highly significant, respectively at $P<0.05$*
DF=degree of Freedom, OA= Overall acceptability, Temp= Temperature

B. Caffeine Calibration Curve



Appendix Figure 1. Caffeine calibration curve for HPLC method

C. **Chromatogram of Caffeine**



Appendix Figure 2. Chromatogram of caffeine in coffee husk samples

D. Sensory Evaluation Questioner Form

Ballot for HOT and COLD beverages hedonic taste using a seven point scale

Please look at and taste each sample of HOT and COLD beverages in order from left to right or right to left as shown on the ballot. Indicate how much you like or dislike each sample by checking the appropriate phrase of category which is listed below and mark your choice with the number that corresponds to your preference on each parameter.

1. Dislike extremely
2. Dislike Very Much
3. Dislike slightly
4. Neither Like nor Dislike
5. Like slightly
6. Like Very Much
7. Like extremely

Sample code	Color	Flavor	Aroma	Taste	Overall acceptability