Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

Faculty of Natural Resources and Agricultural Sciences
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A nutritional analysis on the by-product coffee husk and its potential utilization in food production

– A literature study

En näringsanalys på restprodukten kaffeskal och dess potentiella användningsområden inom livsmedelsproduktion
- en litteraturstudie

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Abstract

The aim with this study was is to give an overview on the chemical composition in the by-product coffee husk and examine its potential in food production. This was accomplished through a literature study. To give a current view on research on the subject, articles published prior to 1995 was excluded. Articles with focus on utilization outside food production are also excluded.

In the study, coffee husk was compared to the other by-products from the coffee industry as few studies has been done on coffee husk. All the by-products are composed of the same compounds and in similar levels, making them theoretically suited for the same processes.

According to the result, the coffee husk consists of a nutritional status and a sufficient levels of minor compounds suitable for utilization in food production. Coffee husk could be potentially utilized as substrate for bioethanol due to the high levels of cellulose. The coffee husk could also be used in “energy drinks”, “energy bars” or as a food supplement due to the high concentrations of caffeine and antioxidants. To brew the coffee husk as tea is one way of extracting the caffeine and utilize the by-product.

Keywords: coffee husk, nutrition, food production

Sammanfattning

Målet med denna studie var att ge en överblick på den kemiska sammansättningen hos restprodukten kaffeskal samt undersöka dess potential som livsmedelsprodukt. Detta är genomfört med en litteraturstudie. För att ge en aktuell bild av hur dagens forskning ser ut är artiklar publicerade innan 1995 exkluderade. Artiklar som undersöker användningsområden utanför livsmedelsproduktion är exkluderade.
I studien jämförs kaffeskal med andra restprodukter från kaffeindustrin eftersom få studier har gjorts på kaffeskal. De olika restprodukterna består av samma beståndsdelar i liknande koncentrationer vilket teoretiskt gör dem passande för samma processer. Enligt resultatet så innehåller kaffeskal goda nivåer av näringsämnen och mindre komponenter vilka kan användas för produktion av livsmedel. Slutsatsen är att kaffeskal skulle kunna användas i ”energidrycker”, ”energibars” eller som ett kosttillskott på grund av dess höga nivåer av antioxidanter och koffein. Ytterligare ett sätt att utnyttja kaffeskalets koffein är att brygga det som te. Dessutom skulle kaffeskal kunna användas som substrat till bioetanol på grund av dess höga nivåer av cellulosa.

Nyckelord: kaffeskal, näringsanalys, livsmedelsproduktion

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1 Introduction

Coffee is one of the most consumed beverages in the world. In 2014, the estimated amount consumed globally was 149 million bags à 60 kg of coffee (ICO, 2015), approx. 17.8 billion packages of coffee bought in common food stores.
The coffee tree or scrub originates from Ethiopia and is cultivated in over 80 countries worldwide (Murthy and Naidu, 2012). The scrubs start blooming after three to four years and provide a full harvest after another six years. The maximum yield are obtained after 10-15 years and it bears fruit for approx. 40 years. The scrub can depending on specie grow to a height of 3-12 meter. During cultivation, the scrub is pruned to a height of 2-2.5 meter to facilitate harvest. The scrub is an evergreen with leathery short-steam leaves and white flower with Jasmin-like fragrance. The coffee fruit, which is a stone fruit and also is called coffee berry or coffee cherry, is cherry-like and grows to 1.5 cm in diameter. The fruit has a green unripe skin which turns red-violet or deep red during ripening, which occurs eight to twelve month after flowering (Berlitz et al., 2009).

1.1 Anatomy of the coffee fruit

Inside the skin, the epicarp, is a sweet-tasting mesocarp called pulp. Within the mesocarp is a thin layer of endocarp called parchment. The endosperm, the coffee bean, is also covered with a spermaderm called silver skin. The bean consists of two hemispheres with flattening adjacent sides. Each bean has an inner layer of silverskin while the parchment both covers the spheres and separated them from each other (Figure 1). There are two species which provides almost 100% of the production in the world: *Coffea arabica* and *Coffee canephora*, which are commonly referred to as *Arabica* and *Robusta* (Berlitz et al., 2009; Mussatto et al., 2011b). The chemical composition differ between the green beans from the two species (Table 1).

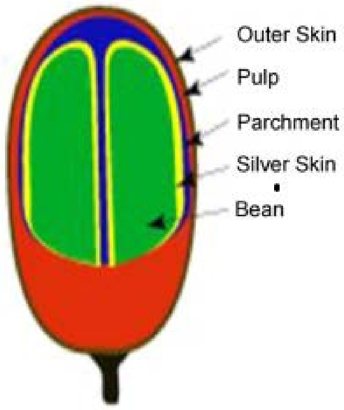

Figure 1. The anatomy of the coffee fruit (Murthy and Naidu, 2012a)

1.2 The processes from fruit to bean

In the processing from the coffee fruit to the exposed bean, called green coffee beans, there are two methods primarily used: the dry or the wet method.
In the dry method, the coffee fruits are spread out on terraces or bars in the sun until dried and the beans are separated from the pulp by shrinking from the parchment layer. A dehulling machine is used to separate the sundried coffee husks, the parchment and the beans from each other (Berlitz et al., 2009).
In the wet method, the skin and pulp are removed leaving the bean with the silver skin, the parchment and a mucilage layer. The beans are washed in water, drained and fermented for 12-48 hours. During the fermentation, the mucilage layer is degraded by the enzymes and naturally occurring microorganisms from the coffee bean. The remains of the mucilage layer are removed with water before the beans are dried, either in the sun or in ovens driven by wood or oil (Berlitz et al., 2009). The beans can be sold with or without the silverskin, which can optionally be removed. The beans are occasionally polished to conceive a smooth surface before the beans are classified and packed (Berlitz et al., 2009). The dry method is generally used for *Robusta* and the wet method for *Arabica* (Mussatto et al., 2011b).
There is also a third method, called the semi-dry or pulped natural method (Duarte et al., 2010). As in the wet method, the pulp is removed from the bean. The beans are then dried with mucilage layer, which in the wet method would been degraded by fermentation.

Table 1. *The chemical composition of green beans from Arabica and Robusta (Berlitz et al, 2009) in % of solids*

	Arabica		*Robusta*
Soluble carbohydrates	9.0- 12.5		6.0- 11.5
Monosaccharides		0.2-0.5	
Oligosaccharides	6.0- 9.0		3.0- 7.0
Polysaccharides		3-4	
Insoluble carbohydrates	46- 53		34- 44
Hemicellulosa	5.0- 10		3.0- 4.0
Cellulosa	41- 43		32-40
Chlorogenic acid	6.7- 9.2		7.1- 12.1
Lignin		1- 3	
Lipids	15- 18		8.0- 12
Protein		8.5- 12	
Caffeine	0.8- 1.4		1.7- 4.0
Minerals		3.0- 5.4	

1.3 The by-products and their applications

During the different processes to obtain the beans, large amounts of by-products are generated (Mussatto et al., 2011b; Nabais et al., 2008) as approx. 50% of the coffee fruit is not used for the production of green coffee beans (Berlitz et al., 2009; Esquivel and Jimenez, 2012). The by-products are mainly used as fertilizers (Berlitz et al., 2009), but the usage for that is limited due to the high amount of organic material. The high concentrations of caffeine, tannins and polyphenols (Mussatto et al., 2011b; Pandey et al., 2000) make the by-products highly pollutant (Fan et al., 2006; Mussatto et al., 2011b) and unsuitable as animal feed in larger quantities (Delfiol et al., 2012; Orozco et al., 2008).
The main by-product from the dry method is the coffee husk which is composed of the dried skin, pulp and parchment (Esquivel and Jimenez, 2012). Of each ton harvest coffee fruit, 0.18 ton of coffee husk are produced. From the wet method, the by-products are the coffee pulp and the coffee silver skin. Another by-product which is obtained after brewing is spent coffee grounds (Murthy and Naidu, 2012a), also called coffee extract residue (Tehrani et al., 2015).

1.4 The chemical composition

The main coveted chemical compounds of coffee husk, as in coffee and the other by-products, are secondary metabolites such as caffeine and other phenolic compounds, e.g. hydroxycinnamate acids and flavonoids, desired for their beneficial antioxidant properties (Farah and Donangelo, 2006).

Caffeine is an plant alkaloid found in i.e coffee, tea and cocoa (Nonthakaew et al., 2015) which, when consumed in moderate levels, can decrease fatigue by increasing energy availability and thereby lead to physical and psychological enhancement (Glade, 2010). *In vitro* studies has shown that in high amounts, caffeine is also an inhibitor for mould (Suárez-Quiroz et al., 2004) and bacteria (Almeida et al., 2012). The concentration of caffeine in coffee depends on the extraction method, the type of coffee and if the beans are fresh or roasted (Nonthakaew et al., 2015). The roasting process was found to increase the amount of caffeine (Hečimović et al., 2011; Wanyika et al., 2010). In Salinas-Vargas and Cañizares-Macías (2014)'s study, the amount of caffeine in fresh versus roasted *Arabica* green beans increased from 4.0 to 9.33 mg/l caffeine.
Methods used to extract the caffeine are e.g. microwave, ultrasonic, heat reflux, solvent soaking and soxhlet extraction (Jun et al., 2011).

Chlorogenic acids are per definition hydroxycinnamates ester of quinic acid with, most commonly, caffeic and ferulic acid as substituent (Jaiswal et al., 2012) The major chlorogenic acid classes, which all have at least three isomers, are caffeoylquinic acid (CGA), feruloylquinic acid (FGA), and dicaffeoylquinic acid (diCGA) (Clifford, 2000). The chlorogenic acids contribute to the pigmentation

and astringency in coffee after roasting due to its incorporation in the melanoidins. The compounds hydrolyzes under roasting and brewing (Farah and Donangelo, 2006).
Murthy and Naidu (2012b) tried to extract chlorogenic acid from coffee husk using different pre-treatment, and concluded that enzyme-treated samples gave the highest yield in comparison to steam-treated.
In the addition to pretreatments, factors like the solvent, the quality and origin of the plant material and storage conditions affect the extracted yield of chlorogenic acids (Ramalakshmi et al., 2009).

Other compounds occurring in coffee husk are the procyanidins. They are precursors to the compound cyanidin, an anthocyanidin (Volz et al., 2014) that causes red, pink, violet and blue color in flowers, fruit and vegetables (Coultate, 2009). They are secondary metabolites and consists of the flavanol monomers (+)-catechin linked with (-)-epicatechin. Except from the origin, the concentration of procyanidins are decreased by processing, e.g. fermentation, drying and roasting. The compounds gives a astringent and bitter taste (Esatbeyoglu et al., 2015).

1.5 Potential utilization

According to different studies on coffee husk, the by-product consists of compounds usable in food production. Murthy and Naidu (2010) concluded that the coffee husk is a useful substrate for mould-, yeast- and enzyme production due to its high amount of fermentable sugars. In 2012, they found coffee husk as a possible useful dietary supplement due to its high concentrations of dietary fibers and natural antioxidant components (Murthy and Naidu, 2012b). The coffee husk is also rich in nutrients and could be used for extraction of caffeine and polyphenols (Esquivel and Jimenez, 2012; Murthy and Naidu, 2012a). Esquivel and Jimenez (2012) concluded the coffee husk is a potential functional ingredient in food production as a source for phytochemicals.

2 Aim

The aim of this study was to give an overview on the chemical composition of the by-product coffee husk and examine the potential usage in food production. This is conducted by a literature review.
The idea for the subject is developed with the Swedish company Nordic Coffee Roastery in Gothenburg.

3 Methods

This study is based on literature primarily found in the databases Web of Science and Google Scholar. Other databases, e.g. Scopus, Primo and ProQuest, were used to search for material but were excluded since few relevant articles were found in full text.
The chosen articles are published within 20 years, from 1995-2015, primarily in 2009-2015 to give a current view of the research on coffee husk. Articles with usage of the coffee husk outside food production is excluded. Used search words are e.g., coffee in combination with berr*, cherr*, fruit, husk, pulp, by-product* and antioxidant, functional food, chlorogenic acid, nutr*, coffee cherry husk, coffee husk, composition, analysis, ethanol, tea, *cascara*, *buno*.
Unscientific sources has been used to describe the usage of coffee husk brewed as tea, since no studies has been made on the subject.

Studies made on other by-products from coffee production are included in the thesis as few studies have been published on coffee husk. Comparisons are made between studies on e.g. the coffee silverskin, pulp and spent coffee ground as they consist of the same structural parts of the coffee fruit as the coffee husk (Pandey et al., 2000). During the literature search, it was found that the main effect on the components are the roasting process. Hence, the main focus on the included studies on other by-products are products obtained prior to heating and roasting.
The compounds in focus are relevant in food- or health perspective.

4 Results

4.1 Nutritional status

In Table 2, the result from ten studies which analyzed the composition of nutrients between 2000 and 2013 are presented. There is a significant difference in the values among the ten studies. For instance, the total amount of carbohydrates varies between 35 g/100 g and 85 g/100 g dry coffee husk. The lower values for total and reducing sugars found by Shenoy et al. (2011) can be explained by the technique of analysis used, as the samples were hydrolyzed with sulfuric acid and high

Table 2. *The composition of coffee husk (% dry matter) according to ten different studies*

	(Pandey et al., 2000)	(Brand et al., 2001)	(Ferraz and Silva, 2009)	(Gouvea et al., 2009)	(Bekalo and Reinhardt, 2009)	(Franca and Oliveira, 2009)	(Shenoy et al., 2011)	(Murthy and Naidu, 2012a)	(Murthy and Naidu, 2012b)	(Navya and Pushpa, 2013)
Total carbohydrates	57.8	35.0	-	72.3	-	58-85	-	-	-	-
Total sugars	-	-	-	-	-	-	1.62 [3]	58±20	-	22.8
Reducing sugars	-	-	-	-	-	-	0.71 [3]	-	-	-
Total fibers	-	30.8	-	-	-	-	-	24±5.9	43±0.5	24.0
Hemicellulosa	-	-	23.8 [1]	11.0	29.7	7.0	28.0	7.0±3.0	-	-
Cellulosa	-	-	23.1 [2]	16.0	24.5	43.0		43±8.0	-	43.0
Lignin	-	-	28.3	9.0	23.7	9.0	72.0	9.0±1.6	-	9.0
Pectin	12.4	-	-	-	-	-	-	1.6±1.2	-	-
Protein	9.2	5.2	-	7.0	-	8-11	-	8.0±5.0	-	11.0
Lipids	2.0	-	-	0.3	-	0.5-3	-	0.5±5.0	-	-
Ash	-	-	0.7	5.4	6.2	-	-	-	-	-
Moisture	-	-	-	15.0	-	-	-	-	-	13.0
Minerals	-	10.7	-	-	-	3-7	-	-	-	-

[1]. Composed of 13.46% xylose, 5.23% arabinose, 2.56% acetic acid and 1.95% glucuronic acid
[2]. 20.76% glucose and 1.83% cellobiose
[3]. g/100 ml acid digested and dried filtrate

pressure prior to analysis.

The most similar result are for protein, lipids and moisture. The protein and lipids content varied in small ranges, 5.2-11 % for protein and 0.3-2% for lipids. The moisture was examined in just two studies which both showed similar values, 15% and 13%, respectively.

4.2 Minor compounds

In Table 3, the result from four studies on coffee husk are compared. The amount of chlorogenic acid are 2.5 g per 100 g coffee husk and the tannins are between 4.5 and 5 g/100g. The concentration of caffeine are between 1-1.3 g/100 g, which are comparable to the amount of caffeine in *Arabica* green beans (Table 1). The total polyphenol concentration differ from 1.22 g/100 g and 0.8 g/100 g, which can be explained by the authors using different equivalents.

Table 3. *The content of chlorogenic acid, tannins, caffeine and total polyphenols (% dry matter) in coffee husk according to four different studies*

	(Murthy and Naidu, 2012b)	(Murthy and Naidu, 2012a)	(Franca and Oliveira, 2009)	(Pandey et al., 2000)
Chlorogenic acid	2.5±0.6	-	-	-
Tannins	-	5.0±2.0	5.0	4.5
Caffeine	-	1.0±0.5	1.0	1.3
Total polyphenols	1.22±0.5[1]	-	-	-

[1]. % w/w gallic acid

Table 4 presents the content of major compounds detected in coffee husk by Mullen et al. (2013), in which they examined the chlorogenic acid and caffeine content of whole coffee fruits and coffee husks from China, India and Mexico. Low concentrations of the chlorogenic acids were found in all samples, expect in the *Robusta* from Mexico in which few acids were detected. Larger quantities, in comparison with the other values, of 5-CGA was found in both sorts of beans from both Mexico and India. Mullen et al. also examined the caffeine content, which was approx. 1 g/100 g, expect in the *Arabica* coffee husk from India that showed a caffeine concentration twice as high, 2.2 g/100g.

Table 4. *A comparison of chlorogenic acids and caffeine found in coffee husk in Arabica and Robusta from Mexico and India (Mullen et al., 2013). Non detected, n.d. Result in mean ± SD in mg/g*

		Mexico		**India**	
Compound	**Abbreviation**	*Arabica*	*Robusta*	*Arabica*	*Robusta*
3-O-caffeoylquinic acid	3-CGA	0.1 ± 0	n.d.	<0.1 ± 0	0.1 ± 0
5-O-caffeoylquinic acid	5-CGA	1.9 ± 0.8	0.2 ± 0.1	0.2 ± 0.1	1.4 ± 0.8
4-O-caffeoylquinic acid	4-CGA	0.2 ± 0.1	n.d.	<0.1 ± 0	0.2 ± 0.1
4-O-feruloylquinic acid	4-FQA	0.1 ± 0	n.d.	<0.1 ± 0	0.1 ± 0
5-O-feruloylquinic acid	5-FQA	<0.1 ± 0	n.d.	<0.1 ± 0	<0.1 ± 0
3,4-O-dicaffeoylquinic acid	3,4-diCQA	<0.1 ± 0	n.d.	<0.1 ± 0	0.1 ± 0.1
3,5-O-dicaffeoylquinic acid	3,5-diCQA	0.1 ± 0	n.d.	0.1 ± 0	0.2 ± 0.1
4,5-O-dicaffeoylquinic acid	4,5-diCQA	0.1 ± 0	n.d.	<0.1 ± 0	0.1 ± 0
Caffeine	-	1.3 ± 0.4	0.9 ± 0.1	2.2 ± 0.7	1 ± 0.5
Total major compounds		**3.9±0.6**	**1.1 ± 0.2**	**2.6 ± 0.8**	**3.2 ± 1.1**
Total (minus caffeine)		**2.6±0.9**	**0.2 ± 0.1**	**0.4 ± 0.1**	**2.2 ± 0.8**

In Table 5, the procyanidins, flavanols and flavonols in *Arabica* and *Robusta* from Mexico, India and China are presented according to the results in the study by Mullen et al. (2013). The *Robusta* coffee husk from India has the highest content of total compounds, 553 µg/g. It also has the highest amount of procyanidins, 534 µg/g. The lowest amount of flavonols, 5 µg/g, is found in *Robusta* from China. The *Arabica* coffee husk from Mexico has the highest amount of flavanols and flavonols.

Mullen et al. (2013) states that their results (Table 3 and 5) due to the wide range of ionization efficiencies are comparable among themselves and not with other samples. The tables are hence more to be seen as guidelines on the components existing in coffee husk.

Table 5. *A comparison between procyanidins, flavonols and flavanols in coffee husk from Arabica and Robusta from Mexico, India and China. (Mullen et al., 2013). Non-detected, n.d. Result in mean ± SD in µg/g*

	Mexico		**India**		**China**	
Compound	*Arabica*	*Robusta*	*Arabica*	*Robusta*	*Arabica*	*Robusta*
Procyanidin dimer	0.3±0.5	n.d.	1±0.5	134.4±1.9	1.8±1.5	n.d.
Procyanidin dimer B2	18.7±1.4	n.d.	60.6±23.4	16.6±0.2	14.4±2.2	0.7±0.6
Procyanidin A type trimer	32.4±2.9	n.d.	67±24.4	306.1±52.8	38.4±6.7	0.1±0.1
Procyanidin B type trimer	10.1±0.4	n.d.	62.2±8.1	42.2±5.2	n.d.	n.d.
Procyanidin A type tetramer	<0.1±0	n.d.	0±0	26.6±2.9	10.7±1.5	n.d.
Procyanidin B type tetramer	2.7±0.1	n.d.	19.4±7.4	n.d.	1.7±1.5	n.d.
Total procyanidins	**115±14.2**	**n.d.**	**252±80**	**534±61**	**104±20**	**1.3±1.2**
Quercetin-O-rutinoside	23.1±9.9	8.1±0.9	3.9±2.2	6.4±3.5	2±0.5	0.7±0.2
Quercetin-3-O-rutinoside	153.8±62.4	3.7±0.2	16.1±9.2	4.7±2.5	9.8±2.2	2.6±0.5
Quercetin-3-O-galactoside	1.4±0.7	2.9±0.3	0.8±0.3	2.9±1.7	0.2±0	0.1±0
Quercetin-3-O-glucoside	82.2±33.4	4.5±0.2	13.1±6.6	5.5±3	4±0.7	1.6±0.3
Total flavonols	**261±106.4**	**20±1.4**	**34±18**	**19±11**	**16±3.3**	**5±0.9**
(+)-catechin	32.4±7.8	n.d.	37.3±15.6	7.7±1.3	21.1±6.2	0.1±0.1
(−)-epicatechin	17.9±2.6	n.d.	4.6±2.1	n.d.	16±2.5	0.5±0.5
Total flavanols	**50.3±10.4**	**n.d.**	**41.9±17.7**	**7.7±1.3**	**37.1±8.7**	**0.6±0.6**
Total compounds	**375±110.8**	**20±1.4**	**286±93**	**553±72**	**120±24**	**6.3±1.6**

4.3 Safety for consumption

Table 6 describes the result from the analysis on coffee husk dried in a green house in Honduras, ordered by the Swedish company Nordic Coffee Roastery in Gothenburg, to evaluate the levels of pesticides and that consumption is safe in further production.

The caffeine concentration was lower, 0.458 g/100 g coffee husk, compared to results described earlier (Tables 2 and 3). The analysis present the CFU/g to below 100 for *Bacillus cereus*, yeast and mould and under 1.0 CFU/g for *Clostridium perfringens*. The four aflatoxins analyzed were under 0.30 µg/kg and ochratoxin A were under 0.15 µg/kg. No *Salmonella* was detected in the analysis.

Table 6. *The analysis on organic Coffee Husk dried in a greenhouse in Honduras. The analysis was performed in Oct. 2014 by ALS Scandinavia AB.*

Compound	**Unit**	**Result**
Caffeine	%	0.458±0.0458
Moisture	-	0.49±0.024
Arsenic	mg/kg	<0.01
Cadmium	mg/kg	0.0068±0.004
Lead	mg/kg	0.0518±0.0102
Mercury	mg/kg	<0.01
Ochratoxin A	µg/kg	<0.15
Aflatoxin B1	µg/kg	<0.30
Aflatoxin B2	µg/kg	<0.30
Aflatoxin G1	µg/kg	<0.30
Aflatoxin G2	µg/kg	<0.30
∑ Aflatoxins	µg/kg	<1.2
Total number aerobic microorganisms	CFU/g	<10000
Total number aerobic microorganisms	log CFU/g	<4.0
Bacillus cereus	CFU/g	<100
Bacillus cereus	log CFU/g	<2.0
Yeast	CFU/g	<100
Yeast	log CFU/g	<2.0
Mould	CFU/g	<100
Mould	log CFU/g	<2.0
Salmonella	/25g	Neg
C. perfringens	CFU/g	<1.0
C. perfringens	log CFU/g	<1.0

5 Discussion

The results on the chemical composition present a wide range of values. In the used studies, the analysis were performed by standard methodologies and therefore the plausible reason for the differences are that the composition of the green beans (Table 1) and husk (Table 3 and 5) might vary between specie and geographical position. This are promoted by Navya and Pushpa (2013) which concluded that the composition on the coffee husk may depend on the varieties and geographical location, but also on the cultivation conditions and resources in the production region.

Mullen et al. (2013) concludes that there is a lack of knowledge about how these parameters affect the composition. Bonilla-Hermosa et al. (2014) also concluded that the latitude, crop variety and development stage on which the coffee fruits were harvested may affect the composition.

Few have specified the species and origin of the analyzed coffee husk. Also, the coffee husk studied in literature originated from different parts of the world, e.g. Brazil (Ferraz and Silva, 2009), Ethiopia (Bekalo and Reinhardt, 2009) and India (Murthy and Naidu, 2012b; Navya and Pushpa, 2013)

Murthy and Naidu (2012b) used coffee husk from both *Arabica* and *Robusta*, but made no difference between them in their study, extracting antioxidants and functional compounds from different coffee by-products. As the dry method is mainly used for *Robusta* (Mussatto et al., 2011b), one conclusion could be that it is the conditions on which the coffee scrub grows which makes the difference.

Despite the inconsistency, the result in Table 4 gives a general view of the components and their ratio in coffee husk.

Coffee husk has properties that could be utilized in a food perspective.

Its high concentration of caffeine and tannins, which are negative in environmental perspective, could be extracted for use in “energy drinks” or “energy bars”. The extraction would also make the husk more available for natural degradation (Navya and Pushpa, 2013).

In comparison with green coffee beans (Table 1), coffee husk contains approx. as much caffeine as the *Arabica* green bean. In comparison with the caffeine concentrations in roasted coffee, Hečimović et al. (2011) showed that the degree of roasting affects the amount of caffeine in coffee beans. A dark roasted *Arabica* or *Robusta* bean only had 0.2-0.3 % more caffeine than prior to roasting. The theoretical conclusion are that the 100g coffee husk can contain as much caffeine as a 100g dark-roasted coffee.

As coffee is the main source of chlorogenic acids for humans (Hečimović et al., 2011) even after the degradation when roasted, the assumption are that the concentration in coffee husk are sufficient for extraction.

Instead of extracting the compound, another utilization is to use the whole coffee husk in e.g. “energy drinks”. Mullen et al. (2013) stated that the use of the whole husk can have positive effects as all polyphenols may not be extractable.

Martinez-Saez et al. (2014) conducted a study on an antioxidant beverage for body weight control made on powdered coffee silverskin. They found that the silverskin consisted of 1.37% caffeine and 1.1-3.0% chlorogenic acids, with low concentrations of reducing sugars and total fiber content between 19 and 23%, which agrees with the characteristics of coffee husk. Because of its low concentration of reducing sugars, high fibers and low glycemic index, the beverage would be suitable in diets for obese people and diabetics.

The difference between coffee husk and silverskin is that the silverskin is a by-product from the roasting process. The silverskin develops melanoidins in the process which mainly gives color and taste to the beverage. Additives could replace the melanoidins in the coffee husk drink.

To produce an “energy drink” with the same amounts of caffeine as commercially available products on the market, 32 mg/100 ml, the required amount of coffee husk would be 7 g, according to Table 6.

The high content of dietary fibers in coffee husk constitutes a problem for the development of a beverage and still make it appealing. With higher density, the fibers would probably generate a non-homogeneous drink with a fibrous layer at the bottom. To include the fibers in a new food product, there would be advantage in making “energy bars”, by grinding the whole coffee husk and thereby including all antioxidants and fiber into the product. As both concentrations of chlorogenic acid (Farah and Donangelo, 2006) and procyanidins (Esatbeyoglu et al., 2015) are decreased by heating, there may also be an advantage making a raw, i.e. uncooked, bar. The coffee husk could also be launch as allergic-friendly, since it’s naturally gluten free.

Another possibility could also be to sell the ground coffee husk as a food supplementary for usage in smoothies, granolas and juices. For the same purpose, the coffee husk could also be retailed whole, recommending the consumers to soak the coffee husk before usage. To make a more attractive product, an attempt of remain the color of the coffee husk could be necessary depending on target group. In apricots, sulphur dioxide is used to protect the carotenoids (Turkyilmaz et al., 2013). In coffee husk, the main colorant are anthocyanin which are water-soluble, heat sensitive and stabilized in acidic conditions (McGee, 2007). Depending on which anthocyanin’s are present in coffee husk, citric acid or ascorbic acid would theoretically work to prevent the color loss.

When comparing the coffee husk with the Goji berry, *Lycium barbarum*, there are some similarities between their compositions. Goji berries contain, like the coffee husk, flavonoids and have a similar protein concentration (Potterat, 2010). The main difference is the levels of vitamins and minerals in the Goji berries. The analysis for vitamin C in the Goji berry showed a concentration comparable to fresh lemon (Potterat, 2010), which contributes in making it a coveted product. A vitamin and mineral analysis on coffee husk would be interesting as it could reveal properties useful, and coveted, in food production and launching of the coffee husk.

A further application for coffee husk is as brewed for tea, called coffee cherry tea (Pabari, 2014), *cascara*, *sultana*, *qishr* or *buno* (Baldwin, 2010, 2009; Pabari, 2014; Wiser, 2011), the name depending in which country the coffee husk are brewed. The coffee husk is brewed alone or with spices, e.g. cinnamon. The taste is described as fruity, with notes from watermelon and blackcurrant (Pabari, 2014) to strawberries and raisins (Wiser, 2011). Recurring are notes of citrus and cherry. Pabari (2014) suggests that the tea contains caffeine, based on the perceived energized experience after consumption. However, no scientific studies have been performed on the subject yet.

Coffee husk could also be used as substrate for bioethanol production.
Sampaio et al. (2013) conducted that during the last years, there have been a large interest from the distillery industries trying to produce new products from agricultural residues to, with evolving potential new flavors, address new markets. Sampaio et al. also conducted that agricultural residues from the coffee production also have advantages due to low cost, characteristic aroma and presence of sugars that can be converted to ethanol. Bioethanol can also be used for fuel and heating. Studies on other by-products gives an idea on how coffee husk can be processed in trials for bioethanol production. Difficulties are whether the composition of the components are in the ratio of a sufficient production and which hydrolyzing method are the most suitable for the substrate to give the maximum yield.
Arrizon et al. (2012) tried to extract bioethanol from coffee husk. They hydrolyzed the coffee husk with a combination of thermal process, steam explosion, and an enzymatic treatment. Their result concluded that coffee husk’s main sugar source are 0.0321 g acetic acid /g coffee husk. They fermented the hydrolysate with *Saccharomyces cerevisiae*, and the resulted presented an ethanol efficiency of 83% per amount glucose and an yield bioethanol of 0.426 ± 0.0015 g/l.
Shenoy et al. (2011) conducted a study where dry coffee pulp was hydrolyzed using sulfuric acid and high pressure. This resulted in an ethanol yield of 82 g/kg dry coffee pulp and 0.45 g ethanol/g sugar.
Gouvea et al. performed a fermentation on sticky coffee husk in 2009, in an attempt to produce bioethanol from the coffee husk. Sticky and regular dry coffee husk differentiate by the sticky husk having higher density, lower fiber content and higher protein content. The sticky husk also has twice as high concentration of fermentable sugars compared to the regular dry coffee husk (Gouvea et al., 2009). In their study, Gouvea et al. (2009) compared the bioethanol yield from ground, whole and aqueous extract from coffee husk fermented with *Saccharomyces cerevisiae*. They found that the best yield of bioethanol were under the whole sticky coffee husk fermentation, with the optimal temperature at 30°C and with 3 g yeast/l. The yielded bioethanol were 8.49 ± 0.29 g/100g dry husk (13.57 ± 0.45 g ethanol/l), which could be compared with the yield from barley. Gouvea et al. could conclude sticky coffee husk as a good substrate for bioethanol production.
Sampiao et al. tried extracting ethanol from spent coffee ground, the by-product from the instant coffee production, by also ferment the residue with *Saccharomyces cerevisiae.* The substrate were hydrothermal treatment to hydrolyze the starch before fermentation and distillation. The process were chosen as it includes aroma extracts from the substrate, useful in the flavoring of the ethanol. The process yields lower amounts of reducing sugars, 3.4 g/l, to the acid hydrolysis which yields ten times the amount from the hydrothermal process, 35 g/l (Mussatto et al.,

2011a). Although, the fermentation resulted in an ethanol concentration at 90 ml/l (9 ml/100 ml).

The reason why more studies has been made on the coffee pulp instead of the husk, can probably be explained by the pulp appearing to be an much more easy handled food stuff, due to its higher concentration of moisture. It is also possible that the coffee husk is less exposed to pathogens in the wet process. The coffee husk, which often are dried in the sun, are more exposed to animals and pathogens due to its unprotected position. Also, in conventional cultivation the pesticides used on the coffee fruit are contained in higher concentrations in the dried husk than in the pulp, in which the exposed skin can be separated from the remaining parts of the fruit.
It also possible that husk may be discarded if the drying has been done with oil driven driers, which may have resulted in a negative taste in the coffee husk.

By viewing the identified components, the coffee husk consists of antioxidants, dietary fiber and caffeine in concentrations which could be useful in food productions. By comparing the coffee husk with studies on other by-products from the coffee production, there is many possible applications for the coffee husk. Further studies are needed to make any final conclusions on its abilities.

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