International Journal of Applied
and Natural Sciences (IJANS)
ISSN(P): 2319-4014; ISSN(E): 2319-4022
Vol. 5, Issue 1, Dec – Jan 2016; 75-82

International Academy of Science, Engineering and Technology
Connecting Researchers; Nurturing Innovations

PROFITABLE EXPLOITATION OF COFFEE PULP- A REVIEW

ADWITIYA DAS[1] & N. VENKATACHALAPATHY[2]

[1]Research Scholar, Indian Institute of Crop Processing Technology, Pudukkottai Road, Thanjavur, Tamil Nadu, India

[2]Associate Professor, Indian Institute of Crop Processing Technology, Pudukkottai Road, Thanjavur, Tamil Nadu, India

ABSTRACT

Wastes from agricultural products are increasing from growing and processing of food materials. Due to advancement of production technology, considerable attention has to be given to agro-industry waste management. Coffee is the second largest traded product and generates a considerable amount of by products during processing. Coffee pulp is the major by product obtained during wet processing which consists of nearly 45% by weight of coffee cherry. The coffee pulp cause environmental problems due to lack of efficient disposal. This paper focuses on the utilization of coffee pulp in various aspects. It exploits the utilization of pulp for the production of enzymes, mushrooms, gallic acid and ethanol. Primary attention has been given to extraction of phenolic compounds from coffee pulp which ranked it as a valuable source of natural antioxidants. Its application in livestock feed and fertilizers have also been explored.

KEYWORDS: Antioxidants, Coffee Pulp, Enzymes, Livestock Feed, Waste Management

INTRODUCTION

Coffee is the second largest traded commodity in the world belonging to the family Rubiaceae, Subfamily Cinchonoideae and Tribe Coffeae (Clifford *et al*., 1989). The Rubiaceae members are largely tropical or subtropical comprising nearly 400 genera and 4800-5000 species. Botanically, coffee belongs to the genus Coffea of the family Rubiaceae. The sub-genus Coffea is reported to compromise over 80 species, which are prevalent in Africa and Madagascar (Bridson and Verdcourt, 1988).

Arabica and Robusta are the two principal species of coffee harvested today. The fruits are oval and they mature in 7 to 9 months; they usually contain two flat seeds (the coffee beans)- when only one bean develops it is called a pea-berry. Arabica is grown at higher altitudes and its cultivation demands great care. Arabica are distinctly milder and more aromatic. Arabica coffee is grown throughout Latin America, in Central and East Africa, in India and to some extent in Indonesia. The term "Robusta" is actually the name of a widely grown variety of this species. The fruits are rounded and take up to 11 months to mature, the seeds are oval in shape and smaller than those of *C.arabica*. Robusta has higher caffeine content. Robusta coffee is grown in West and Central Africa, throughout South-East Asia and to some extent in Brazil, where it is known as Conillon.

Major coffee growing countries have been distinguished under four regions: Africa, North and Central America, South America, Asia and Oceania regions. Across these regions, Brazil, Columbia, Indonesia, Vietnam, Mexico, Ethiopia, India, Guatemala, Cote de Ivory and Uganda are being recognized as top 10 coffee growing countries (Coffee Fair, 2009).India is the producer of both Arabica and Robusta varieties of coffee in the proportion of 33:67. In India, coffee is cultivated in 4,15,341 hectares. Karnataka produces 71% coffee in India which constitutes the major districts of Coorg, Chikmaglur and Hassan. Kerala specializes in Robusta and Tamil Nadu in Arabica. The other non-conventional areas include Coastal tribal Andhra Pradesh and Orissa and North-Eastern regions (14.9%). In the year 2009-2010, coffee production in India stood at 289,600 MT of which Arabica contributed 33% and Robusta contributed 67%.

Coffee generates large amount of coffee by products/ restudies during processing from fruit to cup (Nabais *et al*., 2008; Mussatto *et al*., 2011). Depending up on the method of coffee cherries processing i.e wet or dry process, roasting and brewing solid residues like pulp husk, silver skin and spent are obtained. The coffee husk/peel/pulp, comprises of nearly 45% cherry, and are the main byproducts of coffee industry. They are used for various purposes including extraction of caffeine and polyphenols because they are rich in nutrients (Esquivel and Jimenez, 2012).

CHEMISTRY OF COFFEE PULP

Coffee pulp is obtained during wet processing of coffee. For every two tons of coffee produced one ton of coffee pulp is obtained (Roussos *et al*., 1995). Coffee pulp consists of protein (7.5-15.0%), fat (2.0-7.0%), and carbohydrates (21-32%). It is also rich in minerals, especially potassium and contains appreciable amount of tannins, polyphenols and caffeine (Bressani *et al*., 1972). The organic components present in coffee pulp(dry weight) includes tannins 1.8-8.56%, total pectic substances 6.5%, reducing sugars 12.4%, non reducing sugars 2%, caffeine 1.3%, chlorogenic acid 2.6% and total caffeic acid 1.6% (Murthy and Naidu, 2012).

Utilization of Coffee Pulp for Value Addition

Enzymes and Secondary Metabolites

Coffee by-products, especially coffee pulp and husk rich in carbohydrates, proteins, celluloses, hemicelluloses and minerals, offer potential opportunities to be used as substrate for many bioprocesses (Murthy and Manonmani, 2008). One of its earliest approaches on the application of coffee pulp and husk has been the production of various industrial enzymes such as pectinase, tannase, xylanase, caffeinase, cellulases, proteases, β-amylases, β-glucosidase and lipase etc (Pandey *et al*.,1999). Aspergillusniger was found to be a select potent culture for production of pectinase from coffee pulp by SSF (Boccas*et al*., 1994).SSF was carried out with coffee by-products as substrates for the production of pectinase with initial moisture content of 50% at 27°C using *Aspergillusniger* CFR 302 and fermenting for five days. Among the different coffee substrates, CP showed a highest activity of 7841±99 Ugds with 312.2 mg protein concentration (Pushpa, 2011).Utilization of coffee pulp for production of tannase using *P.verrucosum* was also reported by Bhoite and Murthy (2015) where 3.93 fold increase of tannase production was achieved. Murthy *et al*. (2009) reported that coffee pulp produces more amylase than coffee cherry husk, silver skin, spent coffee and mixture of coffee waste when all were used as a substrate. Coffee pulp was also reported to be an efficient source for the production of polygalacturonase using *A.niger* (Antier *et al*., 1993).

Gallic Acid

Bhoite *et al*. (2013) studied the production of gallic acid through the transformation of coffee pulp tannins by *P.verrucosum*. Among the fungi isolated from coffee by-products, *P.verrucosum* produced 35.23 µg/g of gallic acid with coffee pulp as a sole carbon source in SSF.

Production of Mushrooms

Although first attempts on mushroom cultivation on coffee industry residues were made more than 10-15 years ago, not much work has been done still and only little published information is available. In 1982, isolation and characterization of *Plueurotus* strains capable of growing on sterilized coffee pulp was reported. This was followed by a series of studies which have shown that coffee pulp, either as a sole substrate or mixed with other organic materials, is a good substrate for cultivation of the edible mushrooms *Pleurotus*, *Lentinula* and *Auricularia*. The biological efficiencies of *P.ostreatus* and *P.pulmonarius* strains obtained on coffee-pulp residues presented highest data (≥100%) which was comparable to cardboard, paper waste and softboard residues (Martinez-Carrera *et al*., 2000). Moreover, yield of coffee waste was favoured for *P.pulmonarius*(Velazquez-Cedeno *et al*. 2002). This study concludes that the coffee pulp might be successfully employed in the cultivation of mushrooms, not only because of the production of extracellular enzymes when grown upon this substrate but also because of the abbreviated cultivation cycle associated with this medium favors commercial processes.

Livestock Feed

Coffee pulp has been reported to be used to feed farm animals (Mazzafera, 2002). The pulp has 12% protein content and its incorporation upto 20 % in cattle diet, 5% in poultry feed, 3% in bird and 16 % in pig feed has been recommended. CP showed potential as a feed ingredient in fish diets if fish are reared in earthen ponds or pens instead of concrete tanks and raceways. Coffee pulp ensiled alone and in combination with sugarcane stems, sugarcane tops or elephant grass (*Pennisetumpurpureum*) was studied in rations supplemented with urea and cowdung to yearling rams (Solomon-Demeke, 1991). On the basis of visual appraisal, good quality silage was produced from pure coffee pulp alone and in combination with the forages. Percentage composition of lignin, lignified protein and caffeine were highest in pure coffee pulp silage and decreased, as a result of dilution by the forages. In coffee pulp feed alone intake was low and animals lost weight on all silages. Sheep regained initial body weight after 15 days grazing at the end of the trial. In combined feed, initial body weight was regained at the ninth week of feeding the treatment silages, when gains were 75 to 154 g/d. Productive performance, rumen fermentation and oxidative status of sheep fed diets supplemented with coffee pulp(8% and 16%) ensiled with 5% molasses were evaluated (Salinas-Rios *et al*., 2015). The study concluded that a supplemented sheep diet with coffee pulp up to 16% coffee pulp did not affect their productive parameters but reduced oxidative stress.

Extraction of Phenolic Compounds

Agro-industrial byproducts are good sources of phenolic compounds, and have been explored as sources of natural antioxidants (Fki and AlloucheNandsayadi, 2005). Ramirez-Coronel et al. (2004) found four major classes of polyphenols (viz., flavan-3-ols, hydroxycinnamic acids, flavonols and anthocyanidins) in Arabica coffee pulp. For instance, the phenolic compounds tentatively identified by HPLC in fresh coffee pulp by Ramirez-Martinez (1988) are: chlorogenic acid (5-caffeoylquinic acid) (42.2% of the total of identified phenolic compounds), epicatechin (21.6%), 3,4-dicaffeoylquinic acid, (5.7%), 3,5-dicaffeoylquinic acid (19.3%), 4,5-dicaffeoylquinic acid (4.4%), catechin (2.2%), rutin (2.1%), protocatechuic acid (1.6%) and ferulic acid (1.0%). Later on, Clifford and Ramirez-Martinez (1991) additionally identified 5-feruloylquinic acid in coffee pulp.

In a study involving coffee pulp derived from wet-processed fruits, Esquivel *et al*. (2010) identified cyanidin-3-rutinoside, cyanidin-3-glucoside and its aglycone as the major anthocyanins present before and after tissue browning. Characterization of anthocyanins, polyphenols, and the biological properties of coffee skin/pulp were recently investigated (Murthy *et al*., 2012; Murthy and Naidu, 2012).Anthocyanins were analyzed by high-performance liquid chromatography with photodiode array detection and electrospray ionization mass spectrometry. The anthocyanins from CP yielded 25 mg of monomeric anthocyanins per 100 g of fresh pulp on a dry weight basis. The purified anthocyanin was identified as cyanindin-3-rutinoside and cyanidin-3-glucoside. The red color of coffee peels was attributed to the presence of cyanidin 3-rutinoside, which was confirmed by hydrogen 1 nuclear magnetic resonance (1H-NMR) and carbon 13 nuclear magnetic resonance (13C-NMR). Coffee anthocyanins have shown multiple biological effects resulting in effective α-glucosidase and α-amylase inhibitory activities. It was concluded that coffee skin/pulp are potential sources of colorants and bioactive ingredients to be used in formulated foods (Murthy *et al*., 2012). Various methods have be stated for application in the separation of anthocyanins from coffee pulp, like solvent extraction, microwave assisted extraction, ultrasound assisted extraction, supercritical fluid extraction and enzymatic extraction by Hartati *et al*. (2012), though suitable method is yet to be found out.Condensed tannins (proanthocyanidins) are also important constituents of the fresh coffee pulp (Clifford & Ramírez Martínez, 1991).

Aroma Compounds and Food Products

Adriane at al., 2003 reported that coffee pulp and husk can be used as substrates for *C.fimbriata* for aroma production using SSF. Twenty-one volatile compounds corresponding to higher alcohols, acetates, terpenes, aldehydes, and volatile acids were identified by GC-FID when coffee byproducts obtained from semi-washed process was used as a substrate (Bonilla-Hermosa *et al*., 2014). *Hanseniasporauvarum* showed the best fermentation performance with 12 % w/v of coffee pulp, 1g/L of yeast extract and 0.3 g/L of inoculums. Fresh coffee pulp can be easily processed into various food commodities like jam, juice, concentrate, jelly and flavouring (Murthu and Naidu, 2012).

Ethanol Production

Early studies indicated that biofuel fermented just from CP contained only 2.5–3.0% ethanol (w/v), which would require high energy costs during the distillation stage (Adams and Dougan, 1987). Later, Kefale *et al*. (2012) studied a suitable condition for hydrolysis and fermentation for bioethanol production from coffee pulp using commercial bakers' yeasts proving it to be a potential feedstock for bioethanol production in Ethiopia. A 90% maximum total sugar concentration was obtained at 4h acid-free hydrolysis. The maximum ethanol concentration of 7.4g/l was obtained with distilled water hydrolysis for 4 and 24h of fermentation. It was observed that ethanol concentration decreased with increases in acid concentration, hydrolysis time, and fermentation time. The production of ethanol by fermentation of CP extracts was studied by Menezes *et al*.(2013). The effects of heat treatment and comminution on the yield and composition of CP extracts were evaluated before fermentation, and grinding followed by pressing at room temperature was found to be most efficient. Five different fermentation media were tested for ethanol production: sugarcane juice or molasses diluted with water or with CP extract and a medium with only CP extract. The addition of CP extract to sugarcane juice or molasses did not influence the fermentation or yeast viability, and thus it was concluded that the mixture can be used for the production of bio-ethanol, with a yield of approximately 70g/l.

Composting and Vermin-Composting

Composting and vermin-composting is a cost effective technology which could be used at industrial level for recycling the industrial wastes. Composting of coffee pulp was described in earlier studies (Adams and Dougan, 1987).Decomposition occurs spontaneously in case of coffee pulp, and if not controlled, can result in severe problems, including the proliferation of flies and foul odors, soil infiltration, and others. Furthermore, it has the physical effect of increasing soil's water retention and should improve the long-term quality of the soil.

Coffee pulp is slow in decomposition. Raphael and Volmourougane (2011) evaluated the efficiency of an exotic and a native earthworm from a coffee farm in the decomposition of CP into valuable vermin-compost. Exotic earthworms were found to degrade the CP faster than the native worms, but both vermin-composting efficiency and yield were found to be significantly higher with native worms.

Silage

Coffee pulp is rich in potassium and other mineral nutrients, which has resulted in studies of their application as organic fertilizers without any treatment or after composting. Silage tests to study the reductions of anti-physiological compounds (caffeine and polyphenols) of fresh coffee pulp during the anaerobic fermentation were done (Porres *et al*., 1994). A concrete silo divided into four compartments, with a total capacity of 90 tons of fresh material was utilized. The silage periods ranged between 99-224 days and the four parts included coffee pulp, coffee pulp with sugarcane molasses, coffee pulp with a mixture of molasses and ammonia and screw pressed coffee pulp with molasses. It was concluded that in case of coffee pulp silage presents and ideal method to preserve the material and partially reduce the contents of anti-physiological components. The addition of 5 % molasses and mechanical pressing of fresh coffee pulp improved the quality of the ensiled material.

CONCLUSIONS

Coffee is the second largest traded product after petroleum. Therefore, increasing demands for coffee production leads to increasing amount of waste generation which causes environmental problems. Although attempts have been made to reuse coffee pulp, till date there are only few ways for exploitation of the by-products. Valorization of these wastes should be developed to reduce disposal problems and also to generate value added products.

REFERENCES

1. Adams, M.R., and Dougan, J. (1987). Waste products. *Coffee*, *Springer Netherlands*, 257-291.

2. Adriane BPM, Pierre C, Sevastianos R, Juliana C.G. and Carlos RS. (2003). Coffee residues as substrates for aroma production by *Ceratocystisfimbriata* in solid state fermentation. *Brazilian Journal of Microbiology*, *34*(3): 245-8.

3. Ashok Pandey, P. Selvakumar, Carlos R. Soccol and Poonam Nigam (1999). Solid state fermentation for the production of industrial enzymes. Current Science, 77(1), 149-162.

4. Bhoite, R. N.and Murthy, P. S. (2015). Biodegradation of coffee pulp tannin by *Penicilliumverrucosum* for production of tannase, statistical optimization and its application. *Food and Bioproducts Processing*, *94*, 727-735.

5. Bhoite, R. N., Navya, P. N.and Murthy, P. S. (2013). Statistical Optimization of Bioprocess Parameters for Enhanced Gallic Acid Production From Coffee Pulp Tannins by *Penicilliumverrucosum*. *Preparative Biochemistry and Biotechnology*, *43*(4), 350-363.

6. Boccas, F., Roussos, S., Gutierrez, M., Serrano, L., &Viniegra, G. G. (1994). Production of pectinase from coffee pulp in solid state fermentation system: selection of wild fungal isolate of high potency by a simple three-step screening technique. *Journal of Food science and Technology (Mysore)*, *31*(1), 22-26.

7. Bonilla-Hermosa, V. A., Duarte, W. F.and Schwan, R. F. (2014). Utilization of coffee by-products obtained from semi-washed process for production of value-added compounds. *Bioresource technology*, *166*, 142-150.

8. Brand, D., Pandey, A., Rodriguez-Leon, J. A., Roussos, S., Brand, I. and Soccol, C. R. (2001). Packed Bed Column Fermenter and Kinetic Modeling for Upgrading the Nutritional Quality of Coffee Husk in Solid-State Fermentation. *Biotechnology Progress*, *17*(6), 1065-1070.

9. Bressani, R., Estrada, E. and Jarquin, R. (1972). Pulpa y pergamino de café. I. Composiciónquímica y contenido de aminoácidos de la proteína de la pulpa.*Turrialba*, *22*(3), 299-304.

10. Bridson, D.andVerdcourt, B. (1988). Flora of tropical East Africa: Rubiaceae (part 2). *Rotterdam: AA Balkema*.

11. Clifford, M. N.and Ramirez-Martinez, J. R. (1991). Phenols and caffeine in wet-processed coffee beans and coffee pulp. *Food chemistry*, *40*(1), 35-42.

12. Clifford, M. N., Williams, T. and Bridson, D. (1989). Chlorogenic acids and caffeine as possible taxonomic criteria in Coffea and Psilanthus. *Phytochemistry*, *28*(3), 829-838.

13. Coffee Fair (2009), Report of Fair Trade Coffee.

14. Demeke, S. (1991). Coffee pulp alone and in combination with urea and other feeds for sheep in Ethiopia. *Small Ruminant Research*, *5*(3), 223-231.

15. Esquivel, P.and Jiménez, V. M. (2012). Functional properties of coffee and coffee by-products. *Food Research International*, *46*(2), 488-495.

16. Esquivel, P., Kramer, M., Carle, R. and Jiménez, V. M. (2010). Anthocyanin profiles and caffeine contents of wet-processed coffee (*Coffeaarabica*) husks by HPLCDAD-MS/MS. In *28th International Horticultural Congress. Book of abstracts. Amsterdam: Elsevier*, 129-30.

17. Fki, I, and AlloucheNandsayadi. (2005). The use of polyphenolic extract, purified hydroxytyrosol and 3, 4-dihydroxyphenyl acetic acid from olive mill wastewater for the stabilization of refined oils: a potential alternative to synthetic antioxidants. *Food Chemistry*, *93*(2), 197-204.

18. Hartati, I., Riwayati, I. and Kurniasari, L. (2012, July). Potential production of food colorant from coffee pulp. *Prosiding Seminar Nasional Sains Dan TeknologiFakultasTeknik*, 1(1), 66-71.

19. Kefale, A., Redib, M. and Asfaw, A. (2012). Bioethanol Production and Optimization Test From Agricultural Waste: The Case of Wet Coffee Processing Waste (Pulp). *International Journal of Renewable Energy Research*, *2*(3), 446-450.

20. Martinez-Carrera, D., Aguilar, A., Martinez, W., Bonilla, M., Morales, P., and Sobol, M. (2000). Commercial production and marketing of edible mushrooms cultivated on coffee pulp in Mexico. *Coffee Biotechnology and Quality, Springer Netherlands*, 471-488.

21. Mazzafera, P. (2002). Degradation of caffeine by microorganisms and potential use of decaffeinated coffee husk and pulp in animal feeding. *Scientia Agricola*, *59*(4), 815-821.

22. Menezes, E. G. T., do Carmo, J. R., Menezes, A. G. T., Alves, J. G. L. F., Pimenta, C. J., and Queiroz, F. (2013). Use of different extracts of coffee pulp for the production of bioethanol. *Applied Biochemistry and Biotechnology, 169*(2), 673-687.

23. Murthy, P. S. and Manonmani, H. K. (2008). Bioconversion of Coffee Industry Wastes with White Rot Fungus *Pleurotusflorida*. *Research Journal of Environmental Sciences*, *2*(2), 145-150.

24. Murthy, P. S.and Naidu, M. M. (2012). Sustainable management of coffee industry by-products and value addition—A review. *Resources, Conservation and recycling, 66*, 45-58.

25. Murthy, P. S., Madhava Naidu, M. and Srinivas, P. (2009). Production of α-amylase under solid-state fermentation utilizing coffee waste. *Journal of Chemical Technology and Biotechnology*, *84*(8), 1246-1249.

26. Murthy, P.S., Manjunatha, M.R., Sulochannama, G. and Madhava Naidu, M. (2012). Extraction, characterization and bioactivity of coffee anthocyanins. *European Journal of Biological Sciences*, *4*(1):13-9.

27. Mussatto, S. I., Carneiro, L. M., Silva, J. P., Roberto, I. C. and Teixeira, J. A. (2011). A study on chemical constituents and sugars extraction from spent coffee grounds. *Carbohydrate Polymers*, *83*(2), 368-374.

28. Nabais, J. M. V., Nunes, P., Carrott, P. J., Carrott, M. M. L. R., García, A. M.andDíaz-Díez, M. A. (2008). Production of activated carbons from coffee endocarp by CO_2 and steam activation. *Fuel Processing Technology*, *89*(3), 262-268.

29. P. Antier, A. Minjares, S. Roussos, G.Viniegra-Gonzalez, New approach for selecting pectinase producing mutants of *Aspergillusniger* well adapted to solid-state fermentation. *Biotechnology Advances, 11*(1993), 429-440.

30. Porres, C., Calzada, J.F., and Alvarez, D. (1994). Reduction of anti-physiological compounds of coffee pulp through solid state fungal fermentation. *Advances in Bioprocess Engineering*, *Springer Netherlands*, 391-396.

31. Pushpa, S.M. (2011). Biotechnological approaches to production of bioactives from coffee by-products (Doctoral dissertation, University of Mysore).

32. Ramirez-Coronel, M. A., Marnet, N., Kolli, V. K., Roussos, S., Guyot, S.and Augur, C. (2004). Characterization and estimation of proanthocyanidins and other phenolics in coffee pulp (*Coffeaarabica*) by thiolysis-high-performance liquid chromatography. *Journal of Agricultural and Food Chemistry*, *52*(5), 1344-1349.

33. Ramirez-Martinez, J. R. (1988). Phenolic compounds in coffee pulp: Quantitative determination by HPLC. *Journal of the Science of Food and Agriculture*, 43, 135-144.

34. Raphael, K., and Velmourougane, K. (2011). Chemical and microbiological changes during vermicomposting of coffee pulp using exotic (*Eudriluseugeniae*) and native earthworm (*Perionyxceylanesis*) species. *Biodegradation*, *22*(3), 497-507.

35. Roussos, S., De los Angeles Aquiahuatl, M., del Refugio Trejo-Hernández, M., Perraud, I. G., Favela, E., Ramakrishna, M. and Viniegra-González, G. (1995). Biotechnological management of coffee pulp—isolation, screening, characterization, selection of caffeine-degrading fungi and natural microflora present in coffee pulp and husk. *Applied Microbiology and Biotechnology, 42*(5), 756-762.

36. Salinas-Rios, T., Ortega-Cerrilla, M. E., Sánchez-Torres-Esqueda, M. T., Hernández-Bautista, J., Díaz-Cruz, A., Figueroa-Velasco, J. L. and Cordero-Mora, J. L. (2015). Productive performance and oxidative status of sheep fed diets supplemented with coffee pulp. *Small Ruminant Research*, *123*(1), 17-21.

37. Velazquez-Cedeno, M. A., Mata, G., & Savoie, J. M. (2002).Waste reducing cultivation of *Pleurotusostreatus* and *Pleurotuspulmonarius* on coffee pulp: changes in the production of some lignocellulolytic enzymes. World Journal of Microbiology and Biotechnology, 18(3), 201-207.