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Review Article

Coffee Production Wastes: Potentials and Perspectives

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Abstract

There has been a significant amount of research activity in the area of coffee by-products and coffee wastewater during the last few years. Most of the work is directed towards the potential uses of coffee residues, like utilization of pulp, husk and coffee silver skin as a starting material for production of enzymes and secondary metabolites including acquisition of bioactive compounds, antioxidants or food additives, on the other hand the pollution caused by coffee wastewater has also been a concern in many coffee producing countries due to the high content of organic matter and acid content resulting from the fermentation processes involved in the mucilage. This paper comments on the various research efforts for the management and treatment of coffee by-products with focus on coffee wastewater. It is surely not exhaustive, but serves as a starting point for further research in this highly topical research field.

Keywords: Coffee by-products; Coffee waste water; Organic matter; Mucilage; Bioactive compounds; Phenolic compound; Proteins

Introduction

The forthcoming increase in world population demands for more efficient ways to achieve sustainable development and use of renewable sources. Rising concern on environmental issues drives ahead the improvement of sustainability by closing production cycles underlying the increased need to develop policies and solutions to solve these problems. This trend is also witnessed by a growing amount of research focused towards improving both environmental and economic benefits through efficient reuse of resources [1]. One of the key subjects has recently been reviewed and deals with the extraction of high value-added compounds from agri-food residues by means of supercritical technology [1]. Coffee is the most important food commodity worldwide and ranks second, after crude oil, among all commodities [2]. A recent compilation of the available information focuses in this context on the functional properties of coffee, coffee beans and by-products in terms of the associated potential health benefits [2]. A further review also considers different aspects of coffee by-products utilization and management giving a more detailed focus on the utilization for the purpose of value addition [3]. While trying to attain sustainability non-food applications are also providing economically viable alternatives [3,4]. The criterion for coffee by-products utilization to be industrially favorable is its cost-effectiveness and eco-friendly nature, where the major determining factor is defined in the terms of the availability and quality of the substrates while considering the development for efficient processing in the food and non-food sectors [3].

Coffee waste product utilization

Coffee preparation proceeds in the first step by the elimination of the husks adhering to the beans and can be performed by a dry or a wet process. Coffee cherry husks thus obtained represents about 12% of the berry on dry-weight basis [3]. The dry process, also termed as "unwashed", is the oldest practiced method, where the entire cherry after harvest is first cleaned and then placed in the sun to dry in thin layers or on patios. The wet method is called wet process or washed coffee and in this case the coffee cherries are immersed in water. Unripe fruits will float and the good ripe ones will sink. The skin of the cherry and some of the pulp is removed by pressing the fruit in water through a screen by a machine, generating "coffee pulp juice". The coffee pulp represents 29% dry-weight of the whole berry [3]. The beans are then put in a fermentation tank with a water stream and allowed to ferment to degrade a hygroscopic mucilaginous layer which is an obstacle to the drying. In addition this process generates wastewater which contains organic matter and also involves mucilage removal with high levels of environmental pollutants. Figure 1 shows exemplary a typical small scale factory where such waste water is generated. Both these approaches of coffee preparation are well described [3]. Coffee silver skin is an integument of coffee bean obtained as a by-product of the roasting process [3]. Finally, the fourth main coffee by-product results from the processing of soluble "instant" coffee preparation and is termed as "spent coffee" [5].

The treatment of coffee by-products is generally realized by oxygen-driven biological methods, such as composting, which serves a dual purpose, i.e. valorization via manurial value and as

Figure 1: A small scale wet processing set-up (Santa Sofia) for coffee beans with the location in Aldea Ayarza, Casillas Santa Rosa, Guatemala.

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Table 1: Recent advances on coffee waste utilization (2012-2016; for assessment of the situation before 2012 [3]).

Nr.	Type of coffee waste used	Method of utilization	Reference
1	Coffee by- and waste products (husks, skin, pulp, mucilage, parchment, silverskin, spent coffee, waste water)	Reviews: Different methods of utilization	[2,3,26,46,54,59,74,92,94]
2	Spent coffee grounds from different coffee making art	Source of bioactive compounds (e.g. Phenolic compounds - caffeoylquinic acids, antioxidant dietary fibers, triglycerides)	[51-54,56,57]
3	Spent coffee	Natural biosorbents for removal of heavy metals; Activatedcarbons/ Char	[69,95,96]
			[64,66,97-99]
4	Spent coffee	Decolorization e.g. of real textile wastewaters	[62,63,67,68,70,100]
5	Coffee by-and waste products	Enzymes – e.g. xylanase in solid-state fermentation, beta-glucosidase.	[74,76,77]
6	Coffee silverskin, pulp /spent coffee	Bioethanol production via yeast strains	[34-36]
7	Coffee by- and waste products	Bioenergy – incl. pyrolysis and gasification of biomass residues – char, tar and gas production, biogas, bio-oil, torrefied biomass, briquetting etc.	[21,23,26,29-33,38,39,41,43-47 51,101-104]
8	Coffee husks / spent coffee	Composting / Fertilizer	[6,11,13,14,20]
9	Coffee husks / spent coffee	Polymer composites	[59,105]
10	Coffee husk ash reject material	Ceramic production	[82,83,106]
11	Coffee husks	Bacterial cellulose	[72]
12	Coffee husks	Potential utilization in food production	[107]
13	Spent coffee	Cosmetic formulations	[71,108]
14	Spent coffee	Building materials	[78,81,109,110]
15	Spent coffee	Biosynthesis of polyhydroxyalkanoates	[53]

well as decreasing the pollution potential [3,6]. Many studies have been directed towards this goal of composting coffee wastes [6-13], while implementing among others earthworms [14-16] or with the intention of modulating the mineral recycling [17-20]. The second principle treatment approach concerns realization of sustainability by application in fuel production including biogas [21-33], ethanol [34-36], biodiesel [37] or in briquetting of wastes from coffee plants with efforts also directed towards torrefied coffee residues [38-49]. Table 1 shows a compilation of recent advancements (2012-2016) and available studies featuring the utilization of coffee wastes.

The chemical composition of these four main coffee by-products and their utilization are well documented [3]. The potential uses in the food sector for the solid coffee wastes among others are for the production of enzymes and secondary metabolites. The use of waste streams with novel biotechnological methods have been proposed for the productions of bulk chemicals and value added products such as single cell protein, ethanol, organic acids, amino acids, secondary metabolites, mushrooms and enzymes [50]. Spent coffee grounds, coffee pulp and husks for examples have been utilized for polyphenol [51-57] or auxins recovery [58] among other bioactive compounds [3,54].

The valorization of the solid coffee by-products in the non-food sector has been directed among others towards reinforcement in polymer composites [53,59,60], in activation [3,61] / de-colorization (bio-sorbents) [3,62,63], use as electrode material [64-69], application in waste water treatment [62,64,66,69,70], for cosmetic products [71], cellulose production [72], enzyme production [12,73-77], building materials [78-83] including crystalline nanoparticles [84,85], utilization in storage of gases [86] as well as in control of plant diseases [87].

Coffee pulp residues have been researched with various treatments [88-90] as also already mentioned above, but the characteristics and approaches to the treatment [91] and utilization [92] of coffee waste water generated during the wet processing require more concentrated efforts and attention. The wastewater generated in the cleaning and pulping contains compounds like proteins, antioxidants and secondary plant metabolites (reflecting the composition of the coffee pulp [3]) which can be used as by-products. Furthermore, the process of fermentation generates also wastewater with serious consequences for the environment because of their high Biochemical Oxygen Demand, Chemical Oxygen Demand values and acidic nature such that it is necessary to develop better methods of treatment in order to decrease their content, the envisaged result being to produce better wastewater quality and gaining new valuable products.

The waste water generally has a pH of 4.0 to 4.5. pH stabilization is therefore necessary and is performed by adding an alkali to obtain a pH range close to 7, which allows the proper subsequent processing of such waste. The coffee industry often recommends the use of calcium hydroxide to stabilize the pH of the wastewater although the use of bicarbonate seems to be more appropriate due to sufficient buffering capacity. If wet processing of coffee beans is being performed in big style, the untreated effluents produced will greatly exceed the self-purification capacity of the natural waterways. In order to overcome the pollution potential of processing such waste waters, a clear understanding of its constitution is inevitable to design a feasible treatment system [93].

Finally, to guarantee an efficient valorization, the by-products need to have a certain quality in order to maintain economic viable processing options. The chemical composition will vary from plant to plant from different geographic locations, depending also on their age, climate, and soil conditions [3]. Knowledge of the physical and

chemical properties will lead to a better understanding of application of coffee-by products [3].

Conclusion

We have been seen a significant amount of studies regarding valorization of coffee by-products and wastewater. Some potential utilization possibilities are available, but further work in this area will definitely be more helpful for the maintaining of environment and waterways. Coffee consumption is a global issue and many countries with rich economies import these to primarily roast these according to the individual consumer demand, correspondingly the utilization of spent coffee residues appears to be much more advanced. But those countries producing and primarily processing the raw beans are burdened with low economical incomes to fight against the severe contamination posing serious environmental problems caused by wet processing resulting in coffee pulp and waste water. It is in this direction that more research has to be initiated to develop simple methods of controlling the waste by-product quality and simple solutions to not only increase the pollution awareness but to make re-processing economically more attractive. Finally, a citation in this context from [3] "… applications utilize only a fraction of available quantity as they are not technically very efficient. However, considering the high amounts of waste generated, there is still a need to find other alternative uses for this solid residue (coffee pulp) …" very appropriately underlines the present situation, if we add to it the waste water generated.

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