The Flavours of Coffee Grounds: the coffee waste as accelerator of new local businesses

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1. Silvia BARBERO, 2. Eleonora FIORE

THE FLAVOURS OF COFFEE GROUNDS: THE COFFEE WASTE AS ACCELERATOR OF NEW LOCAL BUSINESSES

1-2. Politecnico di Torino, Department of Architecture and Design (DAD), Viale Mattioli, 39, Turin, ITALY

Abstract: Annual generation of Spent Coffee Grounds (SCG) is estimated around six million tonnes per year. They currently do not have a commercial value and are disposed of in landfills or as compost. Systemic Design approach developed by Politecnico di Torino (Department of Architecture and Design) wants to provide a holistic vision in which these productions are linked together through relationships, output and input, flows of energy and materials, in order to make the SCG recovery activity complex, with almost no waste. This research studies how to make real and profitable a system that values this waste considering the local condition.
Keywords: eco design, systemic design, spent coffee grounds, environmental sustainability

1. INTRODUCTION

Coffee is one of the world's most widely consumed beverages and, for most of the population, it is considered as essential, but its production involves large impacts, because of the strong delocalization between the areas of production (South of the world) [1] and the areas of consumption (mainly Europe and North America) [2].

Italy imports about 410 000 tonnes of raw coffee each year, but also exports about 3,800 tonnes of roasted coffee per year, produced by about 750 coffee roasters [3].

Spent coffee grounds (SCG), the solid residues obtained from the treatment of coffee powder with hot water, are the main coffee industry residues [4]. At the present, they are simply thrown away and, in the best cases, they are differentiated in the organic collection, for fertilizer or compost productions.

In Italy, approximately the 70% of coffee is consumed at home, 25% is consumed in public places, such as cafés, the rest is consumed in offices [3].

Considering this huge amount of coffee residue produced all over the world and impacts involved in its production, its reutilization is a relevant subject [6].

Disposing of SCG in garbage dumps involves both economic costs (for collection, transportation, and treatment) and environmental ones that fall directly on the community as quantity and volume of waste produced [5].

Nowadays, there is a great political and social pressure to reduce the pollution arising from industrial activities. In this sense, conversion of SCG to value-added compounds is of environmental and economical interest [6].

2. METHODOLOGY

The Systemic Design (SD) approach seeks to create not just industrial products, but complex industrial systems. It aims to implement sustainable productive systems in which material and energy flows are designed so that waste from one productive process becomes input to other processes, preventing them from being released into the environment, with a new economic model based on open industrial cycles [7].

SD aims at the production optimization to achieve a total re-use (where possible) of the resources involved in the system that is delineated by connecting all the activities between them, according on what they need to operate and what they generate, as a product or as a waste (following also called "output" to distance it from that negative connotation).

This model is inspired by the theoretical structure of generative science, according to which every modification in resources generates by-products that can represent added value [3].

The goal of this research is to study post-consumption coffee waste in order to obtain a sustainable system. In this study we can identify four steps:

- ✓ research and analysis phase dedicated to *coffee grounds properties*;
- ✓ study of projects, researches and *existing products* using the SCG and
- ✓ *holistic survey on the territory*, in which the systemic project would be settled (city of Turin);
- ✓ design of systemic processes related to the *valorisation of SCG*, within the *house and cafés*, in Turin.

In the design sphere, it is necessary to apply the skills in order to understand the many connections that are generated by the production processes [3].

3. SPENT COFFEE GROUNDS

SCG need to be disposed of in a controlled way, because the residual caffeine, tannins and polyphenols could have negative effects on the environment [8].

In addition to the elements listed, SCG contain also other elements such as minerals, melanoidins, lipids and waxes, lignin, proteins, ashes and polysaccharides (cellulose and hemicellulose are a little less than 50% in the anhydrous SCG) (Figure 1).

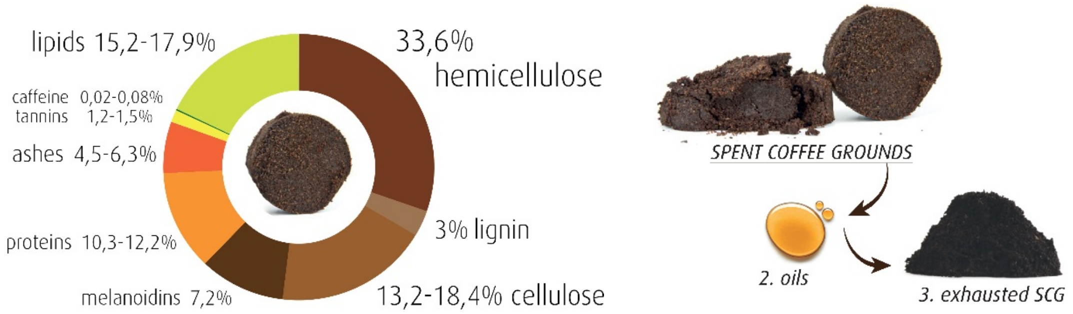

Figure 1 – Composition of anhydrous SCG and their secondary raw materials

These components have high quality and physical characteristics that can be exploited.

The objectives of the work are not only the creation of a system that gives new life to the SCG but also the educational and social aspects related to the valorisation of waste [9].

SCG should be split into their two constituent elements (secondary raw materials): the oils and the exhausted coffee grounds, each of which finds different application sectors.

Some leading companies in the coffee industry investigated SCG oils (Figure 2) in collaboration with some universities, in order to use them as bio-fuel, extracting oils through bio-refineries (Starbuck in collaboration with University of Nevada, Reno, University of Cincinnati – USA, Polytechnic Institute of Porto - Portugal) [10].

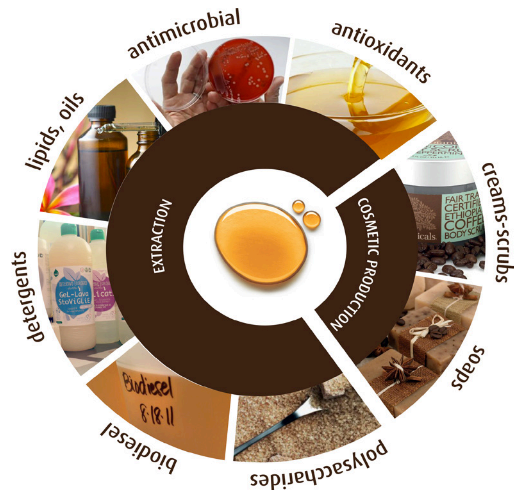

Figure 2 – Application fields of oils

Some universities chemically analysed SCG, pointing out a high presence in them of phenolic compounds with significant antioxidant activity [11; 12; 13; 14], suggesting the possibility of using the waste as a resource of natural antioxidants or as a source of polysaccharides with an immuno-stimulant activity [15]. By extracting the lipids with supercritical fluid extraction (250 bar at 50°C) they were able to develop new cosmetic formulas [16].

Figure 3 – Application fields of exhausted SCG

The exhausted SCG can find many uses after the extraction of oils (Figure 3). All the activities that follow were made without extracting oils from SCG, but they are also suitable for what remains after the oil extraction.

Some companies in the coffee industry began to search for a way to dispose of SCG as compost (Starbucks) or as fertilizer in rice cultivation (Nespresso) or by producing pellets (X Cafè LLC in collaboration with The Maine Technology).

Other researchers have also hypothesized to reusing them as fuel in industrial boilers in the same productive sector, due to its high calorific value of about 5000 kcal/kg [17]. SCG have also absorbent properties that make them suitable for the removal of cationic dyes in wastewater treatment [18] or as cheap active carbon (The Department of Chemistry, The City College of New York). There were also undertaken experimentations on the use of coffee grounds in the production of bricks, in addition to clay [19].

Some companies realized the importance of SCG starting to produce yarns, by exploiting their odour-control and thermal qualities (Singtex - S Cafè fabrics, Taiwan), mushrooms and kits to produce them (Back to the Roots, California and many others), screen printing inks (Altriluoghi organicotton, Italy) and recycled paper (Favini - CRUSH, Italy).

Some designers were involved in the creation of SCG biopolymers for the production of objects (C2C, Canada, 2003 - Cup'a coffee, Sprout Design, Holland, 2006 - Curface, Re-worked, London, 2010 - DECAFÉ - Raul Lauri, Salone Satellite 2012).

However, none of these strategies has been implemented in a lasting way: most of SCG are thrown together with other waste and are disposed of in landfill.

4. PROJECT

The project is carried out by Politecnico di Torino (Department of Architecture and Design) in collaboration with the biggest Italian coffee roasted company, and it has the goal to evaluate the feasibility of SCG valorisation at home and at cafés. Two projects emerged by this approach, with different objectives and targets. The first one is the communication about how to re-use SCG from moka pot at home and increase the consumer awareness.

The second one is more business oriented, even if with a strong educational and social attitude. This one considers the collection of coffee waste in local cafés, to generate new industrial activities. This projects have also a strong educative aspect, because they allow not only to be aware of the environmental problems, but also to be part of the solution [9]

The theoretical model for projects discussed above focuses not only on increasing the value of coffee waste, but also on designing an entire complex system [5].

4.1. The educational role of coffee waste at home

Since the SCG is also a part of household garbage which ends up, in the best cases, in the organic waste collection, or otherwise in the landfill, it was sought a way to raise awareness of the consumers of the value of SCG. Due to low quantities SCG produced by each family and the difficulty of preserving them from becoming mouldy, because of the presence of large amounts of water inside them (which causes the proliferation of bacteria within a few days), it was not possible to plan a system of door to door collection.

The project consists in changing consumer attitude against waste, informing him that what he consider as a waste should be not thrown away, but something still has many useful features that he has to considered as a resource. It is a paradigm shift, a small step that can lead to obtain great results and the generation of many other products [5].

For this purpose, chemical substances contained in SCG were valued and underlined, in order to catalogue possible uses of SCG in the domestic environment, which do not require specific treatment or industrial processes:

- ✓ cosmetics: scrubs, exfoliating mask, facial serum, anti-cellulite.
- ✓ tincture: yarns, fabrics, wood scratches, hair dye;
- ✓ cleaning: cleaning drains, soap, dish detergent;
- ✓ fertilization: vermicompost, compost, fertilizer;
- ✓ odour control: refrigerator, car, shoes, hands and
- ✓ repellents: snails, ants.

In order to ensure that the instrument will be usable by the consumer, the domestic use of the SCG was accompanied to the proceedings to obtain it, through recipes and images.

These proposals of uses are conveyed to the consumer through:

- ✓ special edition packaging, gift boxes;
- ✓ brochures and information booklets;
- ✓ merchandising, gadget and objects and
- ✓ mobile apps, website and social communication.

4.2. Business oriented system for coffee waste at cafés

The analysis of the initiatives taken by companies and other univesities listed above, showed that each one dealt only with one or two aspects.

Through SD approach, instead, all these activities can be organized in sequential and interrelated way getting that the output of one process become input for several other ones, without wasting secondary materials.

The project discussed here focused on deriving value from the waste that is left after coffee has been prepared for drinking. The goal is to plan several activities that could be applied in the near future at industrial level.

Although the quantities produced by the cafés are smaller than those produced by household consume, this kind of waste is more homogeneous and easier to trace than coffee waste produced from domestic consumption [3].

The pilot experiment considers 114 bars in the Turin centre, with a total collection of 735 kg SCG per day. These initial quantities are essential to design the system of collection and to define the real business model, in order to apply it in short term.

SCG are usually collected in a drawer under the coffee machines. In order to start the collection of this waste, the bartender should be informed that he has to be careful not to throw in the same container other waste, which could contaminate SCG. For this project bins were designed in order to meet transport and dimension requirements.

It is necessary to systematize the activities (Figure 4), to understand what should be done first, the necessary working operations and the characteristics of the material after such operations.

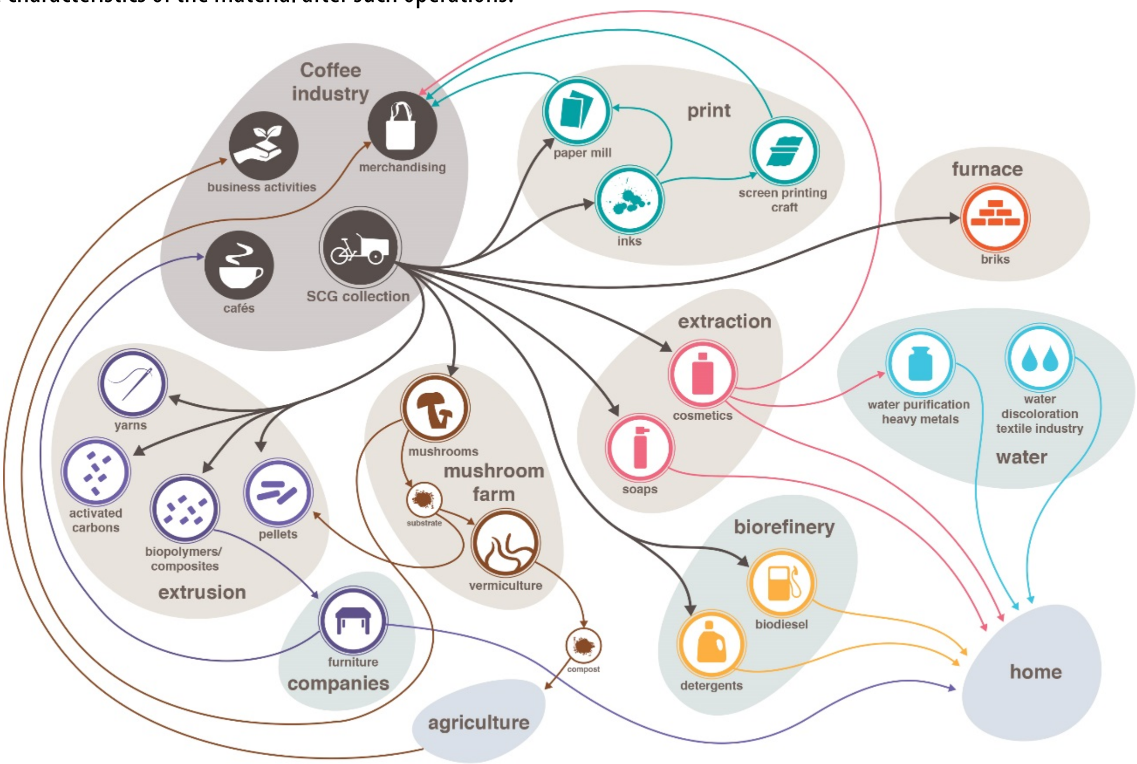

Figure 4 – Systemic scheme of activities

Analysing the products that can be obtained from SCG, it was highlighted that, for example, none of these productive activities require entire SCG: some of them only need for their oil, some others are based on the cellulosic material and the presence or absence of oil does not involve any added value, while other activities require the SCG anhydrous or micronized.

Therefore was clarified that oil extraction should be carried out as first and, later, it could be used exhausted coffee grounds for other activities, carrying out treatments on them.

Design choices were made by investigating the characteristics and experiences of the territory, according to the SD guidelines [7].

4.2.1. Collection

The study of the SCG collection and its logistics is a fundamental aspect of this project.

It was necessary to estimate an efficient collection system, in collaboration with the local collection authority, to pick up SCG from cafés without disturbing their work.

There were identified time sections with fewer customers and it was projected a system of bins, dividing cafés according to their weekly production of SCG.

The number of collections was also calibrated on this parameter, as well as considering the perishable nature of this raw material.

It was studied a collecting system using 4 cargo-bikes, both to reduce the impact on the environment and to ensure their effectiveness even in historic centres and pedestrian areas. This activity will generate new employment in the territory.

At the end of this process, SCG collected are transported all at once by a van to the place of storage.

The costs related to this stage are referred to the entire collection phase: 4 cargo-bikes, 1 van, 250 bins and 6 workers.

4.2.2. Oil extraction

As regards the activity of extraction, it was chosen to avoid the use of supercritical fluid (supercritical CO_2) that, besides having very high costs in terms of equipment, raw materials and energy consumption, requires highly qualified person.

The extraction process chosen is a mechanical one (based on the pressure), which involves minimum quantities of solvents (ether or ethyl alcohol) recycled at the end of the process. This extraction technique was developed in Italy at Università di Napoli Federico II [20].

The process is applied to the 735 kg of SCG in order to obtain 70 litres of oil per day, which could be used in cosmetic and pharmaceutical applications or, through trans-esterification, to produce biodiesel. These products are the most profitable aspect of the project.

The outputs of this process are SCG without their oil and water, which can be used for several other processes, described below.

4.2.3. Mushroom production

The SCG obtained can be used as a component of the substrate, needed for growing edible mushrooms. They contain cellulose, hemicellulose and lignin [3] materials suitable for the mushroom growth, but the production yield increases if they are joined to agricultural by-products, because the SCG are compact and hinder the diffusion of mycelium, increasing its incubation times. In Italy, since 2008, Politecnico di Torino carried out research studies regarding the re-use of SCG for the production of edible mushrooms [3].

It is planned to collect the spent grain generated by artisanal breweries, which are currently used as a supplementary part of the fodder, despite they were not checked to be suitable for that.

After the process of oil extraction, 665 kg of exhausted SCG are obtained, that are mixed with 190 kg of bagasse, and they are used as substratum for growing the mushrooms. Even in the cultivation of the Pleurotus Ostreatus mushrooms, outputs of two processes are used to generate a product that has a market value. The substrate is inoculated with 25 kg of mycelium and it is stored in the dark for several days, at the end of which it takes place the fruiting of mushrooms (Figure 5).

Figure 5 –Experimentation with mushrooms

Part of the production of substrate is packaged to be sold as a kit for growing mushrooms at home, instead, mushrooms that growing from the previous production line, will be sold to local restaurants and their excess will be dried and sold to retail stores. The results from this process are 30 mushroom kits per day, 70 kg of fresh mushrooms and 230 kg of mushrooms that are dried, losing 90% of their moisture, and generating 23 kg of dried mushrooms (in small bag of 50 gr). Mushroom growing kits are sold to customers which are more sensitive to environmental issues and prone to self-produced healthy food. Fresh mushrooms are intended for canteens, restaurants and the same bars that provide SCG, with special agreements. The bags of dried mono-portion mushrooms are intended to the classic retail.

However, the raw material that generated the mushrooms, 510 kg of exhausted substrate, does not reduce its volume and this raises the urgent need for finding a subsequent use for it (see other uses).

4.2.4. Micronization

Part of exhausted SCG, after the oil extraction, will not be used for the mushroom production, but can be reduced in micrometric dimensions, through a process that, in addition to pulverize SCG, deprives them from the residual moisture. This new material finds many uses as reinforcement/additive in the production of recycled paper (which preserves the grain and characteristic colour of the SCG), new textile fibres, bricks, activated carbons, but also for the production of screen printing inks, for the purification of waters by heavy metals and for their discoloration from dyes.

4.2.5. Other uses

After oil extraction, another part of SCG could be intended for the production of biopolymers, with a mixture of 95% of SCG and the remaining 5% consisting of polylactic acid and mixture of paper [21]. This type of pellet can be used by compression moulding, to create new objects and panels.

Even exhausted substrate, that comes from mushroom production (consisting of SCG, spent grain and mycelium), can have different uses in its end of life: it could be hot pressed to produce acoustic panels, or micronized and used as an additive for the production of recycled paper, as above, but also used for vermicompost production. It can also be used to produce pellets for domestic heating. It should be pointed out that the combustion shall not be the first solution when one talk about waste disposal, especially when waste still has a productive value and, consequently, a market one.

The pelletizing process, in this case, was chosen only for the 510 kg of exhausted substrate, trying to exploit SCG as much as possible before burning them. For this material, after all previous process, it appears to be the most economical choice and the most profitable one.

Through combustion, the material becomes ash and can be used as fertilizer for domestic use, since it has high manuring properties.

5. RESULTS

The first purpose was to make the final consumer conscious of the value that SCG have, which currently are treated as a simple waste [9]. This was possible by investigating SCG domestic uses and the way to replicate recipes and procedures easily at home, in order to create an educational tool, which enclose all the possible re-use of the SCG without using specific machinery.

Regarding the systemic project of re-use of the SCG collected from the cafés, the study was carried out up to estimate costs and revenues, showing how it can bring large profit margins.

In particular, the result was the development of two business plans with different levels of complexity. One of these is immediately applicable and includes only the production of mushrooms and the pelletizing process, the other one would require further testing on the real market value of the oil produced and further investigation on the extraction techniques without the use of solvents (under experimentation inn that moment).

The investments for machinery, transport and local adaptation, the annual costs (utilities, employees, advertising, raw materials, interest on a hypothetical financing, taxes, etc.) and income from each activity are considered for both models.

The project feasibility, beyond the academic theory, should be considered an added value. The main purpose of re-using a waste (suitable for quality), without consider difficulties and costs involved for such a complex activity, would relegate it to the hypothetical field and would not encourage productive realities to innovate their approach and to conduct experimentations.

This study, therefore, aims to promote a sustainable and economically active development, that creates an added value for the place in which it takes place, in terms of employments, the reducing of disposal quantities and costs, the use of secondary raw materials, the development of a network of new productions for these ones, the development of know-how and new professional figures, the generation of new products from companies that will study how to use these new materials in their productions, incomes from new activities, with a consequent investment in R&D. This approach seeks to reduce transport emissions and increase economic value for the local community [3].

The system is able to generate a series of relationships with local stakeholders, involving the responsible for waste management, with agreements to transfer waste on the road.

The other beneficiaries of the project are the bartenders, the brewers, some local SMEs, such as the producers of inks, cosmetics and pharmaceuticals, as well as paper mills, wastewater operators, producers of air filters.

During the pilot study some of these actors will be involved, but extending, for example, the project to the entire city of Turin, the quantities of waste could support the activation of several other relationships with companies.

6. CONCLUSIONS

The effects of this project will interest the next parts:

- ✓ The *environment*, starting from a raw material with high social costs, through the recovery of it and the development of clean and sustainable processes and industrial activities. In the pilot experimentation of a city centre 160 ton of organic waste per year can have added valued. This means that, potentially, all over Italy 100,000 ton/year of waste could be used to produce new products.
- ✓ The *territory*, supporting an improvement in the regional competitiveness by increasing the skills of local technicians and operators involved in the production sector, thus valuing local economy, territory productions, and waste arising therefrom.
- ✓ The *society*, for the transferring of skills and know-how between companies and between universities and companies, which provides a general enrichment, making possible to build long term partnerships, for example with the local municipal waste collection, with the bartenders and the brewers. This project involves the employment of 6 people in the business model 1 and 12 people in the business model 2, new local employment, new professional figures able to put into practice the innovations introduced, the discovery of domestic projects to re-use waste.
- ✓ The *economy*, as it is expected an increase in the productive activities of that area and a revenue growth, a company investment in R&D. This approach wishes to generate a set of start-up activities and to give an innovative approach to production processes that have been lost over time (for example paper mills and screen printing craft). The products generated by this virtuous circle could come back at several levels within the company itself, with a significant image return, able to attract media attention regarding environmental sustainability and business foresight. The project involves numerous local

actors, such as producers of inks, cosmetics and drugs, which may obtain a new local raw material 100% biodegradable, avoiding the use of synthetic products.

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REFERENCES

[1] Van Hilten, J.: The best coffee is what is sold at a profit, , www.worldmapper.org, 3. 2. 2014.

[2] Current Worldwide Annual Coffee Consumption per capita, ChartsBin statistics collector team, 2011, chartsbin.com/view/581, 3. 2. 2014.

[3] Barbero, S., and Toso, D.: Systemic Design of a Productive Chain: reusing coffee waste as an input to agricultural production, Environmental Quality Management, 19(2010)3, 67-77.

[4] Tokimoto, T., Kawasaki, N., Nakamura, T., Akutagawa, J., Tanada, S.: Removal of lead ions in drinking water by coffee grounds as vegetable biomass, Journal of Colloid and Interface Science, (2005)281, 56-61.

[5] Barbero, S., Toso, D.: Buone previsioni dai fondi di caffè: Ricerca applicata alla coltivazione dei funghi dai fondi di caffè, Time&mind press, 2008.

[6] Solange I. Mussatto, Livia M. Carneiro, João P.A. Silva, Inês C. Roberto, José A. Teixeira: A study on chemical constituents and sugars extraction from spent coffee grounds, 2010.

[7] Bistagnino, L.: Systemic design: designing the productive and environmental sustainability, Slow Food Editore, Cuneo, Bra, 2011.

[8] Panusa, A., Zuorro, A., Lavecchia ,R., Marrosu, G., Petrucci ,R.: Eecovery of natural antioxidants from spent coffee grounds, Journal of agricultural and food chemistry, 61(2013)17, 4162-4168

[9] Barbero, S., Bicocca, M.: Design for a sustainable coffee (post)consumption, International Symposium on Sustainable Design (ISSD), Porto Alegre, Brasil, 2013, 182-188.

[10] Sendzikiene, E, Makareviciene, V, Janulis, P, Kitrys, S.: Kinetics of free fatty acids ester- ification with methanol in the production of biodiesel fuel, European Journal of Lipid Science and Technology, (2004)106, 831-836.

[11] Yen, W. J., Wang, B. S., Chang, L. W., Duh, P. D.: Antioxidant properties of roasted coffee residues,. Journal of Agricultural and Food Chemistry, 53(2005), 2658-2663.

[12] Remalakshmi, K., Jagan Mohan Rao, L., Takano-Ishikawa, Y., Goto M.: Bioactivities of low-grade green coffee and spent coffee in different vitro model systems, Food Chemistry, 115(2009), 79-85

[13] Zuorro A., Lavecchia R.: Polyphenols and energy recovery from spent coffee grounds, Chem. Eng. Trans 25(2011), 285-29.

[14] Zuorro A., Lavecchia R.: Spent coffee grounds as a valuable source of phenolic compounds and bioenergy. 2012.

[15] Simões, J., Madureira, P., Nunes, F. M., Domingues, M. R., Vilanova, M., Coimbra, M. A.: Immunostimulatory properties of coffee mannans Molecular Nutrition & Food Research, 53(2009), 1036-1043.

[16] Couto R. M., Fernandes J., Gomes da Silva M. D. R., Simoes P. C.: Supercritical fluid extraction of lipids from spent coffee grounds, Journal of Supercritical Fluids (2009)51, 159-66.

[17] Silva, M. A., Nebra, S. A., Silva, M. J. M., Sanchez, C. G.: The use of biomass residues in the Brazilian soluble coffee industry, Biomass and Bioenergy, (1998)14, 457-467.

[18] Franca, A. S., Oliveira, L. S., Ferreira, M. E.: Kinetics and equilibrium studies of methylene blue adsorption by spent coffee grounds, Desalination, (2009)249, 267-272.

[19] Eliche-Quesada, D., Martínez-García, C., Martínez-Cartas, M. L., Cotes-Palomino, M. T., Pérez-Villarejo, L., Cruz-Pérez, N., Corpas-Iglesias, F. A.: The use of different forms of waste in the manufacture of ceramic bricks, Department of Chemical, Environmental, and Materials Engineering, Higher Polytechnic School of Linares, University of Jaén, Spain, 2011.

[20] Naviglio, D., Caruso, T., Iannece, P., Aragòn, A., Santini, A.: Characterization of high purity lycopene from tomato wastes using a new pressurized extraction approach, Journal of Agricultural and Food Chemistry, 56(2008)15, 6227-6231.

[21] O'Mahony, M., Gwilt, A.: Waste in the City Seminar, 24. 8. 2010., wasteinthecity.wikispaces.com, 3. 12. 1013.