POTENTIAL ENVIRONMENTAL APPLICATIONS OF SPENT COFFEE GROUNDS

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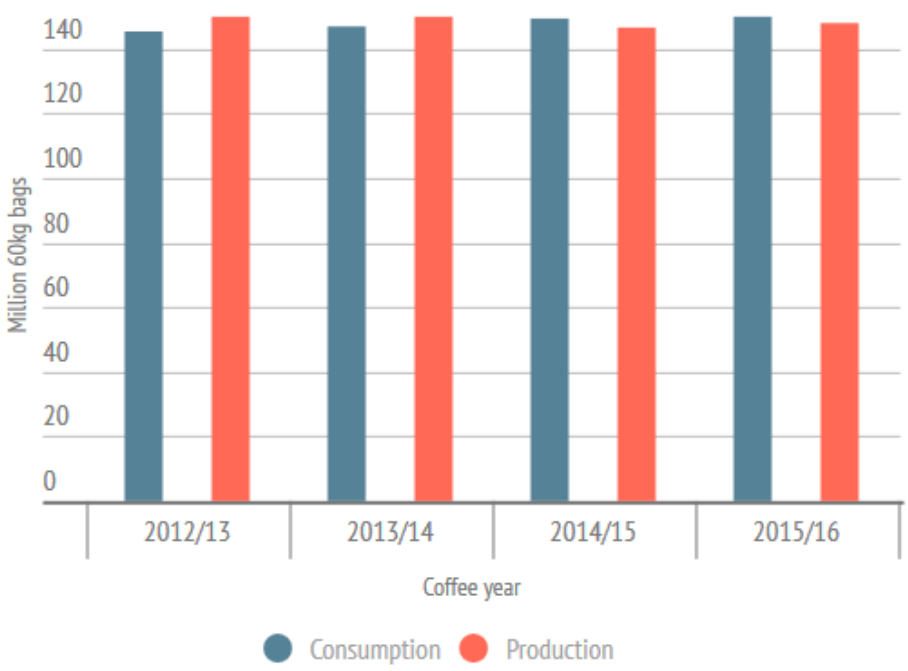
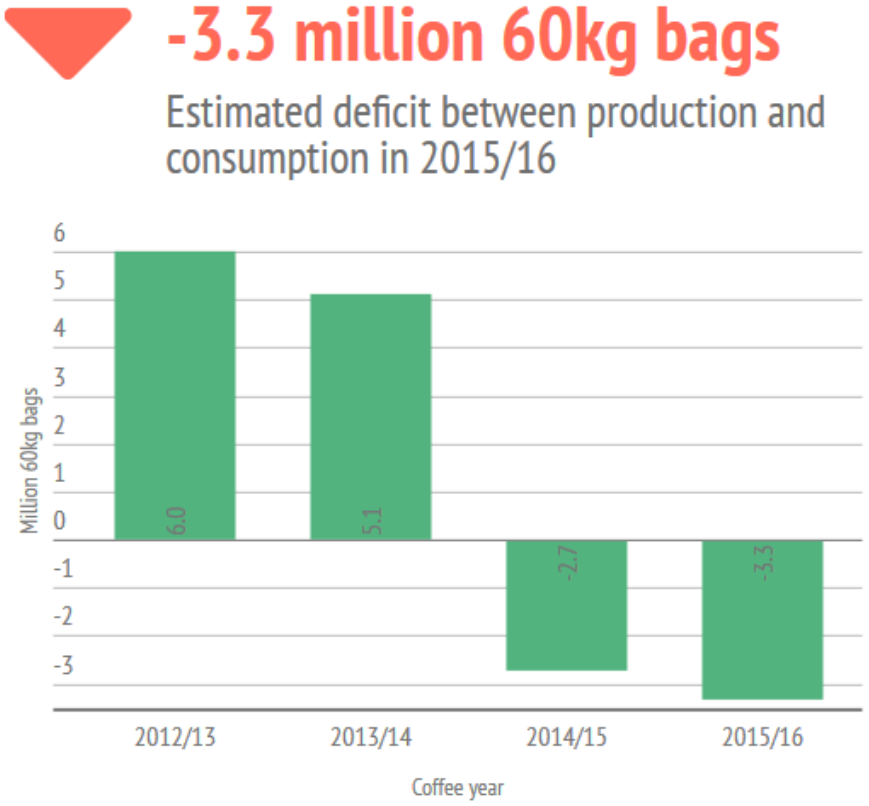
Outline

- Introduction – Coffee and waste
- Composition of SCG
- Environmental applications
  - Barriers? - Issues to be solved?
- Conclusions

Coffee world consumption, production (2012/13 - 2015/16)

- Coffee is considered the most popular beverage in the world.





- *Data as at 14 October 2016*

http://www.ico.org/monthly_coffee_trade_stats.asp

Coffee and waste

- this results to the production of million tons of relevant wastes, i.e.
  - plastic cups,
  - aluminium capsules (Nespresso) and
  - spent coffee grounds (SCG)

Chemical composition of SCG

- Preparation process of a coffee beverage

unique organic waste stream

with little to no contamination

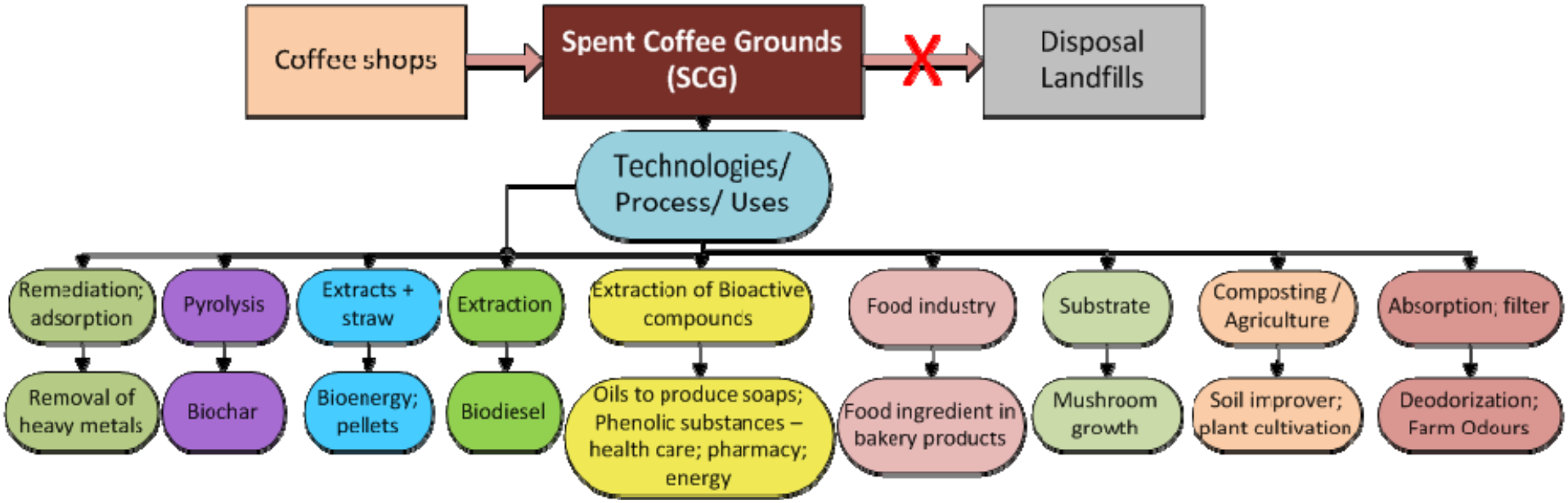
is collected separately

- Due to these processes, SCG has a high humidity content (80% to 85%), fine particle size, organic load and acidity (~6,3).

Chemical composition / Parameter	Content (wt%)
Cellulose	8.6-13.3
Hemicellulose	30-40
Arabinose	1.7
Galactose	13.8
Mannose	21.2
Proteins	6.7-13.6
Oil	10-20
Lignin	25-33
Insoluble	17.59
Soluble	6.31
Polyphenols	2.5
Caffeine	0.02
Ashes	1.6
Organic matter	90.5
Nitrogen	2.3
Carbon/nitrogen (C/N ratio)	22/1

Chemical composition of SCG - Uses

- Its' chemical composition, reveals a product rich in sugars, proteins, oil, lignin and polyphenols components, which are valuable if they are obtained from SCG and used in other applications.



Applications of SCG - Barriers

- **Source of natural antioxidants - Bioactive compounds**

nutritional supplements, foods, for health care and for pharmacy applications

Phenolic compounds have received considerable attention due to their beneficial effects on human health, and are ascribed to their antioxidant activity

Extracts produced from SCG exhibited anti-tumor and anti-allergic activities, which were related to the presence of phenolic compounds such as chlorogenic acid in their composition

S. I. Mussatto, L. F. Ballesteros, S. Martins, and J. A. Teixeira, 'Extraction of antioxidant phenolic compounds from spent coffee grounds', *Sep. Purif. Technol.*, vol. 83, pp. 173–179, Nov. 2011

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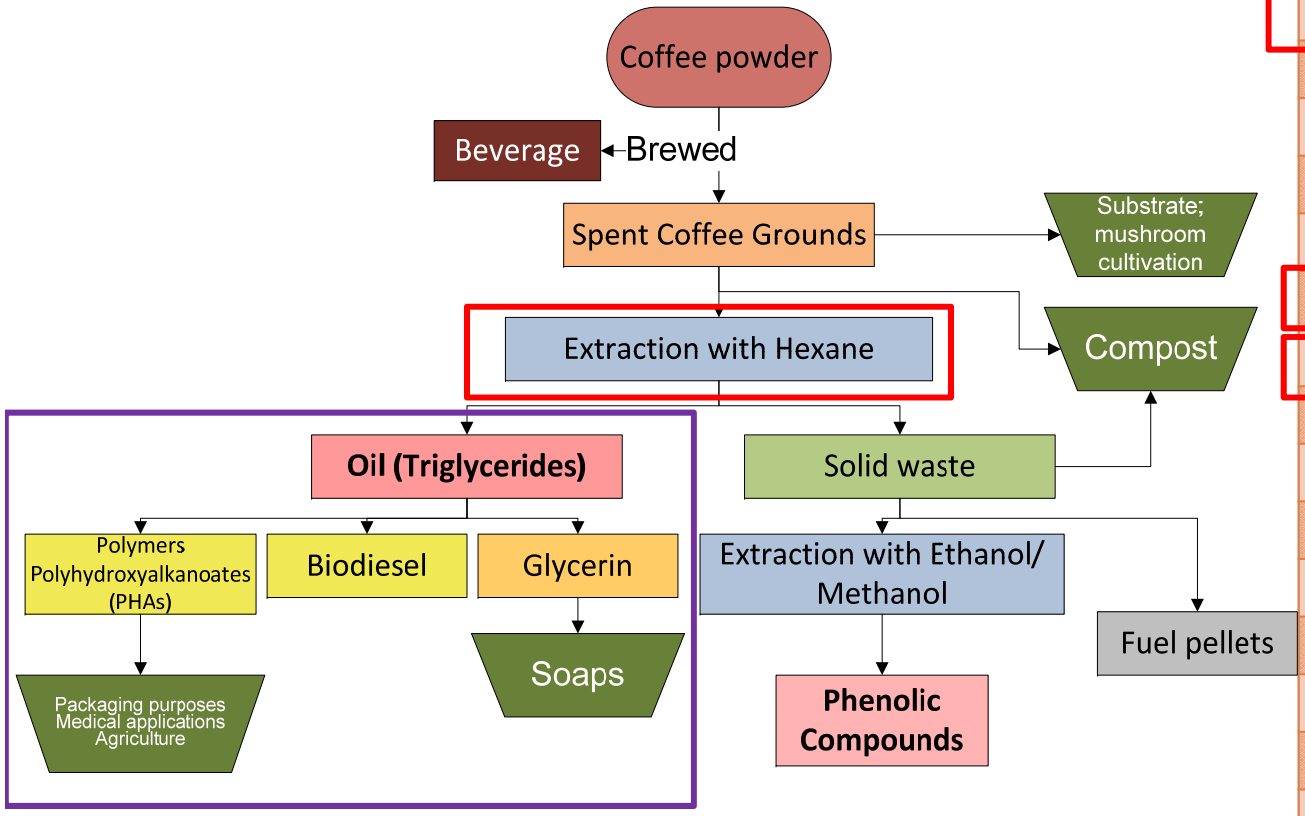
Energy

- Extraction of oil from SCG has also gained much attention due to the increased interest in biodiesel as an environmentally-friendly fuel



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Energy

- Direct conversion of bioethanol from SCG was not found to be a desirable option, because of the relatively slow enzymatic saccharification behavior in the presence of triglycerides and the free fatty acids (FFAs) found to exist in the raw materials

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E. E. Kwon, H. Yi, and Y. J. Jeon, 'Sequential co-production of biodiesel and bioethanol with spent coffee grounds', *Bioresour. Technol.*, vol. 136, pp. 475–480, 2013.
Z. Al-Hamamre, S. Foerster, F. Hartmann, M. Kröger, and M. Kaltsacid chmitt, 'Oil extracted from spent coffee grounds as a renewable source for fatty methyl ester manufacturing', *Fuel*, vol. 96, pp. 70–76, 2012

Energy

- Limousy et al. (2015) investigated the production of compressed logs for energy production from SCG.
  - The use of an industrial press compressed various blends of SCG and wood chips and its chemical properties and calorific value was analyzed.
- The results showed that SCG leads to better combustion but CO and particle emissions increased leading to lower CO_2 concentrations, which indicated that the combustion of compressed logs is not suitable under the specific stove design and may lead to uncomfortable heating

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L. Limousy, M. Jeguirim, S. Labbe, F. Balay, and E. Fossard, 'Performance and emissions characteristics of compressed spent coffee ground/wood chip logs in a residential stove', *Energy Sustain. Dev.*, vol. 28, pp. 52–59, Oct. 2015

Agronomic potential of SCG and its impact on soil biology and fertility

- Compost
- Plants

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Agronomic potential of SCG and its impact on soil biology and fertility

- High concentrations of nutrients and carbon/nitrogen ratio makes SCG as a valuable material for the composting process.

Evaluation of different composting systems → SCG reduced earthworm growth and survival which was faced by adding cardboard

K. Liu and G. W. Price, 'Evaluation of three composting systems for the management of spent coffee grounds', *Bioresour. Technol.*, vol. 102, no. 17, pp. 7966–7974, 2011

Hardgrove and Livesley (2016) showed that applying SCG directly to urban agriculture soils greatly reduces plant growth

S. J. Hardgrove and S. J. Livesley, 'Applying spent coffee grounds directly to urban agriculture soils greatly reduces plant growth', *Urban For. Urban Green.*, vol. 18, pp. 1–8, 2016

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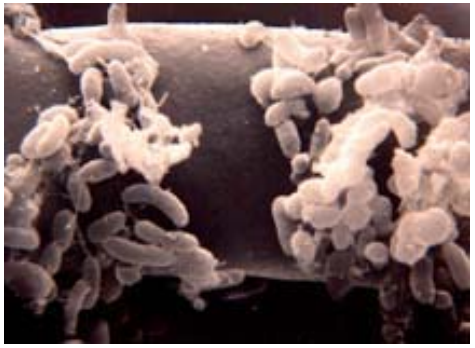
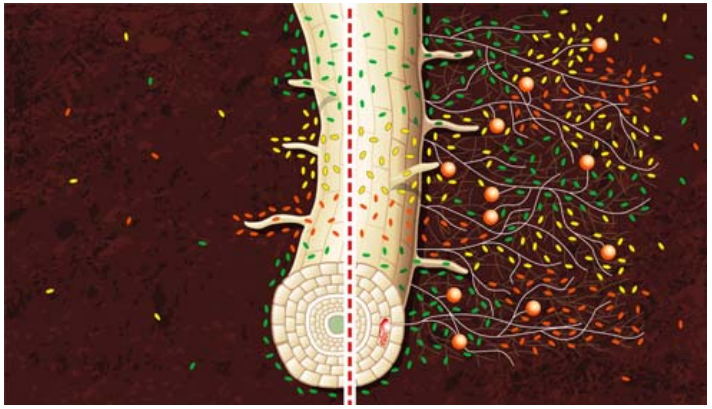
Agronomic potential of SCG and its impact on soil biology and fertility

- SCG is a promising alternative source of nutrients for plants, its environmental safety has been overlooked.

- Data?
  - impact of SCG on soil functional microbial communities?
  - change the community structure plant growth promoting bacteria (PGPB)?
    - to increase plant growth by supplying the plant with nutrients and hormones;
    - reduced susceptibility to diseases



Rhizosphere bacteria on a root.



The left side is an example of a root without PGPB and the right side is an example of what the root would be like with PGPB

https://microbewiki.kenyon.edu/index.php/Plant_Growth_Promoting_Bacteria

As food ingredient in bakery products

- Martinez-Saez et al (2017) showed that SCG are:
  - a natural source of antioxidant insoluble fibre,
  - essential amino acids,
  - low glycaemic sugars,
  - resistant to thermal food processing and digestion process, and
  - totally safe

able 3
mino acids composition (% protein) of spent coffee grounds (SCG).

Amino acids	SCG (% protein)
Alanine (Ala)	2.34 ± 0.71
Arginine (Arg)[a]	0.01 ± 0.01
Aspartic acid (Asp)	5.10 ± 0.71
Cysteine (Cys)	0.15 ± 0.01
Glutamic acid (Glu)	4.13 ± 0.56
Glycine (Gly)	2.68 ± 0.17
Histidine (His)[a]	0.39 ± 0.08
Isoleucine (Ileu)[a]	0.94 ± 0.13
Leucine (Leu)[a]	2.49 ± 0.37
Lysine (Lys)[a]	0.59 ± 0.10
Methionine (Met)[a]	0.26 ± 0.03
Phenylalanine (Phe)[a]	1.18 ± 0.22
Proline (Pro)	1.63 ± 0.29
Serine (Ser)	0.57 ± 0.10
Threonine (Thr)[a]	4.71 ± 1.01
Tyrosine (Tyr)	0.33 ± 0.09
Valine (Val)[a]	1.69 ± 0.14
Essential AAs (% total)	42.0 ± 1.2
BCAA (Val + Leu + Ile)	5.12 ± 0.6
AAA (Phe + Tyr)	1.51 ± 0.3
Fisher Ratio	3.40 ± 0.3

esults are expressed as mean ± standard deviation (n = 3).
[a] Essential amino acids.

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Dietary Fibers	60.46
Insoluble	50.78
Soluble	9.68

N. Martinez-Saez *et al.*, 'Use of spent coffee grounds as food ingredient in bakery products.', *Food Chem.*, vol. 216, pp. 114–22, Feb. 2017

Sorption and Biochar

Biosorption of heavy metals from aqueous solutions has also been investigated, showing very good results for the removal of Cd, Cr(II), Cr(IV), Cu and Pb.

A. P. Davis, R. Govaerts, D. M. Bridson, and P. Stoffelen, 'An annotated taxonomic conspectus of the genus Coffea (Rubiaceae)', *Bot. J. Linn. Soc.*, vol. 152, no. 4, pp. 465–512, Dec. 2006.

G. Z. Kyzas, 'Commercial Coffee Wastes as Materials for Adsorption of Heavy Metals from Aqueous Solutions', *Materials (Basel).*, vol. 5, no. 12, pp. 1826–1840, Oct. 2012.

N. E. Dávila-Guzmán *et al.*, 'Copper Biosorption by Spent Coffee Ground: Equilibrium, Kinetics, and Mechanism', *CLEAN – Soil, Air, Water*, vol. 41, no. 6, pp. 557–564, 2013.

N. E. Davila-Guzman, F. J. Cerino-Córdova, M. Loredo-Cancino, J. R. Rangel-Mendez, R. Gómez-González, and E. Soto-Regalado, 'No TitlStudies of Adsorption of Heavy Metals onto Spent Coffee Ground: Equilibrium, Regeneration, and Dynamic Performance in a Fixed-Bed Columne', *Int. J. Chem. Eng.*, vol. 2016, p. 11, 2016

Biochar (pyrolysis) from SCG and its use for heavy metal removal was investigated giving promising results for Zn, Cd, Cu and Zn.

M.-S. Kim *et al.*, 'The effectiveness of spent coffee grounds and its biochar on the amelioration of heavy metals-contaminated water and soil using chemical and biological assessments', *J. Environ. Manage.*, vol. 146, pp. 124–130, 2014

Kemp et al (2015) proposed a mechanism for the formation of activated carbon from SCG. SCG activation at 900 °C showed to be an effective and stable medium for methane storage and also exhibits an impressive hydrogen storage capacity

K. C. Kemp, S. Bin Baek, W.-G. Lee, M. Meyyappan, and K. S. Kim, 'Activated carbon derived from waste coffee grounds for stable methane storage', *Nanotechnology*, vol. 26, no. 38, p. 385602, 2015

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Mushroom growth

Caffeine present in SCG may serve as a chemical defence mechanism in some plants, while adversely inducing toxicity in other plants.

Caffeine in SCG is completely degraded by *Pleutotus Ostreatus LPB 09* fungal cultures enabling economical utilization of SCG as substrates for edible fungi/mushroom cultivation without any pre-treatment.

Campos-Vega, Rocio, Guadalupe Loarca-Pina, Hayde A. Vergara-Castaneda, and B. Dave Oomah. 2015. 'Spent Coffee Grounds: A Review on Current Research and Future Prospects'. *Trends in Food Science & Technology* 45 (1): 24–36

https://grocycle.com/

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Biogas production from coffee waste through anaerobic digestion

- **Anaerobic digestion** (AD)

Working under mesophilic conditions failed to degrade coffee grounds by means of AD because of the recalcitrant lignocellulosic composition of the substrates.

M. Shofie, W. Qiao, Q. Li, K. Takayanagi, and Y.-Y. Li, 'Comprehensive monitoring and management of a long-term thermophilic CSTR treating coffee grounds, coffee liquid, milk waste, and municipal sludge.', *Bioresour. Technol.*, vol. 192, pp. 202–11, Sep. 2015

A gradual decrease in biogas production in a mesophilic reactor after 80 days, due to unknown inhibitory compounds

A. G. Lane, 'Anaerobic digestion of spent coffee grounds', *Biomass*, vol. 3, no. 4, pp. 247–268, Jan. 1983

The inhibitory effects produced by bioactive compounds contained in coffee grounds e.g. aromatic compounds, polyphenols, and alkaloids could be minimized by mixing different substrates.

Braun, R. and A. Wellinger, 'Potential of co-digestion. In IEA Bioenergy', 2003.

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Biogas production from coffee waste through anaerobic digestion

- **Anaerobic digestion**

A common practice to increase biogas production and to alleviate phenolic inhibition is through anaerobic digestion at thermophilic temperatures and/or co-digestion with other waste, such as milk waste (C/N ratio: 6–12) and sludge (C/N ratio: 5.8) to obtain a nutrient balance.

Research on biogas production from SCG after phenolic extraction.

The phenolic extraction is expected to remove part of inhibition of anaerobic biomass; therefore it is possible the digestion to take place under mesophilic conditions.

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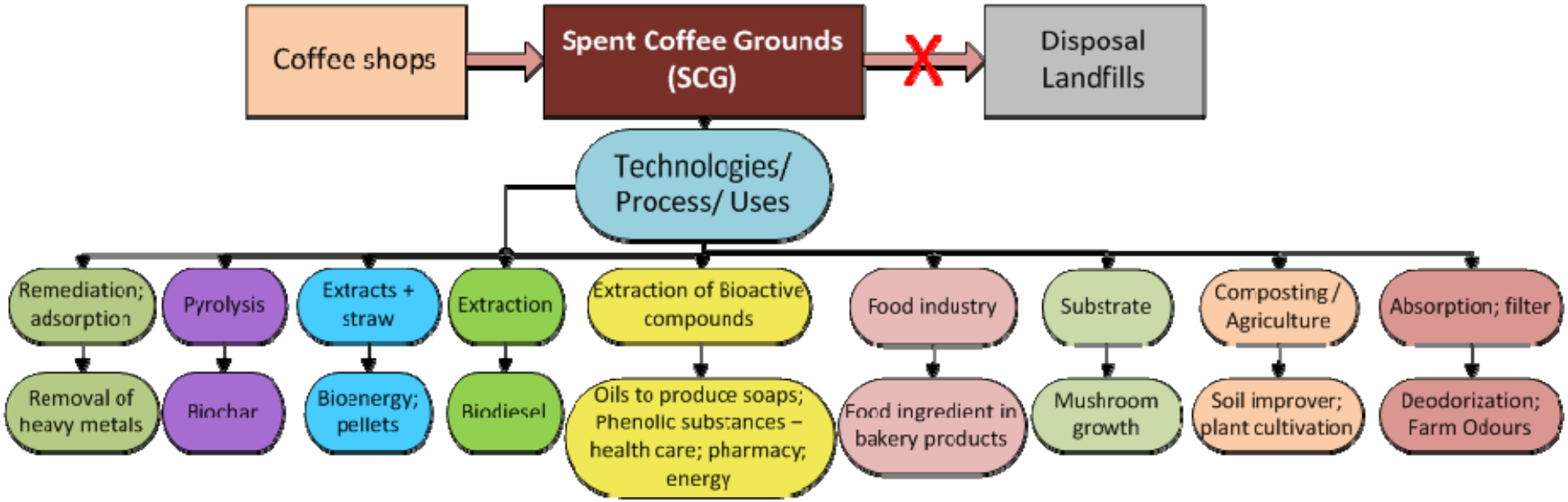
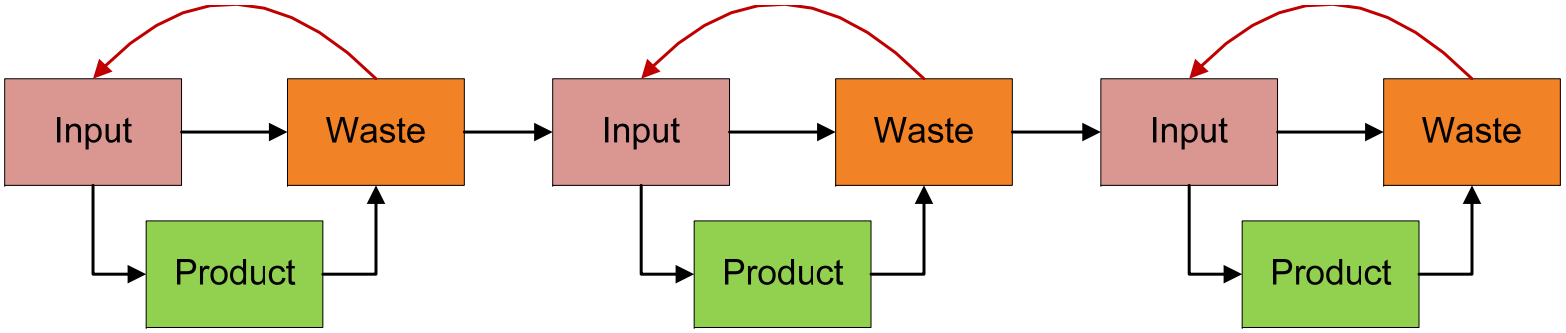
Conclusions

- SCG are nutrient rich and have the potential to be used as a value added product in multiple different processes.



SCG and circular economy

- where the waste from one process is used as an input by another.



  - Within this setup the use of resources are optimised
  - waste generation is minimised and
  - there is an economically viable role for every product of a manufacturing process

Cyprus (Nicosia) vs London city

- The challenges of waste collection
  - Population
  - Volume produced
  - Interest to participate
  - Collection services available

Thank you for your attention

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