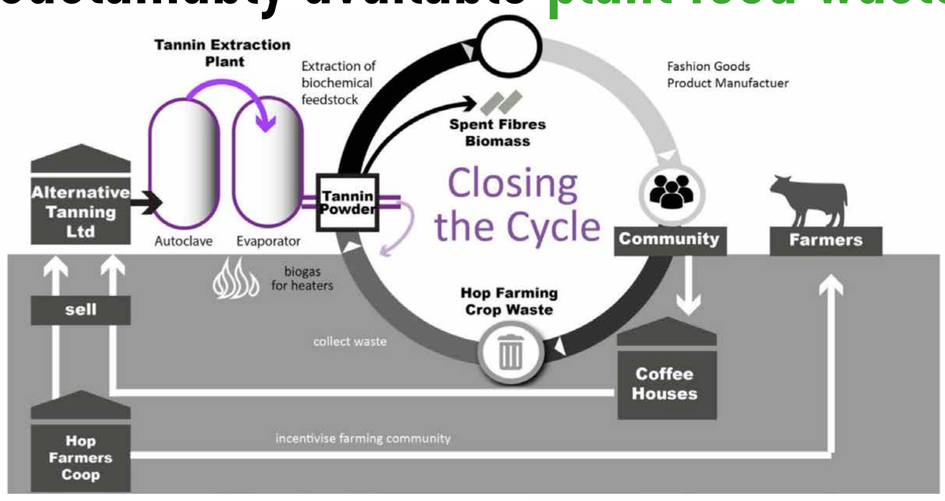
Closed-loop and chromium-free leather for the circular economy through refining sustainably available plant food waste



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COFFEE LEATHER

1. Introduction

The purpose of this research determines **the feasibility of losed-loop and chromium-free leather, fit for the circular economy, through bio-refining sustainably available plant food waste**

Currently, 80% (1700 km2) of global leather manufacture is tanned with chromium (III) salts, which are not renewable and problematic to recover at end-of-life. (Covington 2007) Commercial vegetable tanning agents are extracted from cultivated stocks, which are insufficient to replace the current consumption of chromium (III) salts. Further expansion of existing plantations is not a sustainable method to generate sufficient tannin extracts to meet current demands. Therefore, alternative bio-based waste sources are required to effectively reuse resources and reduce the need for new fossil-based inputs and reduce the environmental footprint of leather manufacture.

The UK consumes 30 billion cups of coffee a year (Nescafe 2020), which leads to 500,000 tonnes of waste coffee grounds that are not fully exhausted of their useful extracts. Recently, coffee ground recycling services have been established to recycle spent grounds into a range of sustainable products. The utilisation of this waste material has the potential to be further diversified into chemical feedstock extraction for the leather industry without disrupting the current recycling model. Coffee grounds are only one of a range of bio-based by-products that have the potential to substitute non-circular input chemicals in the leather industry.

Literature supports the presence of tannins in coffee waste. Low et al (2015) and Bhoite et al (2013) confirm the presence of both condensed and hydrolysable tannins with C13 NMR and MS data. This observation can be extended to many waste streams in the food and beverage sector. Underpinning tanning application has been demonstrated through trials by Baskar at ICLT, which shows the extracted coffee waste replaces conventional veg tannins which includes both tanning and retanning stages. Typical concentrations of tannins required to fully tan are more than 30% of the hide weight, therefore, the use of waste sources has the potential to replace a significant quantity of leather processing chemicals. Currently at TRL 3, the project aim is to develop a scalable leather manufacturing process with tannins extracted from food and beverage wastes thus replacing Cr and plantation crop tanning agents.

Properly made and sourced leather is a truly sustainable material.

Michael Redwood, Leather Naturally

References:

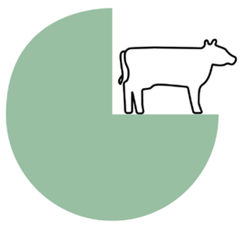
A. Covington, Quo vadit chromium? The future direction of tanning technologies. Proceedings of IULTCS (International Union of Leather Technologists and Chemists Societies) congress, 2007.

The Grocer. The UK is a Nation of Coffee Lovers, https://f5f09489f4d6b22f-7cfc-476354e4409503c0bf1163d0a2b97f47.ssl.cf3.rackcdn.com/161459_GRO_SEP12_D_NestleFactfile_proof.pdf

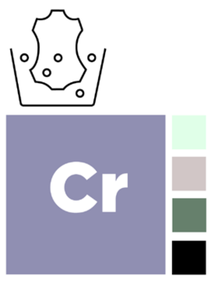
J. H. Low, W. A. Rahman and J. Jamaluddin, Confirmation for condensed and hydrolysable tannins presence. Industrial Crops and Products, 2015, 69, 456–461.

R. Bhoite, P. Navya and P. Murthy, Presence of both condensed and hydrolysable tannins, C13 NMR and MS data to predict the structure of tannins in spent coffee grounds. Preparative Biochemistry and Biotechnology, 2013, 43, 350-363.

2. Literature Review
Waste Coffee and Leather Facts

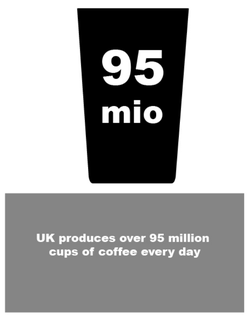


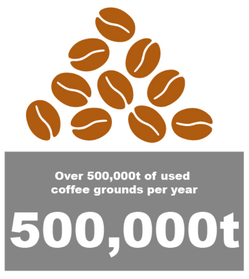
Modern leather manufacturing recycles over 270 million cow hides each year. Skins from from cattle, goat, sheep and pig are a by-product of the food industry. Leather makes a sustainable contribution as it is durable and recyclable. Otherwise over 7 million tonnes would go to landfill, incinerated or processed into gelatine.

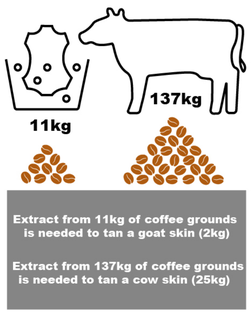


80% of leather is Chrome tanned. Whilst economical, the end-of-life and recovery of Chromium remains problematic. Other 20% tanning methods include synthetic (syntan), glutaraldehyde (wet-white) and vegetable tanning. Tannins extracted from plant waste are of interest to the circular economy.

Material of choice for body protection and comfort. Sustains artisan communities. However, there is a shift with 50% decline of leather use in footwear, mainly substituted by synthetics. Leather remains strong in luxury goods and is standard in premium cars.

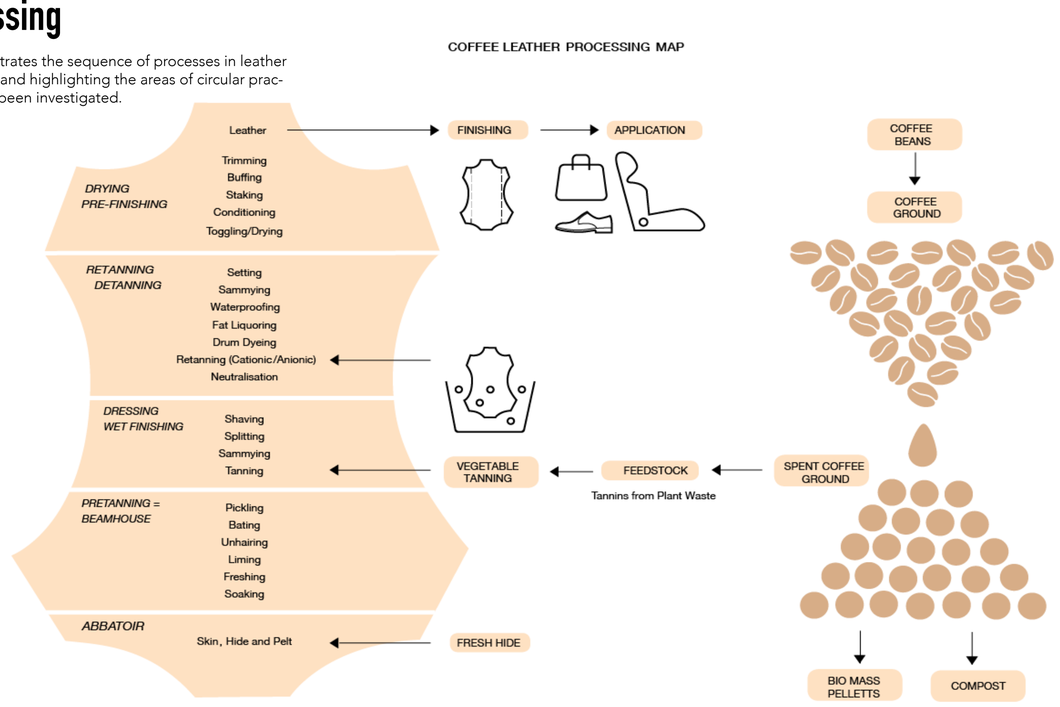






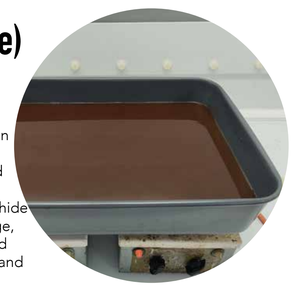
3. Method
Closed-Loop Coffee Leather Processing

Diagram illustrates the sequence of processes in leather manufacture and highlighting the areas of circular practice that has been investigated.



4. Lab Trials

Plant Matter (Waste) as Tannins



Samples from tanning experiments on the reuse of plant waste. Alternative tannages from plant matter, farm and forestry waste that contain phenolic tannins. Experimental tanning of rawhide with apple pulp, alder tree and foliage, chestnut and cherry tree shavings and bark, spent coffee gound waste, tea and hops.

Hop and Coffee as Feedstock

Invesitgation of plant waste as feedstock, rich in natural phenols traditional used as a bittering agent in brewing.
The hop crop is seasonal and traditionally grown in Kent and the Hallertau area of Bavaria. Tannins distilled at ICLT Northampton. Larger quantity of plant waste is required for extraction.

Malt Grain Extract

Coffee Grounds

Exploring the creative and commercial potential of vegetable tanning with a strong narrative through prototype of coffee retanned leather from from another waste stream, i.e. cround coffee waste from Highstreet coffeeshops, through distilling and tanning trials led by ICLT.
Coffee retanned leather being debossed with coffeebean shaped design on an embossing press.

Scaling-up Vegetable Tanning

Practical experiment to use plant waste in a laboratory evironment. Tanning effect has been observed and compared to commerical traded mimosa and chestnut extracts. Scaled up extraction and distillation has been investigated for future trials. Currently at TRL 3, the project aim is to develop a scalable leather manufacturing process with tannins extracted from food and beverage wastes thus replacing Cr and plantation crop tanning agents.

5. Results

Experimental tanning of rawhide with coffee ground A variety of waste streams available in significant quantities have useable tannin contents

Waste streams considered significant enough to be suitable for industrial scale up.

Other waste streams are being investigated at the Institute for Creative Leather Technologies (ICLT) Black tea, Green tea, Hops.

Proof-of-concept pieces produced and working on process optimisation

Extracts can be applied as a primary tanning agent or as a retanning agent

Parameters	Mimosa ME	Malt Grain Extract	Coffee Extract	Rapeseed Extract
% Tannin	70.2	13.1	21.8	16.6
% Non Tannin	22.5	71.2	35.4	7.0
% Insolubles	3.4	12.6	40.9	70.1
% Moisture	3.9	3.1	1.9	6.4

6. Conclusion
Designing Leather that fits the Circular Economy

Extraction and application of tannins from waste sources is achievable at laboratory scale.

The tannins double as a colourant and effectively dyes the leather without the need for the addition of synthetic dyes

The produced leather has imparted properties distinctive to the tanning agent used and easily adds a unique selling point

The potential for the waste streams of other industries to convey circular economic benefits to the leather industry have been demonstrated. Working prototype has been developed at ICLT.
Technology Readiness Level 3 (Proof-of-Concept)