WHITEPAPER

Biodegradability and disintegration

of leather

NERA
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Biodegradability and disintegration of leather

A sustainable leather value chain not only focuses on the production of the materials but also on their end-of-life scenarios. Society asks for a re-focus on the sustainability of leathers that are more biodegradable, and not just durable. Explaining the biodegradability of leather in specific and understandable terms is a key element to the sustainability of the leather industry. This whitepaper lays out the differences in the terminology and draws a distinction between chemical and whole material testing.

Executive Summary

The understanding of what substances that leather breaks into after usage and whether they are benign or harmful is important information for consumers who want to make purchases that fit their environmental preferences. Relevant test results are useful for consumers to understand the impact their product will have at the end-of-life stage.

The differences in the terminology depict a major distinction between the testing of the separate chemical substances and whole-material testing. Practitioners in the leather industry should be familiar with the jargon used, the end-of-life scenarios, and with the basic testing that is used to simulate the different end-of-life environments.

A key advancement in the future success of leather will depend upon the development of a balance between long-lived leathers and ecological benign short-lived leathers.

Sustainability at end-of-life

The end-of-life of a leather article is a vital part of its sustainability. Video footage of ocean plastic has highlighted just how important it is that materials can degrade under natural conditions with minimal interference[1,2,3]. The biodegradability of leather is something that leather manufacturers and fashion houses are increasingly interested in. The end-of-life (bio)degradation of materials depends on the environmental conditions: wet or humid, with or without air, hot or cold. These situations are simulated using different standard test methods[4,5]. Explaining the biodegradability of leather in easy to understand terms is a key element to the end-of-life sustainability of leather.

Before hides/skins are tanned, they are naturally biodegradable. The tanning process changes the chemistry inside the leather fibers to make it more difficult for the enzymes from bacteria and fungi to break them down. Any leather can be composted but the environmental impact depends on the tanning chemistry used. The tanning technologies developed in the past mainly focused on the durability (and longevity) of the leathers; however, current society asks for an additional sustainability property – leather that biodegrades into components that can enter natural cycles once again[6,7]. The tanning industry (both leather manufacturers and chemical companies) has recognized this re-focus and is increasingly researching and creating new tanning technologies that are supporting more biodegradable, ecologically benign leathers.

Biodegradability - three areas for testing

Materials such as leather are composed of multiple components. The substrate (the hide) that provides the strength can be tested for its own biodegradability, and the substances (the chemicals) contained in the material also can be tested for their biodegradability[6-12]. Finally, the material such as leather composed of substrate and substances results in a separate area for testing.

Chemical producers test the biodegradability of the individual substances and the terminology used is designed to interrelate with the metrics specified in their test methods[6,9]. A leather manufacturer, on the other hand, cannot adopt all the terms[8,18] that the chemical industry uses when describing substance because in some of the definitions they reference test methods that are not used when testing leather.

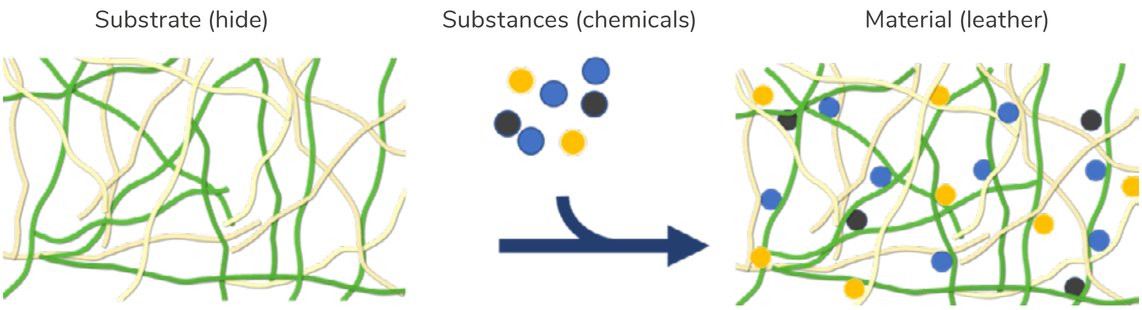

Figure 1. Substrate and substances combine into material

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GLOSSARY FOR LEATHER AND CHEMICALS		
Term	**Definition**	**Relates to**
Degradation	*The process by which any material or substances is broken into simpler components through non-enzymatic methods using chemical (e.g., acid), physical (e.g., wave action), or both (e.g., light)*[7,8,9,10,11].	Leather and chemicals
Biodegradationt	*The process by which organic materials or substances are decomposed by micro-organisms into simpler components such as carbon dioxide, water, and ammonia*[7,8,9,10,11].	Leather and chemicals
Composting	*Biodegradation in a: humid; organic; aerobic; high temperature (industrial), ~60°C; or aerobic room temperature (home), ~25°C; environment*[5,10,11,14].	Leather
Ultimate biodegradability	*The level of degradation achieved when the test compound is totally utilised by microorganisms resulting in the production of carbon dioxide, water, mineral salts and new microbial cellular constituents (biomass)*[8,9,10,11].	Leather and chemicals
Readily biodegradable	*An arbitrary classification of chemicals which have passed certain specified screening tests for ultimate biodegradability; these tests are so stringent that it is assumed that such compounds will rapidly and completely biodegrade in aquatic environments under aerobic conditions, see OECD 301 for specific screenings*[8].	Chemicals
Inherently biodegradable	*A classification of chemicals for which there is unequivocal evidence of biodegradation in any test of biodegradability*[8].	Chemicals

Testing of chemicals

The main test used to measure the biodegradability of chemicals (substances) is the Organisation for Economic Cooperation and Development (OECD) 301 method[9]. OECD 301 is not used to measure the biodegradability of leather because it is a composite of hide and chemicals. Companies have been measuring the biodegradability of chemicals for decades and this method tests whether organic compounds can be broken into carbon dioxide and water and how easily that is achieved[6,8]. The terms for ‘inherently biodegradable’, ‘readily biodegradable’, and ‘ultimately biodegradable’ are defined in OECD 301[8] and apply to chemicals only.

Which chemicals are biodegradable, and which are not, is more complex than initially thought. Each chemical needs to be checked to be able to determine the ability to biodegrade in a fast, or slow manner - or whether the time it will take will be too long for the test[8]. It is essential to separate the tests for chemicals from those used for leather[10].

Stages of biodegradation

Biodegradation of a material such as leather undergoes three different stages[7,9,19]:

1st stage: Biodeterioration, (e.g., black spots on bananas – surface breakdown)

2ndstage: Biodisintegration (e.g., the banana becomes soft due to bacterial breakdown, material breaks into smaller pieces)

3rd stage: Bioassimilation (e.g., the banana is broken into compost mass, taken into biomass) – also called ultimate biodegradability.

During the first two stages, leather breaks down into smaller components. In the third stage, these components are assimilated as nutrients by microorganisms. Materials that remain at the 1st or 2nd stage are not ultimately biodegradable and persist in the environment, typically as small pieces or scraps[6].

Compostability is a special case of biodegradability[11]. Compostability is the capacity of a material to be biodegraded into compost and it relates to the first two stages of biodegradation. It requires specific environmental conditions where ecological toxicity criteria are applicable. Composting produces biomass that is nutrient-rich and can be used for soil enhancement. The growth of biomass, based on the compost from the biodegraded materials, closes the material cycle.

Compostability is tested according to the ISO 20200 norm for packaging material which is adapted for testing of leather. The compostability test ranges from mainly the 1st to 2nd stage of biodegradation. By adding a plant growth test to the compostability test, the 3rd stage can be fully simulated.

The ultimate biodegradability of (bio)disintegrated, i.e. ground, leather material under aqueous conditions is tested according to ISO 20136. This test focusses only on the 3rd stage, bioassimilation, for the biodegradability. When a material passes through all three stages of biodegradability then it is fully taken up as new biomass and closes the material cycle.

End-of-life environments

Leather and the articles made from it at the end of their life can be found in environments such as landfills, effluent treatment plants, and composting units or littered in nature[7]. In Figure 2, these environments are compared and the common tests used to simulate the different environments are shown[4,5,13,14]. A single environment could contain oxygen (aerobic) and be relatively dry in which case it could compost (either through high or low-temperature methods). In other environments, the leather could be found in a large amount of oxygenated water and the bacteria present could break down the leather.

A landfill is the most common environmental fate of leather and is typified by no oxygen (anaerobic), sometimes with a large amount of water. The bacteria in these landfill environments can resist high temperature[13].

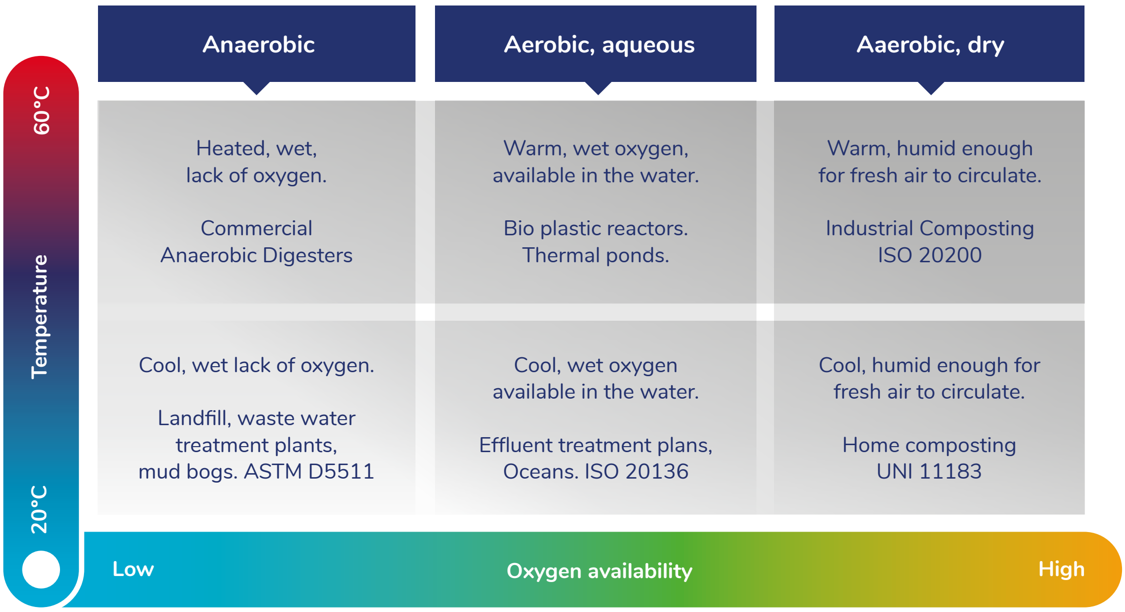

Figure 2. The range of end-of-life environments and the test used to simulate them.

Low moisture content in leather is a leading determinant of its biodegradability and is generally what makes leather resistant to breakdown during its working life. If the leather is susceptible to biodegradation, then the water content could limit whether that biodegradability takes place.
Like a biscuit, which is very biodegradable, the bacteria and fungi present on that biscuit can never begin their degradation until they get a supply of water. This level is known as water activity. Leather cannot biodegrade in a dry biosphere environment, which may include day-to-day life. End-of-life biospheres are typified by high moisture contents which encourage microbiological growth.
Most types of leather are coated with polymers that range from biodegradable substances to inert plastics. In general, as the polymer becomes more inert chemically, the biodegradability decreases[6,7]. Some of these coatings may take hundreds of years to break down[6].

Test methods

The tests used to understand the biodegradability of leather can be broadly divided into two types: 1) end-of-life simulations that artificially copy different environments, and 2) tests to see if leather in those environments will have a positive or negative impact. Materials such as plastic, biopolymers, textiles, have individual test methods, specifications, and terminology for their biodegradability[10,11]. The ISO 20200 /UNI 11183/ ASTM D5511 biodegradability methods are used for leather but are originally designed for plastics, or other materials[5,13,14].

ISO 20200 /UNI 11183 tests the compostability of materials. The ASTM D5511 method is used to test leather biodegradability behaviour in landfills. ISO 20136 tests the ultimate biodegradability of grinded leather. The ecological toxicity and plant response (OECD 208) tests examine the leather-containing compost to consider the environmental impact of that compost.

See appendix for a full explanation of all test methods and the relevant conditions and criteria, Appendix A.

Conclusion

Stakeholders in the value chain of sustainable leathers and leather articles must have a focus on the end-of-life scenarios of their products. Society now asks for a re-focus on the sustainability of leathers to become more biodegradable, and not just durable. Understanding and explaining the biodegradability of leather in terms of readily biodegradable, ultimately biodegradable, or compostable, is a key element to the sustainability of the leather industry.

This paper has laid out the differences in the terminology and has drawn an important distinction between the testing of chemical substances on the one hand, and whole-material testing on the other hand. Stakeholders in the leather industry can now also understand that biodegradability, is determined both by disintegration as well as bioassimilation. For the different end-of-life scenarios, specific jargon is used as well as specific testing methods. Biodegradability of leather in an aerobic humid condition is tested through a composting test for the biodisintegration, and a plant growth test for the bioassimilation, eventually closing the material cycle. Understanding what components the leather breaks into and whether the breakdown products are benign or harmful is important for consumers who want to make better environmental purchases related to the impact their product will have at the end-of-life stage.

A key advancement in the future success of leather will depend upon the development of a balance between long-lived leathers and ecological benign short-lived leathers.

Appendix A

TEST METHODS FOR LEATHER AND LEATHER-CONTAINING COMPOSTS			
Method	**Details**		**Relates to**
OECD 301 (A-F) *Aqueous ultimate biodegradability of substances* [9].	**Conditions**	Aqueous solution (of the substance), 25°C, inoculum, essential nutrients (28 days).	*Chemicals*
	Why?	Substance undergoes biodegradation in solution to see if they can be broken into CO^2 and water.	
	Criteria	The material will be defined as non-biodegradable, inherently biodegradable, or readily biodegradable (by definition).	
ISO 20200 *Industrial thermal/ biodisintegration of plastic (or similar) material* [5].	**Conditions**	Test pieces, compost, air, moisture, 58°C, compost inoculum (90-180 days).	*Leather*
	Why?	The material undergoes biodisintegration in industrial composting to see if it will breakdown.	
	Criteria	The test material is said to be biodisintegrated if no more than 10% of the material is retained in a 2 mm rated sieve after 90 days testing.	
UNI 11183 *Home thermal/ biodisintegration of plastic (or similar) material* [14].	**Conditions**	Test pieces, compost, air, moisture, 25°C, compost inoculum (6 months).	*Leather*
	Why?	The material undergoes biodisintegration in industrial composting to see if it will breakdown, same as ISO 20200, but at ambient temperature.	
	Criteria	The test material is said to be biodisintegrated if no more than 10% of the material is retained in a 2 mm rated sieve after 90 days testing.	
ISO 20136 *Determination of degradability by micro-organisms* [4].	**Conditions**	Aqueous, 25°C, leather powder, sludge inoculum, some nutrients, and controls (28 days) – CO^2 evolved measured.	*Leather*
	Why?	To see whether leather can be broken down into CO^2 (and water) at a rate comparable to a collagen standard.	
	Criteria	The collagen control must biodegrade more than 70% during the test. If the leather can match or better than that then the leather is said to be aerobically ultimately biodegradable.	
ASTM D5511 – *Landfill simulation to degrade any solid material* [13].	**Conditions**	Anaerobic, high solids, 25°C, landfill digestate inoculum, leather (28 days) – biogas measured.	*Leather*
	Why?	To see if leather can biodegrade in the anaerobic conditions of landfills sites.	
	Criteria	The control must biodegrade into biogas more than 70% during the test. If the leather can match or better than that then the leather is said to be anaerobically ultimately biodegradable.	
Ecotox - *Toxicity of resulting leather compost* [17].	**Conditions**	Standard tests that check for restricted substances in compost or soil.	*Compost*
	Why?	The use of leather composts should not add unwanted substances to soil.	
	Criteria	Restricted substance free composts do not include lower metals, halogenated chemicals, pesticides, polycyclic aromatic hydrocarbons, and phthalate esters compared to EU and US soils limits.	
WRAP 3.0, ASTM E1963, OECD 208 - *Plant response test (PRT) to leather compost* [15,16,17].	**Conditions**	Growth media and leather compost, plant seeds, light, water (28 days), 23°C	*Compost*
	Why?	PRT tests whether leather compost can bioenrich or biosupress the growth of plants.	
	Criteria	Plant growth, measured by: mass, total number of leaves and the visual observation of the plants are compared to the growth of a positive and negative control.	

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More information

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