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Flaxstic V1 and Pela Case V1 Testing Results
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INTRODUCTION

Pela conducts ongoing testing on their products, and the raw materials used to make their products, to ensure they will ultimately biodegrade into C02, water, inorganic compounds and biomass in 3 to 12 months in a compost environment instead of hundreds of years like conventional plastic products.

The raw materials used in Pela products have the applicable international testing certifications and Pela conducts additional ongoing internal and 3rd Party external testing on both the Flaxstic material and the Pela products.

Testing results indicate Flaxstic V1 and Pela Case V1 will completely biodegrade in compost within as little as 12 weeks and will also biodegrade in landfill.

The information presented herein provides the testing results specified by the European Norm (EN) EN 13432 for compostability of packaging and other disposable materials and are comparable to American Society for Testing and Materials (ASTM) ASTM D6400 standards for compostability.

An independent testing laboratory (OWS) with over 30 years of experience in the field of biodegradability and compostability testing, was contracted to conduct analytical testing.

Analysis was based on the above referenced guidelines, focusing on Chemical Characteristics (Section 1.0), Biodegradation Under Controlled Composting Conditions (Section 2.0), Plant Toxicity (Section 3.0) and Disintegration (Section 4.0). The testing was conducted on a 2.2 mm thick Pela Case V1 made with Flaxstic V1 and the results are summarized in Section 5.0.

1.0 CHEMICAL CHARACTERISTICS

Materials were analyzed to determine the presence of hazardous substances such as volatile solids, heavy metals and fluorine.

The analytical results indicate Flaxstic V1 and Black masterbatch fulfill the requirements on material characteristics (volatile solids, heavy metals and fluorine) as defined by EN 13432 (2000), NF T51-800 (2015), ASTM D6400 (2019), CAN/BNQ 0017-088 (2010) and ISO 17088 (2012). The results are presented below in Table 1.

Table 1: Heavy metals and Fluorine content (ppm on total solids)

Analysis	Flaxstic V1	Black masterbatch	Limit values				Test procedure
			Europe EN 13432 (2000)	France NF T51-800 (2015)	USA** ASTM D6400	Canada Can/BNQ 0017-088 (2010)	
Heavy metals*							
Zn	<10	<10	≤150	≤150	<1400	<463	DIN EN ISO 17294-2
Cu	<1	2.2	≤50	≤50	<750	<189	DIN EN ISO 17294-3
Ni	2.9	<1	≤25	≤25	<210	<45	DIN EN ISO 17294-4
Cd	<0.1	0.23	≤0.5	≤0.5	<19.5	<5	DIN EN ISO 17294-5
Pb	<1	<1	≤50	≤50	<150	<125	DIN EN ISO 17294-6
Hg	<0.1	<0.1	≤0.5	≤0.5	<8.5	<1	DIN EN ISO 12846
Cr	4.9	<1	≤50	≤50	-	<265	DIN EN ISO 17294-8
Mo	<1	<1	≤1	≤1	-	<5	DIN EN ISO 17294-9
Se	<0.75	<0.75	≤0.75	≤0.75	<50	<4	DIN EN ISO 17294-10
As	<1	<1	≤5	≤5	<20.5	<19	DIN EN ISO 17294-11
Co	<1	<1	-	≤38	-	<38	DIN EN ISO 17294-12
F	<10	<10	≤100	≤100	-	-	DIN 51723 mod.

* Microwave digestion was executed on the sample according to DIN EN 13657, before analysis of the heavy metals

**Maximum levels for USA (according to ASTM D6400 (2019) heavy metals content must be less than 50% of those prescribed for sludges or composts in the country where the product is sold)

2.0 BIODEGRADATION UNDER COMPOSTING CONDITIONS

Biodegradation is tested to ensure the material undergoes degradation by biological processes (from the action of naturally occurring microorganisms such as bacteria, fungi, and algae) to yield carbon dioxide, water, inorganic compounds, and biomass at a rate consistent with other known compostable materials. The test also ensures the biodegraded materials leave no visible, distinguishable or toxic residue, and no microplastics.

Biodegradation can be demonstrated for both industrial and home composting conditions by testing at 58°C (representing industrial composting and meeting the 90% biodegradation criterion within 180 days), and at 28°C (representing home composting and meeting the 90% biodegradation criterion within 365 days).

Biodegradation tests were conducted as per the following standards:

- ISO 14855 (EN 14046) Evaluation of the Ultimate Aerobic Biodegradability and Disintegration of Plastics under Controlled Composting Conditions
- EN 13432 – ISO 17088 – AS 4736 & ISO 18606
- ASTM D5338 Standard Test Method for Determining Aerobic Biodegradation of Plastic Materials under Controlled Composting Conditions
- ASTM D5511 (2018) High-Solids Anaerobic Digestion Test

Flaxstic V1 materials were tested for aerobic biodegradation at 58°C, aerobic biodegradation at 28°C, and anaerobic biodegradation at 37°C. The test results are presented below.

2.1 Aerobic Biodegradation at 58°C

An absolute biodegradation of 90.2% was measured for the Flaxstic V1 material within 180 days, as such the 90% biodegradability requirement stipulated in the standards was met and the test was stopped at the scheduled period of 180 days. The results are presented in the Table 2 and Figure 1 below. The biodegradation of cellulose above 100% can be explained by a synergistic effect, also called priming.

Table 2: Net CO_2 production and biodegradation after 180 days

Test series	Net CO_2 (mg/g test item)	Biodegradation (%)		
		AVG	SD	REL
Cellulose	1677	107.1	2.5	100
Flaxstic V1	1905	90.2	5.9	84.2
with AVG = average, SD = standard deviation, REL = relative biodegradation				

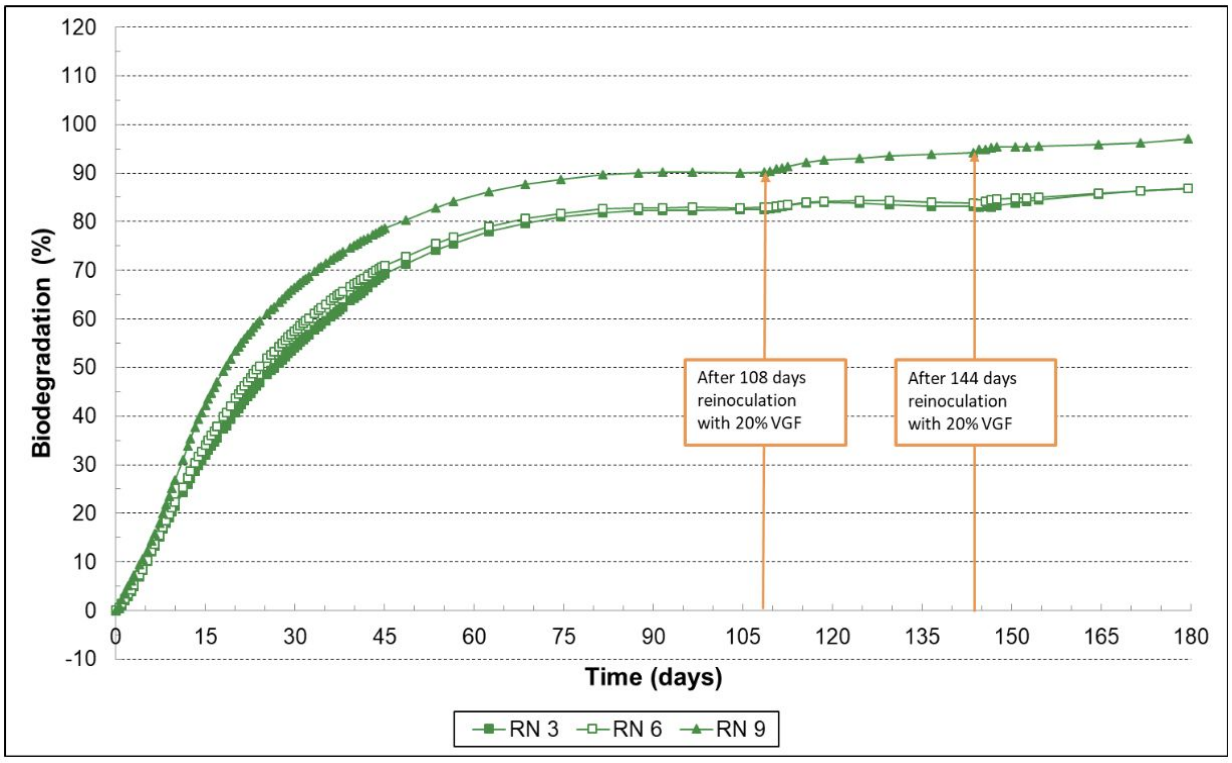


Figure 1: Evolution of biodegradation of replicates (RN 3, RN 6 and RN 9) of Flaxstic V1 at 58°C

2.2 Aerobic Biodegradation at 28°C

A relative biodegradation of 32.4% was measured for the Flaxstic V1 material after 75 days and a relative biodegradation of 43.0% was measured after 105 days. The maximum allowed test duration in home composting as determined by the ASTM and EN standards is 1 year. The biodegradation observed at 105 days indicates the material can biodegrade completely if exposed to a suitable home compost environment for up to 1 year. The results are presented below in Table 3 and Figure 2.

Table 3: Biodegradation percentage after 47 and 105 days

Test series	Average C_{input} (g)	Average $C_{gaseous}$ (g)	Biodegradation (%)		
			AVG	SD	REL
After 47 days					
Cellulose	34.1	28.4	83.2	0.7	100.0
Flaxstic V1	46.1	12.4	27.0	0.1	32.4
After 105 days					
Cellulose	34.1	30.0	88.0	1.1	100.0
Flaxstic V1	46.1	17.4	37.8	0.9	43.0
with AVG = average, SD = standard deviation, REL = relative biodegradation					

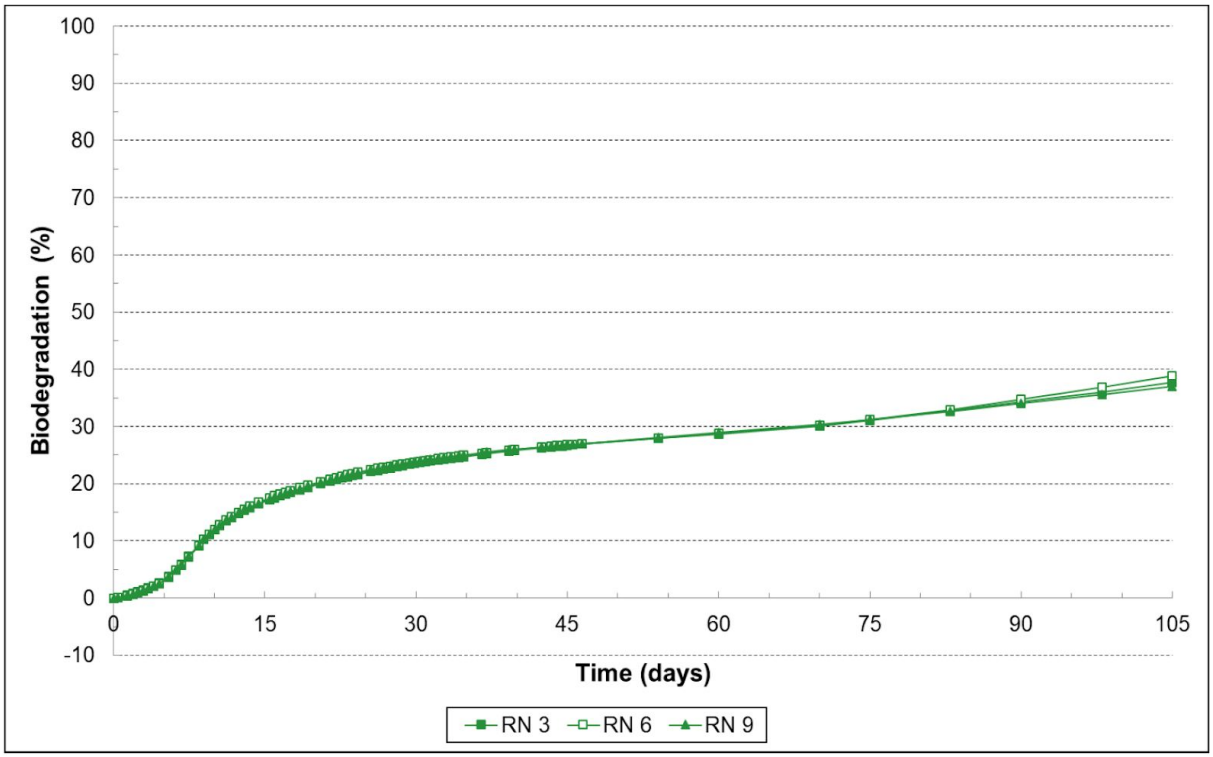


Figure 2: Evolution of biodegradation of replicates (RN 3, RN 6 and RN 9) of Flaxstic V1 at 28°C

2.3 Anaerobic Biodegradation at 37°C

Anaerobic testing was conducted to determine if Flaxstic V1 and Pela Case V1 materials will biodegrade in landfill. A relative biodegradation of 14.2% was reached under high-solids, mesophilic, anaerobic conditions within 90 days at 37°C, suggesting the Flaxstic V1 and Pela Case V1 will biodegrade in similar landfill conditions within 1 to 5 years.

The results are presented below in Table 4 and Figure 3 below.

Table 4: Anaerobic biodegradation percentages after 90 days of incubation

Test series	Average C_{input} (g)	Average $C_{gaseous}$ (g)	Biodegradation (%)		
			AVG	SD	REL
Cellulose	6.4	5.7	90.1	1.4	100
Flaxstic V1	8.6	1.1	12.8	1.1	14.2
with AVG = average, SD = standard deviation, REL = relative biodegradation					

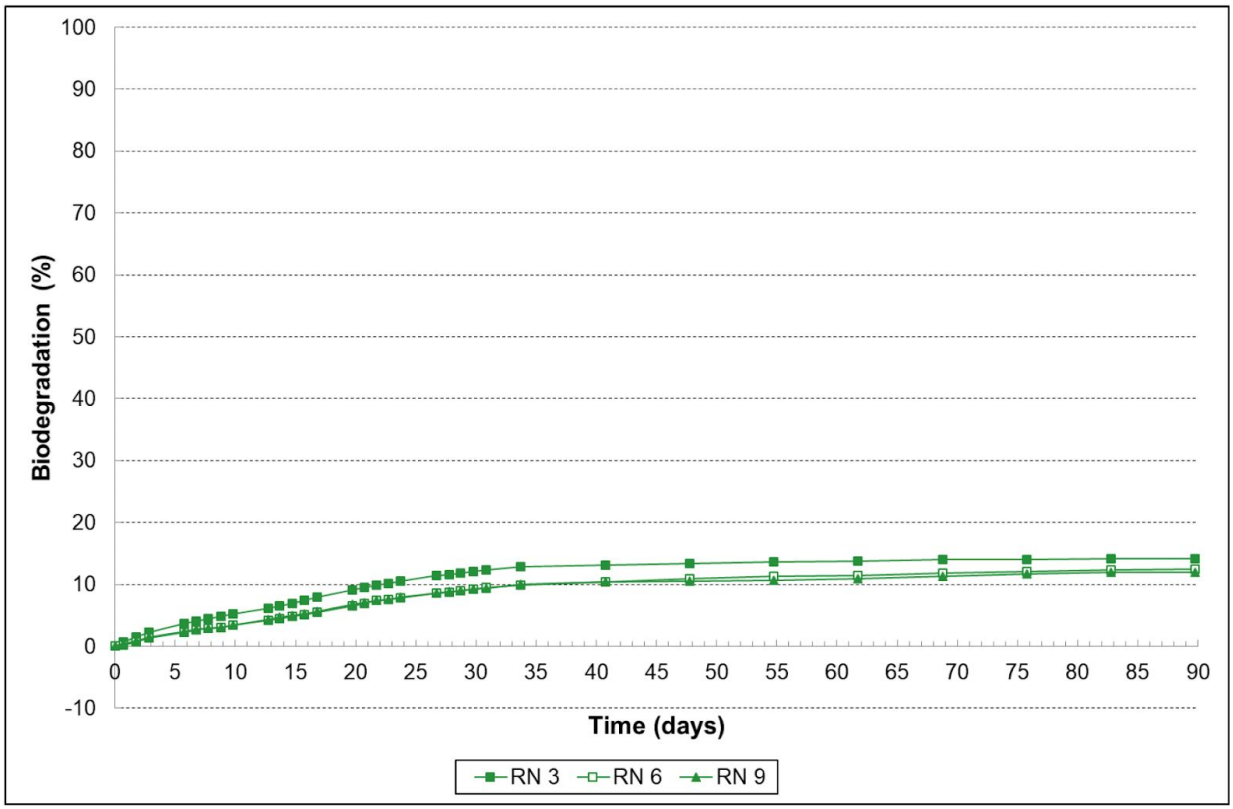


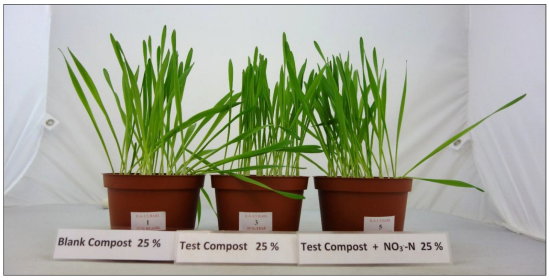
Figure 3: Evolution of anaerobic biodegradation (RN 3, RN 6 and RN 9) of Flaxstic V1 at 37°C

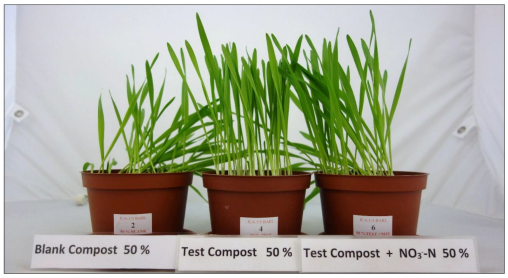
3.0 PLANT TOXICITY (ECOTOXICITY)

Phytotoxicity tests were conducted to ensure materials have no adverse impacts on the ability of the compost to support plant growth, and the materials must not introduce unacceptable levels of regulated metals or hazardous substances into the environment. The composted Flaxstic V1 material was tested to ensure there were no adverse effects on barley plants and cress plants. The results are presented below.

3.1 Toxicity Test with Barley Plants

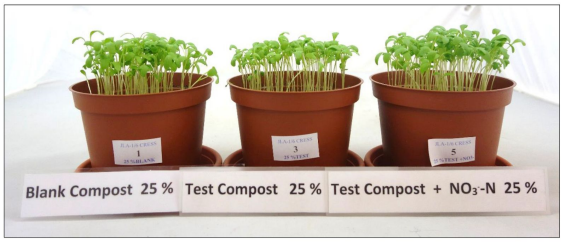
After composting Flaxstic V1 material in a 10% concentration and Black masterbatch in a 0.07% concentration, no residuals were left such as metabolites, undegraded components and inorganic components that exert a negative influence on the germination and growth of barley plants. It was concluded that the requirements of ASTM D6400 (2019), EN 13432 (2000) and ISO 17088 (2012) on ecotoxicity are fulfilled for barley plants. Photographs of the barley plant tests are presented below.





3.2 Toxicity Test with Cress Plants

After composting Flaxstic V1 material in a 10% concentration and Black masterbatch in a 0.07% concentration, no residuals were left such as metabolites, undegraded components and inorganic components that exert a negative influence on the germination and growth of cress plants. It was concluded that the requirements of ASTM D6400 (2019), EN 13432 (2000) and ISO 17088 (2012) on ecotoxicity are fulfilled for cress plants. Photographs of the cress plant tests are presented below.



4.0 DISINTEGRATION

Disintegration tests are conducted to determine if the material will disintegrate during composting such that any remaining plastic residuals are not readily distinguishable from the other organic materials in the finished product. The material or product must not be found in significant quantities during screening prior to final distribution of the industrial compost.

The EN 13432 standard notes it is not necessary that biodegradation of packaging material or packaging be fully completed by the end of biological treatment in technical plants as biodegradation can subsequently be completed during the use of the compost produced.[1]

The thickness of a biodegradable material or product is one of the main factors contributing to its disintegration rate. Thick pieces of a biodegradable material will take more time to disintegrate than thinner pieces of the same biodegradable material; however, the end results still eventually yield carbon dioxide, water, inorganic compounds, and biomass.

The existing guidelines have been developed mainly for thin films, single use packaging and disposable materials less than 1 mm thick, and not necessarily for consumer products greater than 1 mm in thickness. Studies from the international scientific community have shown there are common difficulties for biopolymers to comply with the disintegration tests and have suggested operative and cataloguing techniques (i.e. scarcely, medium and highly biodegradable and compostable plastics) to describe biodegradable and compostable materials.[2]

Pela Case V1 products made with Flaxstic V1 vary in thickness from approximately 1 mm to 3 mm; therefore, a 2.2 mm thick piece was tested to provide a baseline for predicting distinergration rates for products with a variety of thickness.

The results for field compost testing for disintegration at 40°C to 65°C, laboratory compost testing for disintegration at 28°C and benchmark testing for disintegration at 40°C to 65°C are presented below.

[1] DIN EN 13432: Requirements for packaging recoverable through composting and biodegradation - Test scheme and evaluation criteria for the final acceptance of packaging. Page 7.

[2] Common difficulties faced by biopolymers and plastics containing additives (oxo and no-oxo) in complying with the disintegration test (UNI EN 14045) (i.e. impossibility to comply with the UNI EN 13432 norm – biodegradable and compostable) Paolo. Broglio, Elena D'Adda, Simona Ramponi Ecologia Applicata srl. via A.N.Porpora, 9 -20131 Milano (Italy)

4.1 Field Composting Testing for Disintegration at 40°C to 65°C

Field tests were conducted to demonstrate the effect of product thickness, environmental conditions and time on disintegration in municipal/industrial compost piles.

Clear evidence of disintegration have been observed and documented after testing 2.2 mm thick Pela Cases V1 in a municipal compost pile (~40°C to 65°C) after 6 weeks, 12 weeks and 18 weeks. A timeline of results is presented in the photographs below. The disintegrated cases will continue to biodegrade in this municipal compost pile, will not end up as microplastics and will not lead to plastics accumulation in this environment.

After 6 Weeks

After 12 weeks

After 18 weeks

The variation between product thickness and disintegration rates have been observed and documented after testing 1 mm, 2 mm and 6 mm thick Flaxstic V1 and Pela Case V1 in a municipal compost pile (~40°C to 65°C) after 6 weeks. A comparison of results is presented in the photographs below. The thickness of the Flaxstic V1 material determines the disintegration rate and the material will continue to biodegrade in this municipal compost pile, will not end up as microplastics and will not lead to plastics accumulation in this environment.

1 mm Thick - 6 weeks

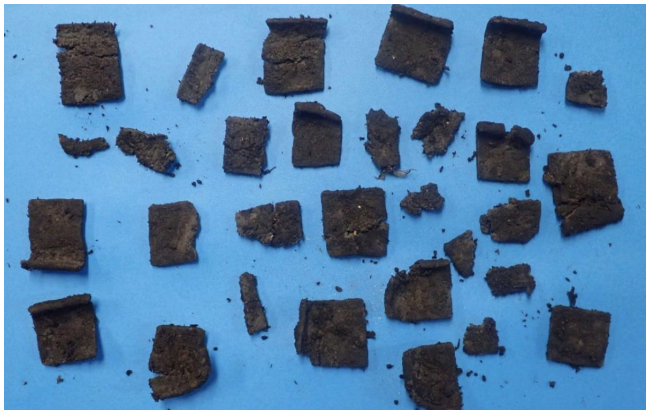
2 mm Thick - 6 weeks

6 mm Foam - 6 weeks

4.2 Compost Testing for Disintegration at Ambient Temperature (28°C)

Laboratory tests were conducted on Pela Case V1 to demonstrate the effect of product thickness, environmental conditions and time on disintegration in compost at ambient temperature.

After 30 weeks of composting at 28°C tears were observed in test item pieces at 2.2 mm tears and some pieces had fallen apart into smaller pieces, suggesting the material can disintegrate and biodegrade completely if exposed to a suitable home compost environment for up to 1 year.



After 30 Weeks

4.3 Benchmark Testing for Disintegration (40°C to 65°C)

A conventional plastic phone case was tested along with a Pela Case in the municipal compost piles for 12 weeks for benchmarking purposes. The image below shows how the Pela Case has significantly disintegrated while there is no visible degradation of the conventional plastic case (in orange).

After 12 weeks

5.0 SUMMARY

Flaxstic V1 and Pela Case V1 testing results indicate they will ultimately biodegrade into carbon dioxide, water, inorganic compounds and biomass in 3 to 12 months in a compost environment instead of hundreds of years like conventional plastic products.

The results of the internal and external testing indicate Flaxstic V1 and Pela Case V1 fulfill the evaluation criteria for material characteristics and compost quality, and fulfill the evaluation criterion for biodegradation.

The disintegration testing results demonstrate how disintegration of biodegradable materials is affected by product thickness, environmental conditions and time. Environmental conditions including temperature, moisture, pH, quantity and quality of microorganisms and the compost itself causes the biodegradation and disintegration rate to increase or decrease; therefore, the disintegration rate during biodegradation for Flaxstic V1 material and Pela Case V1 will vary depending on material thickness, environmental conditions and time.

Small or thin materials disintegrate more rapidly during biodegradation, similar to a tree trunk versus saw dust, and significant variance in disintegration rates are also observed in fruit peels. For example banana peels may take three to four weeks to decompose while orange peels may take upto six months; however, eventually both the peels (thick or thin) biodegrade to yield carbon dioxide, water, inorganic compounds, and biomass as end products.

Flaxstic V1 material and Pela products ranging in thicknesses between 1 mm and 3 mm would be classified as medium to highly biodegradable and compostable, based on suggested operative and cataloguing techniques referenced in studies from the international scientific community.

The term “compostable” means the material is capable of undergoing biological decomposition, within a specific time period, resulting in the material being visually indistinguishable from finished compost, and being broken down into carbon dioxide, water, inorganic compounds and biomass. Compost facilities are operated according to jurisdictional standards or guidelines that govern the materials that can be accepted for composting, the operation of the compost facility, and the quality of the compost product created. Any inputs into the composting process must not negatively impact the operation of a composting facility or the compost product produced.[3]

The results presented in this report indicate the Flaxstic V1 and Pela Case V1 will not negatively impact the operation of the compost facility or the compost product produced.

[3] CAN/BNQ 0017-088 Canadian Compostability Standard and Certification Protocol