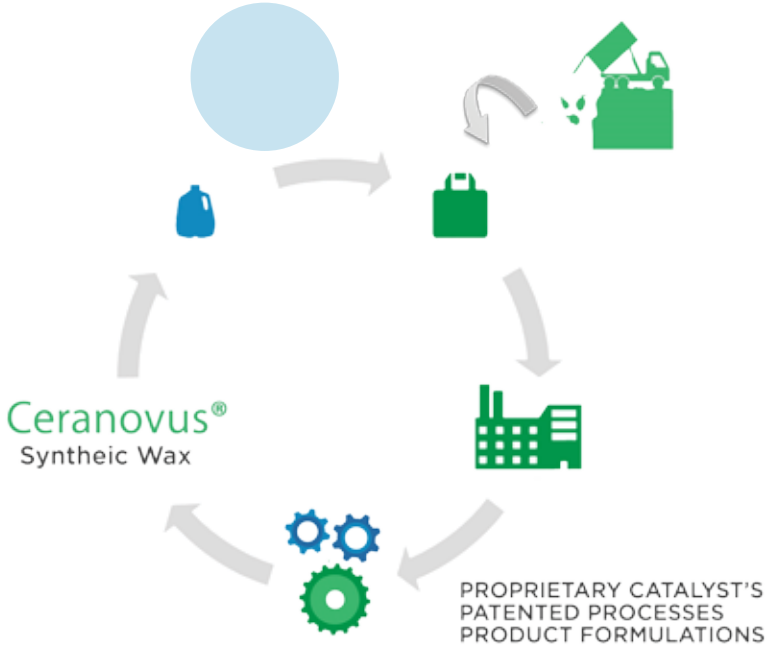
CERANOVUS™ PRODUCTS

for Polymer Processing

GreenMantra™ Ceranovus™ *Synthetic Wax Additives—Cost-Effective Performance and Process Enhancement for Recycled Plastics and Downstream Products*

Synthetic waxes from virgin sources are commonly used to assist in commercial plastics processing. They provide external lubrication for processing and can act as dispersing agents for color in masterbatch applications. However, plastics reprocessors generally omit traditional virgin wax additives despite potential benefits. Virgin waxes are too costly, lower a product's percent recycled content, and may, in some cases, be challenging to integrate well with the materials being recycled.

GreenMantra Technologies has come up with a solution: a new, patented commercial process for synthesizing waxes from recycled plastics. This is the first type of wax made with 100% waste polymers, specifically designed for cost-effective use by plastics reprocessors. Third-party laboratory testing and subsequent large-scale commercial case studies have proven benefits including energy savings, increased production throughput, reduced backpressure (for reduced equipment wear) and lower overall cost of recycled plastics production. Furthermore, unlike virgin waxes, Ceranovus™ brand waxes blend uniformly with recycled feedstock, not only preserving recycled content levels, but increasing melt flow, percentage elongation, and product strength in the final pellet or formed product.



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Third party testing confirms energy savings and throughput benefits

To determine the performance characteristics of the new wax products, GreenMantra engaged Plastics Forming Enterprises, LLC, an independent plastics consulting, research and engineering firm, to conduct testing. After initial laboratory tests suggested the new waxes were likely to succeed in achieving desirable recycled plastics processing benefits, Plastics Forming Enterprises initiated a commercial-scale study, with technical assistance from extrusion manufacturer Starlinger. The goal was to assess how the addition of GreenMantra's Ceranovus A120 wax would impact processing and the final pellet of formed product. The wax was blended with post-consumer recycled (PCR) high-density polyethylene (HDPE) natural bottle flake—a common recycling feedstock—and processed on typical Starlinger commercial extrusion equipment. The resultant reprocessed pellet and subsequent injection-molded or extrusion-blown products were then evaluated.

Fig. 1: Natural post-consumer HDPE bottle flake

For the trial runs, the test material was introduced to the flake blend at the screw. Temperature was maintained at 248-250°C throughout. Back pressures, energy usage, screw speed and pounds of product per hour were recorded. Differences in pressure, energy usage and throughput were calculated, relative to the control. Melt flow properties of the resultant pellet were measured with a melt rheometer.

The first trial compared the performance of HDPE flake with 0% (control), 2% and 4% A120 in a steady-state extrusion at a constant screw speed of 125 RPM. Results are shown in Table 1. Addition of the novel wax product increased melt flow by 30-40% in the final pellet. With the unchanged screw speed, throughput was essentially constant. However, adding the wax had a significant beneficial effect on back pressure, which decreased up to 11%, correlating to less wear and tear on equipment. In addition, the resultant decrease in back pressure resulted in a decrease in energy usage of 15-20%, which could be expected to reduce energy costs.

Table 1: Recycled plastic processing effects of adding Ceranovus A120 wax to PCR HDPE. Trials ran 3 hours at constant temperature to allow for stabilization. In this phase of the test, screw speed was held constant while A120 wax was added at 2 to 4% with respect to the flake at around 290 lbs/hr. Note the relative increased melt flow, decreased backpressure and decrease in kilowatt usage and cost per pound.

% Wax & Screw RPM	0% Control 125 RPM	2% Test 125 RMP	4% Test 125 RPM
Temperature (˚F)	249	250	250
Fractional Melt Flow	0.47	0.62	0.67
Melt Flow (% rel. to Control)	N/A	32%	42%
Average Pressure (PSI)	1769	1595	1566
Pressure (% rel to Control)	N/A	-10%	-11%
Average Energy Usage (kW/hr)	68.5	54.7	58.9
Energy Usage (% rel. to Control)	N/A	-20%	-14%
Average Throughput (lbs/hr)	289	293	285
Throughput (% rel. to Control)	N/A	1.4%	-1.0%
Energy Use per Pound (kW/lb)	0.237	0.187	0.207
Cost Change (% rel. to Control)	N/A	-21%	-13%

In the second set of trial runs, test material was fed at a rate that would stabilize the extruder at the same average back pressure as the control run—ie around 122 bars. Results are shown in Table 2. Maintaining a set pressure kept the energy usage near constant. In this case, however, the ability to increase screw speeds allowed for a significant increase in throughput—up to 28%.

Table 2: Recycled plastic processing effects of adding Ceranovus wax to PCR HDPE. In this phase of the test, backpressure was held essentially constant while % wax was increased. Note the relative increases in melt flow and throughput, and the decrease in energy cost.

% Wax & Screw RMP	0% (Control) 125 RMP	2% Test 165 RPM	4% Test 170 RPM
Temperature (°F)	249	248	248
Melt Flow Index	0.47	0.63	0.63
Melt Flow (% rel. to Control)	N/A	34%	34%
Average Pressure (PSI)	1769	1827	1798
Pressure (% rel. to Control)	N/A	3.3%	1.6%
Average Energy Usage (kW/hr)	68.5	72.4	70.3
Energy Usage (% rel to Control)	N/A	5.7%	2.6%
Average Throughput (lbs/hr)	289	366	370
Throughput (rel. to Control)	N/A	27%	28%
Energy Use per Pound (kW/lb)	0.237	0.198	0.198
Cost Change (% rel. to Control)	N/A	-16%	-20%

Fig 2: Natural HDPE flake reprocessed to pellet using Ceranovus A120 wax

Overall, energy, pressure and throughput enjoyed a direct benefit from the addition of the novel wax additive. When processing at a constant screw speed, adding this wax resulted in an energy benefit, reduction in equipment wear, and an increase in melt flow. Higher speed processing with the same approximate energy consumption achieved an output benefit and maintained the same increase in melt flow. Of note, maintaining, as opposed to increasing RPM processing speeds, may offer an advantage in that the material and additive have more time to blend with increased residence time in the screw.

Further testing demonstrates performance benefits for pellets and parts

Processing gains are beneficial only if the quality of the end-product is maintained. To determine the impact of Ceranovus waxes on end-products such as injection molded parts and extrusion blown bottles, parts and bottles made with plastic that contained the wax were evaluated.

The injection molded parts test data is shown in Table 3. Melt flow rates have increased in parts containing A120 wax compared to the control, as seen with pellet samples. This is an expected result due to the external lubrication of the added wax, which reduces the degree of crosslinkage occurring at the interface between the polymer and barrel or mold. The 0%, 2% and 4% wax-content samples exhibit similar moisture levels and densities. Izod impact testing, flex modulus and tensile strength also show comparable results, with slight improvements in each parameter compared to the control. The percentage elongation for the sample containing 2% wax registers a 19% increase and, for the 4% sample, a 62% increase over the control. It is suspected that this improvement is related to the internal lubrication and blending of the A120 wax additive with the polymer matrix. Overall, these results demonstrate the beneficial effect of adding the novel wax product, for the extrusion of plastic parts.

Table 3: Injection molded parts test data for pellets and bottles with 0%, 2% and 4% Ceranovus A120 wax content.

% Wax	0%	2%	4%
Pellet Melt Flow Rate	0.4	0.63	0.63
Part Melt Flow	0.38	0.53	0.53
Volatile (%)	0.008	0.008	0.008
Density	0.949	0.94	0.949
Izod (lbf-ft-in)	10.20	11.44	10.20
Flexural Modulus (PSI)	164447	168343	166538
Tensile @ Yield (PSI)	3805	3921	3921
Elongation Average	374%	444%	607%
% Elongation Increase (rel. to Control)	N/A	19%	62%

Fig. 3: Blow molded bottle produced from pellet reprocessed with Ceranovus A120 wax

Extrusion blow-molded bottles were made with reprocessed pellets containing 0%, 2% and 4% A120 wax, under identical process conditions. The experimental bottles were drop-tested. Results are shown in Table 4 and demonstrate a reduction in breaks/failures by 50% and 100% in the bottles containing 2% and 4% A120 wax, respectively.

Table 4: Bottle drop test results for bottles with 0%, 2% and 4% experimental wax content.

0% Wax Content (Control)

Height (ft)	Bottle Number																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
5	X																			
6		X																		
7			X																	
8				X																
9					X															
10						X														
11							X						X		X					
12								X	X	X	X	B		B		X	X	X	X	X

Note: #12 Break at bottle thread, #15 Break base seam pin hole

2% Wax Content

Height (ft)	Bottle Number																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
5	X																			
6		X																		
7			X																	
8				X																
9					X															
10						X														
11							X				X									
12								X	X	B		X	X	X	X	X	X	X	X	X

Note: #10 Break base corner slit

4% Wax Content

Height (ft)	Bottle Number																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
5	X																			
6		X																		
7			X																	
8				X																
9					X															
10						X														
11							X													
12								X	X	X	X	X	X	X	X	X	X	X	X	X
12								X	X	B		X	X	X	X	X	X	X	X	X

Note: No Breaks

Multiple value opportunities for reprocessors using GreenMantra's wax technology

It seems clear, then, that this new type of wax additive potentially offers significant processing and end product benefits for plastics re-processing. But how can recyclers best take advantage of the value opportunities this technology offers?

GreenMantra Technologies teams up with interested plastics reprocessing businesses in a number of ways, often dependent upon the size of the process. The most straightforward option is for a business to simply blend GreenMantra Ceranovus wax pellets into their own feedstock.

For larger plastics reprocessors, GreenMantra can use the company's own typical feedstock to produce a custom wax. Even traditionally hard-to-recycle materials such as films—for instance, plastic bags and agricultural film—may be used. The resultant wax will blend perfectly into the mix. The target result is up to a 30% increase in throughput, increasing margins and decreasing total processing costs. A throughput improvement of even 10% or a 10% energy savings could have a significant effect on the bottom line.

For an even larger reprocessor, GreenMantra Technologies also offers co-location services. The small footprint of the manufacturing process enables the company to locate a wax manufacturing unit on the reprocessor's premises, providing an ongoing and cost-effective source of wax tailored to the reprocessor's requirements.

Summary

GreenMantra Technologies offers several avenues whereby plastics reprocessors can benefit from a novel, patented technology utilizing 100% recycled materials. This cost-competitive wax blends well with the feedstock being recycled and increases melt flow. Commercial-scale, third party testing has shown that blending this type of wax into the feedstock at a rate of 2% can:

- Reduce backpressure, decreasing energy use by 10%, resulting in energy savings and lower equipment wear.
- Achieve as much as a 30% increase in throughput using the original, control pressure.
- Maintain or improve end-product performance: 30-40% increase in melt flow, 20-60% increase in elongation, and 50-100% fewer breaks/failures in product forming.

For plastics reprocessors, these new waxes synthesized from recycling feedstocks solve the problems associated with the use of virgin synthetic waxes and offer numerous advantages—including lowering the overall cost of recycled plastics processing.