Compostability of petroleum wax-based coatings

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ABSTRACT: Composting is an important aspect of solid-waste management. Results of one independent study and a second continuing study demonstrate that waxed packaging may be composted to produce a high-quality end product with certain limitations on the proportions of materials which comprise the compost mixture. Contaminants from packaging material are the main constraints to compost quality. There are suggestions for developing readily compostable packaging.

KEYWORDS: Carbon, coatings, composites, compost, design, evaluation, formulations, packaging materials, paraffin wax, sources.

The composting process is a crucial component of the recycling strategy to reduce North America's reliance upon landfills for solid-waste disposal. This is important for paper and paperboard packaging treated with moisture-proofing agents because these components create special problems in existing recycling facilities (*1*). There is particular pertinency to single service items such as sandwich wraps and drinking cups which are heavily contaminated with foodstuffs and are difficult to segregate.

As the infrastructure for composting develops on a commercial scale, the success of the program will largely depend upon the markets available for the compost product. The quality of the compost will in turn dictate the suitable outlets.

For the past 18 months, IGI International Waxes Division has sponsored studies at McGill University and the University of Guelph as well as internally to evaluate composting of waxed packaging. This paper presents the results of these studies, particularly the impact of the packaging components on the composting process and product.

Wax biodegradability

The results of a 1988 test of petroleum waxes and wax-based coatings for evaluation of biodegradability by ASTM G21 and G22 procedures yielded a growth rating of 4, which is the highest possible category (*2*). This indicated that these materials can support the growth of degradation organisms.

In 1990, TNO laboratories in Holland under the aegis of the European Wax Federation published the results of an extensive study showing that paraffin waxes and paraffin-based coatings are inherently biodegradable according to Organization for Economic Cooperation and Development (OECD) Guideline 301B (*3*). The studies revealed greater than 60% degradation after 28 days and nearly complete degradation by the end of an 84-day test. In addition, a study of the fate of waxed paper in a woodland litter layer natural site indicated a complete degradation in 3–6 months. This matches the decomposition rate of natural leaf litter (*4*). Microcrystalline waxes showed much slower degradation, however.

McGill University study

The intent of a study at McGill University to evaluate the compostability of waxed corrugated containers was to determine under what conditions waxed boxes could be composted and the impact of wax on compost quality. Corrugated boxes using both a saturation process and a curtain coating process for wax application were prepared. The coating in the saturation case contained primarily paraffin waxes with small amounts of microcrystalline and polyethylene wax. The curtain coating material contained paraffin wax, microcrystalline wax, poly(ethylene vinyl acetate) (EVA), and a hydrocarbon resin.

Procedure

The corrugated boxes were hammermilled into pieces approximately 3 cm^2. The ingredients indicated in **Table I** show the basic formula with varying levels of waxed board and differing nitrogen sources and inocula mixed and formed into cylindrical piles of a minimum of one cubic meter in size. Seven different treatments as shown in the table were composted using the

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static pile procedure. The piles were turned weekly. The composting proceeded over the summer period for 92 days. The process was monitored by temperature measurements at various levels as well as by the evaluation of physical properties such as appearance, odor, etc. The completed compost was analyzed for stability, nutrient content, contaminants, and wax content. A bioassay of the compost consisted of a germination test and a growth experiment. Both of these were performed using barley. The quality of the compost was compared to Province of Ontario Ministry of the Environment proposed guidelines.

Results

All the compost mixes showed a temperature increase from ambient to 60–75°C within 7 days except for the material containing a high corrugated level which reached 60°C after 12 days.

Composting proceeded readily. After 42 days, the piles had completely changed in appearance to a dark brown, crumbly material. The compost was allowed to mature for an additional 50 days. Then it was tested for stability, wax degradation, nutrient levels, contaminants, moisture holding capability, and bioassay.

As can be seen in **Table II**, the wax had degraded 100% or almost that level in the mixes with the exception of the high wax mixture (HCC). The acceptable maximum standard of 40% total volatile solids was met in all cases indicating good compost stability. Nutrient levels of nitrogen, phosphorus, potassium, and magnesium exceeded the minimum requirements. Calcium was below the guidelines except for the low wax mix (LCC).

Results of the bioassay indicated good germination rates of the barley seedlings in all composts with no significant differences between them. Mixtures of garden soil and compost were prepared over a complete range of composition. As seen in **Fig. 1**, the barley showed good growth in the media with the composts contributing significantly to the growth. The material with a high corrugated content showed lower yields as seen in **Fig. 2**, however. There were some toxic effects which have been attributed to boron whose presence is discussed below.

Impact of wax on composting

The duration of the thermophilic or heating phase of the composting process varied directly with the wax content. This is a potential benefit since a high temperature phase is important to ensure the death of harmful organisms. The wax can plainly serve as an energy source for the degrading organisms.

At the high level of corrugated, some temperature fluctuation was noted. This was probably due to inadequate air circulation and moisture retention. Additional time was also required for stabilization. Superior grade compost can probably be obtained by maintaining the wax content below 16% by weight. Finer particle size as well as good air circulation and moisture control such as is achieved with "in-vessel" composting could help to reduce any delay.

Effect of coating ingredients on composting

The paraffin wax component of the saturation waxed corrugated board was rapidly and almost completely degraded. There was no further analysis work undertaken for this system.

Due to the presence of EVA, hydrocarbon resin, and microcrystalline wax in the curtain coating composition, additional testing was initiated to try to determine the amount of degradation of these components. Although decomposition of the wax fraction was essentially complete, a small residue was extracted and analyzed by gas chromatography. **Figure 3** depicts these results. Preferential decomposition of normal hydrocarbons, particularly those shorter than 25 carbon numbers, was quite apparent. This is consistent with the European findings of preferential biodegradation for low molecular weight components. That work also reported equal degradation of normal and isomeric hydrocarbons.

The polymer and resin components were evaluated by size exclusion chromatography as shown in **Fig. 4**. These results confirmed the degradation of almost all the wax components. By comparison, there appeared to be little or no decomposition of the higher molecular weight resin and EVA fractions. Unfortunately, quantitative analysis of these materials was not possible due to interferences. There is a suggestion that some types of resins may inhibit biodegrada-

I. Compost composition

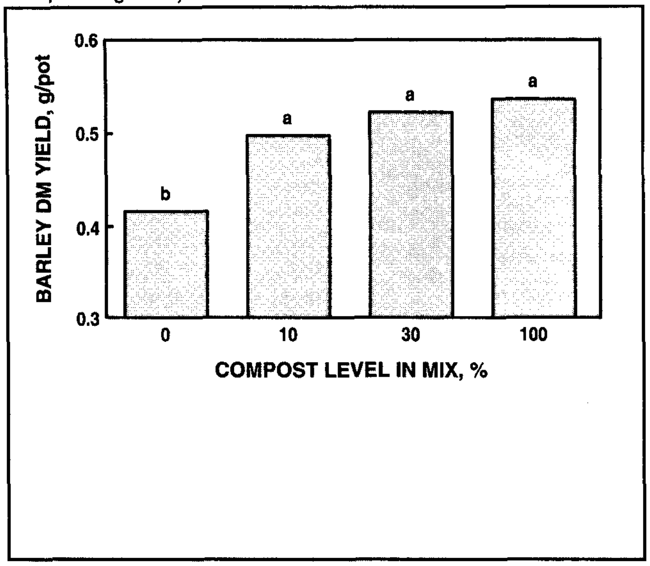
Basic formula	*% Dry weight*
Waxed corrugated (WC)	51
Hay	18
Liquid dairy manure (LDM)	12
Feather meal	5
Peat moss	8
Compost	6

CTL: 51% saturation waxed corrugated
HCC: 69% saturation waxed corrugated
BDI: CTL with biodynamic inoculum
EBI: CTL with ecobac inoculum
SSN: Sewage sludge nitrogen source with no LDM
CCC: 50% curtain coated corrugated
LCC: 34% saturation waxed corrugated

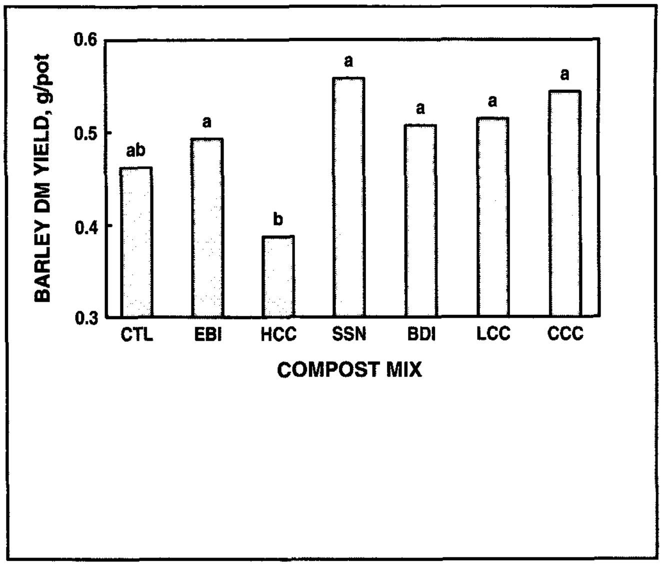
II. Degradation of wax and total volatile solids (TVS) in WC mixes after 92 days of composting

Compost mix	*Initial % wax*	*% Wax degradation*	*% TVS*
CTL	23	97	75
EBI	23	97	73
HCC	31	90	72
SSN	23	96	73
BDI	23	95	72
LCC	16	98	68
CCC	11	100	72

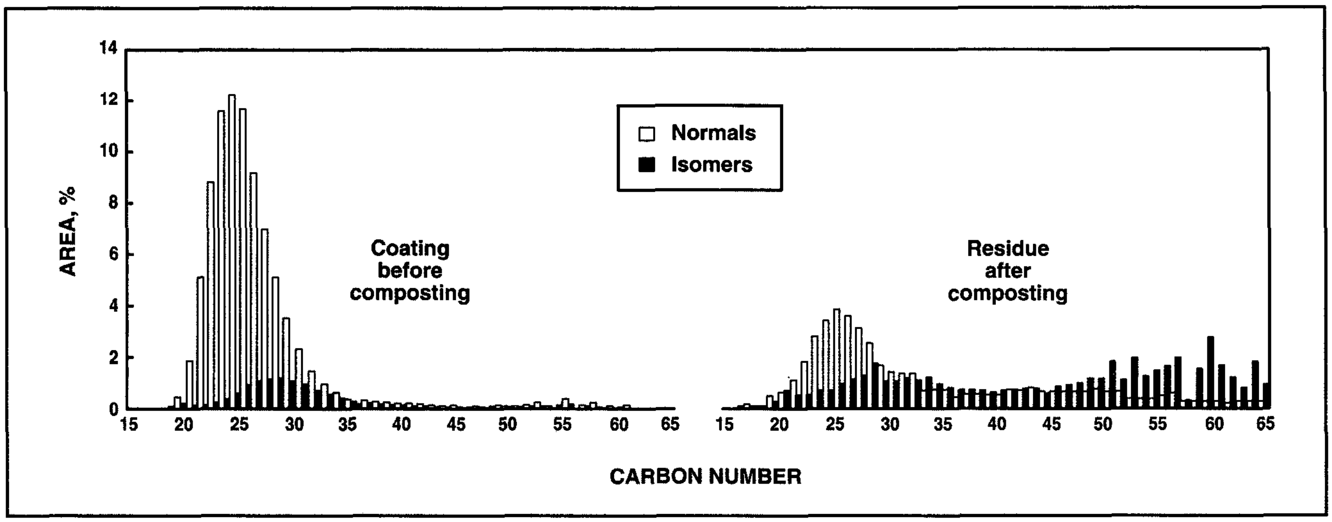
1. Dry matter (DM) yield of barley after 21 days in 4 levels of WC compost mixed with soil (Bars capped with the same letter are not significantly different at $p \leq 0.05$ confidence level using Duncan's multiple range test)



2. DM yield of barley after 21 days in 7 WC compost mixes (Bars capped with the same letter are not significantly different at $p \leq 0.05$ using Duncan's multiple range test)



3. Gas chromatographic analyses



tion in wax coatings (*5*), but C_5 aliphatic resins are innocuous in this regard.

Impact of other packaging components.

The other packaging components were not studied directly for their impact on composting. Some contaminants were nevertheless of concern to the product quality as shown in **Table III**. Note that the concentrations in the table are given as leachate and may not reflect the true content.

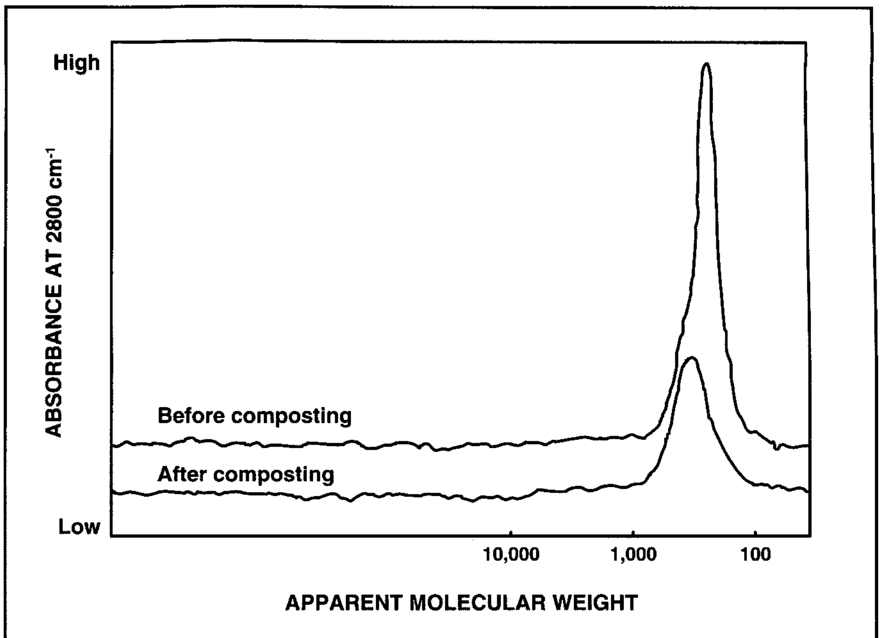
High levels of contaminants in the SSN mix are attributable to the sewage sludge. Of more concern are the high copper levels in all mixes. These may have come from the blue printing ink used on the corrugated boxes. The source of the molybdenum has yet to be ascertained. Atomic absorption analysis, however, has indicated that it is not present in the corrugated stock.

Although no limits have been set by the Ontario Ministry of the Environment for boron content, the boron levels encountered were high. The boron originated as borax which is added to the starch-based adhesive applied on the corrugator. Although boron is a plant micronutrient, levels of boron approaching 100 ppm may have deleterious effects on plant growth. At higher levels of 1000–2000 ppm, boron can terminate the composting process completely. Fortunately, boron is readily washed out of the compost. Thus it could possibly provide an advantage for the boron deficient soils which occur in northeastern North America.

University of Guelph study

In this continuing study, commercial waste streams from a fast food restaurant containing foodstuffs, waxed papers, waxed cups, and other packaging materials are being evaluated for compostability. The study compares over-the-counter waste stream treatment, behind-the-counter waste stream treatment, and a nitrogen amendment waste stream treatment using poultry manure. The preliminary results indicate that the waste streams are compostable, but the process rate is slow. This is due in part to poor water retention caused by the high proportion of water resistant materials as well as inadequate commingling of the carbon source (packaging) and nitrogen source (foodstuffs). These problems could be readily alleviated by improved comminution and mixing.

4. Size exclusion chromatographs



III. Level of toxic substances present in WC final composts: heavy metals, boron, and PCBs in ppm

Parameter	*CTL*	*EBI*	*BDI*	*SSN*	*HCC*	*LCC*	*CCC*	*Limit*[a]
As	0.50	0.50	0.60	1.20	0.46	1.80	0.54	10.0
Cd	0.07	0.07	0.21	1.20	0.13	0.14	0.18	3.0
Cr	23.4	23.46	23.5	43.5	22.4	30.0	19.4	50.0
Co	3.6	4.0	3.5	3.7	3.3	5.2	2.9	25.0
Cu	48.6	61.6	62.0	300.0	48.5	47.0	36.4	60.0
Pb	10.1	9.7	10.2	30.0	8.6	23.5	6.5	150.0
Hg	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.15
Mo	2.2	2.2	1.75	3.3	1.3	1.9	1.8	2.0
Ni	11.5	10.8	10.9	17.2	10.2	16.0	9.4	60.0
Se	0.04	0.04	0.04	0.66	0.03	0.05	0.04	2.0
Zn	162.0	185.0	157.0	96.0	150.2	161.7	141.5	500.0
Boron	90.4	94.0	83.0	84.5	82.2	126.0	99.0	-
PCB	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.5
Mm[b]	36.0	36.0	35.0	41.0	33.0	47.0	36.0	-

[a] Ontario Ministry of the Environment limit values from "Interim guideline for the production and use of aerobic compost in Ontario," 1991.
[b] MM = total mineral matter content, %

Conclusions

Properly formulated waxed packaging can be used as a carbon source to produce a superior quality compost, although there are some content limitations. Waxes are unique as coating materials because they provide excellent moisture barrier properties. Since they are not polymers, they are inherently biodegradable.

Some key factors have been identified for designing a compostable paper package as follows:

- Minimize the metal content in the package especially through the proper selection of printing inks.
- Choose biodegradable adhesives and minimize borax use in aqueous products.
- Select low molecular weight paraffins as water-resistant, wax-based coatings because these are biodegradable and compost most readily.

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