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Project Summary

Life Cycle Design of Milk and Juice Packaging

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A life cycle design demonstration project was initiated between the U.S. Environmental Protection Agency–National Risk Management Research Laboratory, Dow Chemical Company, and the University of Michigan to investigate milk and juice packaging design. The primary objective of this project was to develop design metrics and guidelines for environmental improvement of milk and juice packaging systems. Material production energy accounted for a large portion of the total life cycle energy for these systems. Conversely, post-consumer waste was responsible for a majority of their life cycle solid waste generation. Packaging systems were also evaluated with respect to key performance criteria, life cycle costs, and regulatory trends at the local, state and national levels. Environmentally preferable containers were identified, and tradeoffs and correlations between design criteria were highlighted.

This Project Summary was developed by EPA's National Risk Management Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Integration of environmental considerations into the design process represents a complex challenge to designers, managers and environmental professionals. A logical framework including definitions, objectives, principles and tools is essential to guide the development of more ecologically and economically sustainable product systems. In 1991, the U.S. Environmental Protection Agency collaborated with the University of Michigan to develop the life cycle design framework. Using this framework, environmental, performance, cost and legal criteria are specified and used to investigate design alternatives.

A series of demonstration projects with Dow Chemical Company, Ford Motor Company, General Motors Corporation, United Solar and 3M Corporation have been initiated with Cleaner Products through the Life Cycle Design Research Cooperative Agreement. Life cycle assessment and life cycle costing tools are applied in these demonstration projects in addition to establishing key design requirements and metrics. This is a summary report of the Dow Chemical packaging project that investigated the life cycle design of milk and juice containers.

Project Description

This study considered the life cycle aspects of both milk and juice packaging for sale to households. Packages used for the delivery of fresh dairy milk and/or reconstituted orange juice were selected for study. Systems for delivering milk and juice to on-site users, such as school lunch programs, were not included in this study. Additionally, this study did not address impacts associated with beverage production.

A total of nine different container types were included in this study. Glass bottles, HDPE bottles, paperboard gable-top cartons, flexible pouches, polycarbonate bottles, aseptic cartons, PET bottles, steel cans, and composite cans were studied using previously published life cycle inventory data. Many of these containers were included with various sizes, refill rates, and recycling rates in the study. Although complete inventory data were not available for PET bottles, steel cans, or composite cans; these containers were only partially analyzed based on data availability.

In order to compare containers on an equivalent use basis, a functional unit of 1000 gallons was selected. All criteria were evaluated based on quantities necessary to deliver 1000 gallons to the consumer.

Although both juice and milk containers were included in all aspects of the study, for some categories, only results for milk containers are presented in this summary since more complete information was available for these containers.

Results

A multicriteria analysis of the performance, cost, environmental, and regulatory issues influencing each container system was conducted. The scoring table, (Table 1) summarizes the results of this analysis. In this table the life cycle data are normalized to arrive at life cycle scores ranging from 0 (best) to 10 (worst). Scores represent the ratio of the data for a specific container relative to the highest reported value in the same category. A complete explanation of the scoring system is contained in the full report. The following sections briefly examine each assessment category. Scores based on energy use and solid waste data were averaged to determine the total environmental score.

Environmental

Energy Use

Total life cycle energy for selected containers is shown in Table 2. Material production energy is also shown for these containers when known.

Our analysis indicated a key design trend in the container systems; material production accounted for a majority of the life cycle energy. On average 91% of milk container life cycle energy was consumed in the material production process, and 85% of juice container energy was used in material production.

Solid Waste

For each container system the published life cycle solid waste was collected and post-consumer solid waste data were calculated based on container mass. Total life cycle solid waste values reported include waste from industrial processing in addition to post-consumer waste. Our analysis indicated that for both milk and juice packaging, post-consumer solid waste accounts for approximately 80% of total life cycle solid waste. Both post-consumer and life cycle waste can be greatly affected by changing refill rates and unit container size.

The one-gallon, 50-trip refillable HDPE bottle generated the least solid waste over its life cycle (4 kg/1000 gal). In contrast, the single-use, one-liter glass bottle generated the greatest mass of life cycle solid waste (1220 kg/1000 gal).

Table 1. Milk Container Evaluation

Container Type	Energy Use	Solid Waste	Total Environmental*	Cost	Performance	Overall**
Flexible Pouch	2.1	0.14	1.1	1.1	6.2	2.8
Gable Top Carton	10.0	1.1	5.6	1.8	5.0	4.1
Glass Bottle						
refillable	4.9	1.1	3.0	1.2	10.0	4.7
single use	8.8	10.0	9.4	10.0	7.5	9.0
HDPE Bottle						
refillable	2.9	0.05	1.5	0.7	3.8	2.0
single use	9.7	0.55	5.1	3.4	1.2	3.2
Polycarbonate	3.3	0.04	1.7	1.0	5.0	2.6

Each energy use, solid waste and cost rating is based on data from the full report, using a scale form best to worst of 0 - 10, where the highest energy, waste and cost data for the selected containers receive a 10 and all other data normalized to this point; performance ratings convert the subjective evaluations in the full report to numerical values.
* Total environmental score is the average of energy use and solid waste.
** Overall score is an average of total environmental, cost and performance.

Table 2. Energy Use, MJ/1000 Gal Delivered

Container	Trippage	Total LIfe Cycle	Material Production
Glass Bottle			
refillable	20	3900	1910
single use	-	7000	
HDPE Bottle			
refillable	50	2320	470
single use	-	7720	6930
Gable Top Carton			
single use	-	8000	
Polycarbonate			
refillable	40	2630	1020
Flexible Pouch			
single use	-	1700	1550

Airborne/Waterborne Emissions

Due to the fact that emissions data were available for only a limited number of containers and these data were highly variable, emissions data were not used in evaluation. Both airborne and waterborne emissions are reported, where available, in the full report.

Cost

Costs representative of the life cycle of each container product were determined from published information and industry sources. The costs of seven processes/stages in the container life cycle were summed to arrive at the total life cycle container cost. These costs were: empty container, transportation (fuel use), filling equipment, municipal waste collection, recycling, incineration, and landfill disposal. These costs are shown in Table 3. In this table, waste collection, recycling, incineration, and landfill disposal costs are combined to give the End-of-Life cost. Complete cost data appear in the full report. Costs for milk and juice containers were evaluated using the same method.

The price of empty containers accounts for the majority of total life cycle costs as calculated by the NPPC. For the container systems examined empty container cost represented 75% of the total on average. Costs for refillable container systems are less dependent on empty container costs than single-use systems.

Performance

Performance requirements for beverage packaging were determined with a multiple-step process. First, a literature search was conducted to determine which physical characteristics and other properties influence beverage retailers and consumers. Next a set of six performance measures were chosen based on their apparent importance. These criteria are clarity, burst/shatter resistance, ease of opening, weight, resealability, and necessity of storing empties.

Each container was then subjectively evaluated for the six performance measures and ranked as follows: good (+), neutral (0) or poor (-). Using this ranking the performance measures were weighted equally to determine overall performance. Additional market research would be necessary to establish more accurate weighting factors.

Two containers for both milk and juice were determined to have a good overall ranking. The single use HDPE bottle was the only container to receive a good ranking overall for use with both milk and juice. Of the milk containers, refillable HDPE was the only other container to receive a positive ranking overall. The only other juice container to receive a positive ranking was the PET bottle. The refillable glass bottle received a poor performance ranking overall for use in both milk and juice packaging.

Legal

A complex set of legal requirements exist for milk and juice packaging in the US and other countries. These requirements vary substantially and have impacts throughout the life cycle. Legal requirements detailed in the full report are grouped into five categories: fees and taxes, municipal/state/federal goals, bans and mandates, recycling/waste minimization requirements, and manufacturer requirements. Different packages and materials might be favored under some of the regulations, but none of them optimally meet every requirement. In general, current regulations target post consumer waste, however, the trend is toward broader more flexible packaging laws.

Design Guidelines

Simplified guidelines for evaluating the environmental performance of milk and juice packaging were developed based on analysis of previous life cycle inventory studies. The following guidelines were proposed to address life cycle energy and life cycle solid waste issues in packaging design and management.

1. Life cycle energy can be approximated by computing the material production energy of the package. For this reason, less energy-intensive materials should be encouraged along with less material-intensive containers. For refillable containers, high refill rates should be achieved to best exploit the initial energy investment in the production of the container.

2. Life cycle solid waste is largely determined by post-consumer packaging waste; consequently less material-intensive containers in general should be emphasized. The full report details the analysis done and the conclusions drawn from this analysis.

Conclusions

This project used the life cycle design framework and tools to develop environmental and cost metrics for guiding milk and juice packaging design. In addition, analysis of milk and juice container systems highlighted both tradeoffs and some consistent patterns among criteria and metrics. Refillable HDPE and polycarbonate bottles and the flexible pouch were shown to be the most environmentally preferable containers with respect to life cycle energy and solid waste criteria. These containers were also found to have the least life cycle costs. The strong correlation between least life cycle cost and least life cycle environmental burden indicates that the market system is encouraging environmentally preferable containers in these cases. In other cases, significant externalities (environmental burdens) not reflected in the market system may create a barrier for market penetration of an environmentally preferable container.

Table 3. Cost, $/1000 gal delivered

Container	Trips	Empty Container	Transportation/Filling	End-of-Life	Total LC
Glass Bottle					
refillable	20	$64.00	$37.37	$14.14	$115.51
single use	-	$773.00	$24.40	$171.39	$968.79
HDPE Bottle					
refillable	20	$45.00	$23.73	$1.21	$69.94
single use	-	$300.00	$19.97	$8.27	$328.22
Gable Top Carton					
single use	-	$132.00	$21.43	$21.13	$174.56
Polycarbonate					
refillable	40	$70.00	$23.52	$1.00	$94.52
Flexible Pouch					
single use	-	$80.00	$19.83	$3.41	$103.24

End-of-Life = recycling, incineration, and landfill disposal

Several performance criteria present potential barriers to otherwise preferable containers. For example, containers that require significant changes in merchandising and/or consumer practices may encounter market resistance. In the case of refillable containers, merchants must accommodate returns of refillable containers while consumers must be responsible for rinsing and returning them to the grocery store. In the case of the pouch, performance issues must be addressed in order to achieve successful market penetration. A pitcher, which must be cleaned periodically, is required to hold the pouch and facilitate pouring and storage. Thus, although this system is currently popular in Canada, both the pouch and refillable bottles exhibit clear performance tradeoffs. Public education about the environmental merits of these systems is required to influence their acceptance.

Based on the findings of this study and other life cycle assessments, regulations should be reviewed to encourage more environmentally preferable packaging. Regulations that support post-consumer solid waste minimization should be encouraged, but they should not prohibit systems such as the flexible pouch which are among the most environmentally preferable container systems.

Dow's overall objective in this project was to use the life cycle design framework as a method of enhancing their strategic planning capabilities for producing and marketing milk and juice packaging resins. Dow's participation in this project demonstrates how a material supplier can take a proactive role in life cycle management of its products. Their efforts in life cycle design enable the company to partner with their customers (package fabricators) in a more effective way to both enhance environmental performance and economic success. Partnerships are particularly valuable in addressing the complex parameters that affect multiple stages of a product life cycle.

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The complete report, entitled "Life Cycle Design of Milk and Juice Packaging," (Order No. PB98-100 423; Cost: $25.00, subject to change) will be available only from:
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