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A COMPARISON OF METHODS FOR EVALUATING "ENVIRONMENTAL CHOICE" PACKAGING*

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ABSTRACT

Determining "environmental choice" products within product categories is not always obvious, and formal life cycle assessment is rarely possible for solid waste educators. Three more streamlined packaging evaluation methods and the practice-based assessments of a waste reduction educator are compared in evaluating product choices in dishwashing liquid, fabric softener, cranberry juice, pancakes, and soup. The Cornell method includes weight and volume-based measures, with an adjustment for local recyclability of packaging materials, and a transportation efficiency measure. The Tellus method assigns "environmental costs" based on the unadjusted weight of packaging waste, while the CONEG method entails qualitative application of "preferred packaging guidelines." The methods ranked products within categories similarly when choices involved different sized versions of the same packaging materials. They disagreed when product choices involved different packaging materials, not all of which were locally recyclable. Recommendations include more development of source reduced, recyclable packaging containing concentrated products.

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Everyday purchasing decisions made by consumers have important implications for reducing solid waste and saving energy. With today's dizzying array of consumer products, functionally similar products are often packaged quite differently or are more or less durable, so that one choice generates substantially more waste than another. Yet while in some cases identification of the "environmental choice" seems quite obvious, in others, it is less clear how to balance trade-offs between waste reduction and recycling in determining what is the "environmental choice."

In this article, we discuss why formal life cycle assessment remains an unrealistic tool for environmental educators and waste management practitioners seeking to promote environmental shopping. As an alternative, we compare three simpler, cheaper methods that have been used for evaluating products in conjunction with a project on Waste Reduction through Consumer Education conducted in New York State. To these methods, we contrast the practice-based assessments of an experienced waste reduction and recycling educator.

LIMITATIONS OF LIFE CYCLE ASSESSMENT

The appeal of "environmentally friendly" consumer products has widened, as public concern about the environment grows. However, without a clear, widely accepted definition of what makes something "environmentally friendly," such terms are often applied inappropriately by marketers and prove confusing or, worse, misleading to consumers. In response, environmental and technical specialists have worked to develop life cycle assessment procedures that would evaluate the environmental impacts and resource use from "cradle to grave" in a product's life. Such criteria as recycled content, recyclability and reusability, degradability, hazardous or toxic content, water pollution, soil pollution, air pollution, noise pollution, production processes and resource/energy use have figured in specific methodologies used in evaluating programs [1]. The intent is to achieve a more holistic view of the total environmental consequences associated with particular products or processes [2].

To date, many life cycle studies have focused on specific controversial products (e.g., disposable vs. cloth diapers) [3, 4] or product materials (e.g., polystyrene foam) [5]. However, many of these studies have been criticized for using private data sources and selective analytical procedures, which, critics argue, often ensure that the results conform to the sponsor's interests. In response to such concerns, work by the Society of Environmental Toxicology and Chemistry [6] and the U.S. E.P.A. [7] has aimed at clarifying the assumptions and standardizing the procedures of life cycle assessment. Such work stresses the separate, but necessarily related components of life cycle assessment: life cycle inventory, life cycle impact analysis and life cycle improvement analysis [2, 6]. Most of the work to date has taken the form of life cycle inventories which enumerate the releases to the environment of various particular pollutants and the energy used during each stage of product manufacturing, use and disposal. In addition, there have been efforts in the United States, Canada, and Europe to use "streamlined" versions of life cycle assessment to establish environmental labeling programs [8, 9].

Despite this attention, life cycle inventories are themselves controversial because of the numerous assumptions embedded in their construction [10]. Even if there were agreement regarding life cycle inventory data, however, the next step in the analysis entails the tremendous leap from a listing of emissions to an assessment of their relative impacts [11]. To illustrate the problem, in order to accurately determine which product is "better for the environment," one must know not only what emissions are released to the environment and what forms and amounts of energy are used; one must further compare the effect on "the environment" of discharging some number of tons of pollutants A, B, and C in various locations to the effect of discharging some different number of tons of pollutants X, Y, and Z somewhere else. While current efforts may hold promise for improving the comparability and reliability of life cycle assessments in the long terms, it is clear that comprehensive, systematic analysis of packaging impacts is not yet sufficiently developed to provide detailed or reliable comparisons of relative environmental consequences.

Aside from the methodological controversies about how best to conduct formal life cycle assessments, the time and cost required for such research are simply beyond the means of most solid waste educators and practitioners, who more typically must design and implement programs on environmental consumer education as quickly as possible using limited resources. As a result, some educators and practitioners may make attributions about "environmental" products that derive from programmatic experience and individual interpretation of priorities in solid waste management. In many cases, they have been involved longer with recycling programs than with waste prevention programs, and are thus predisposed to evaluate recyclable products and packaging more highly than non-recyclable source reduced alternatives. Although educators' and practitioners' assessments of product packaging incorporate invaluable practice-based criteria, they are rarely juxtaposed to more quantitative evaluations of the products from which consumers must choose. Indeed, educators and practitioners find it difficult to quantitatively measure source reduction. As shown in this article, there are cases where these different approaches lead to different conclusions regarding the preferable "environmental choice."

A PROJECT ON WASTE REDUCTION THROUGH CONSUMER EDUCATION

The challenge of identifying "environmental choice" products within product categories has been important for a consumer education project on waste reduction conducted collaboratively by Cornell University, the Ulster County Resource Recovery Agency, Cornell Cooperative Extension of Ulster County and Wakefern

Food Corporation through research supported in part by the New York State Energy Research and Development Authority. The project involved tracking changes in purchases of selected "waste-generating" and "waste-reducing" products in fifteen product categories through the use of supermarket scanner data at two supermarkets in a New York county. Five separate waste reduction educational strategies have been tested, including countywide public information messages, in-store education, targeted educational mailings, shopper tours, and financial incentives (i.e., coupons) for the waste-reducing alternatives.

During the project, we quickly discovered that the choice between versions of functionally similar products is rarely a dichotomous one, opposing a clear-cut "environmentally good" product to an equally obvious "environmentally bad" choice. In many product categories, consumers face an array of choices, where different levels of source reduction and recyclability must somehow be balanced and assessed. In addition, these "shades of gray" are locality-specific. Because materials that may be recyclable in one community are often not recyclable in others, assessments of environmental packaging are necessarily geographically specific.

To illustrate these challenges, we compare and contrast the results of three methods for evaluating the waste implications of five consumer product categories selected because they illustrate the complexity of performing such evaluations. We also include the practice-based assessment of packaging impacts from an experienced waste reduction and recycling educator. The analysis is locality-specific, focusing on the range of product choices within brands for hand dishwashing liquid, fabric softener, cranberry juice, pancakes, and chicken noodle soup carried in two stores of a particular grocery chain. Our selection of these products reflects product choices at the two stores in August 1993; thus, at another time or at other grocery stores a different set of product choices within these categories might confront consumers. Furthermore, in those product evaluation methods that take account of recyclability, our analysis considers the potential influence of *actual* local recycling opportunities in determining impacts rather than giving "credit" for technically feasible recyclability in the absence of viable local programs and markets.

EVALUATION METHODS

Cornell

The Cornell system of product evaluation relies on a laboratory assessment of packaging component weight and volume, following a methodology developed by the Minnesota Office of Waste Management for its S.M.A.R.T. Shopping Project [12]. Both weight and volume are important to assess. The weight of garbage often determines landfill and incinerator charges and measures the amount of material used, while volume has a bearing on landfill and collection vehicle capacity [13].

Products were weighed full and unopened, using an electronic scale. Contents were emptied and usable product, total packaging, and packaging by constituent material were also weighed. Weight measurements were rounded to the nearest 0.1 gram. Volume of waste was measured using the water displacement method. First, packaging waste was compacted manually or by foot stomping, by average sized women of average strength, in an effort to approximate what consumers in the household actually do with their trash. Following the Minnesota protocol, packaging was then placed in a plastic bag, so air could escape from the bag as it was submerged, yet water not fill all the empty space. Larger packaging was submerged in water in a five gallon pail, while smaller packaging was submerged in a 250 ml cylinder. Measurements were rounded to the nearest 10 mls. The volume measurement was not always precise due to variable compaction and reexpansion of some packaging materials. The difference in packaging materials and shapes also made it difficult to maintain consistency in eliminating air within the outer plastic bag. To compensate for the variability in volume measurements, these measurements were taken three times for each package and then averaged.

In contrast to the Minnesota S.M.A.R.T. shopping protocol, the Cornell system also attempts to take recyclability into account. As some materials in our evaluation are recyclable in the locality under study, we acknowledge those recycling opportunities in calculating the amount of waste destined for disposal. Because data on the diversion rates for different recyclable materials in the study locality are not available, we use diversion factors derived from recent research conducted for the American Plastics Council [14-16]. Data on the participation rates of residents in recycling programs and the capture of recyclables (i.e., the percent of potentially recyclable materials which these participants recycle) in six communities were used to arrive at a projected diversion rate for each of the locally recyclable packaging materials in our study locality. Because New York is a "bottle bill" state, we based the calculations on research from the states with bottle deposit legislation (Massachusetts, Vermont, Oregon). The diversion or recovery rates obtained through these calculations are: 69 percent for container glass; 66 percent for steel; 38 percent for natural non-beverage high density polyethylene (HDPE); 30 percent for pigmented HDPE; and 22 percent for custom polyethylene (PET).

To arrive at an adjusted weight of waste, the percentage of locally recyclable waste projected for diversion through recycling was subtracted from the total weight of waste, so that only that proportion not diverted for recovery was counted as waste under the Cornell method. In effect, this approach assumes that the portion recycled is environmentally benign, generating no waste or impacts, which tends to make recycling look more favorable than it actually is. Furthermore, this method does not "give credit" for recycled content of packaging materials. An adjusted volume of waste was calculated using the same approach. The equation, based on weight or volume of constituent materials for each product and its package, is as follows:

(recyclable package components × non-recovery rate) +
non-recyclable package components = total waste

The total waste figures were then standardized by either the amount of usable product or by the number of servings in a given product choice to arrive at the amount of waste per ounce or per use for each product choice. Uses or servings were based on the manufacturer's claims posted on the label; in the case of product categories, such as pancakes, where a range (e.g., 8-10 pancakes) was cited, the mid-point (e.g., 9 pancakes) was used. Thus, a lower weight or volume of waste per use would within this method indicate a "more environmentally" packaged product.

We also sought to consider the impacts of transportation. Some research suggests that fully loaded trucks get poorer mileage than emptier ones, but require fewer trips per unit of weight conveyed [17]. However, to compare loads of similar products, we assumed that truck transportation impacts depend largely on the number of truckloads and not on the weight of the load [18]. Product loads for choices within the studied product categories were obtained from distribution personnel at Wakefern Food Corporation. In each product category, the number of uses or servings that fit into a standard truck were compared. Thus, more servings or uses per truckload constitute greater efficiency and less environmental impact. These data are rendered as a ratio, where within each product category, the number of uses for the product choice with the highest number of uses per truckload is divided by the number of uses per truckload for each product choice. Thus, a ratio of one represents the most transportation efficient product choice within the category, with higher numbers less desirable.

Tellus Institute

A study conducted by the Tellus Institute for the Council of State Governments, New Jersey Department of Environmental Protection and Energy, and the U.S. Environmental Protection Agency has drawn considerable attention from both industry and environmentalists for its efforts to assess packaging impacts [19]. The study developed and applied a methodology to address a major gap in life cycle assessment, namely establishing the relative environmental costs of different types of emissions. The approach derives a dollar value for each pollutant and applies this to life cycle inventory data to arrive at a single monetary figure representing the total environmental burden for each packaging material. The higher the cost, then, the greater the impact. Although the methodology of the study is far from universally accepted [10], it represents, to our knowledge, the only attempt to develop such a holistic evaluation. Another attraction of the Tellus study lies in its use of publicly available, rather than proprietary data, even though some critics have charged that the data are outdated and fail to reflect more recent changes in pollution control technology [2]. Overall and within these limitations, the Tellus approach offers another way to compare products within the product categories that attempts to incorporate the full life cycle impacts rather than focusing only on waste disposal.

In applying the Tellus method, we used Tellus figures for the full life cycle cost of packaging material from production through disposal [19]. Production includes the environmental costs associated with controlled emissions, but not those associated with industrial solid waste, generation rates for which are difficult to determine. In those cases where packages were made of multiple materials and constituent packaging materials were difficult to identify, we contacted manufacturers for information. The total unadjusted weight of waste (in grams) of each constituent packaging material for each product choice (determined through the laboratory procedures described above, but unadjusted for local recyclability) was then multiplied by the dollar cost per gram (derived from Tellus estimates of full cost for each material). Table 1 presents the full environmental cost factors used in our application of the Tellus approach. The environmental costs of all the constituent materials within product choices were then summed. This total environmental cost was then divided by the number of servings or uses, to standardize to the amount of product in the package. By this methodology, therefore, a lower dollar cost per unit of product indicates a lower environmental cost for the packaging associated with that product choice. Our application of this method does not "give credit" for post-consumer recycling of materials, but it does adjust for the recycled content of packaging materials, such as glass (see Table 1).

CONEG

In the late 1980s, the Source Reduction Task Force of the Coalition of Northeastern Governors (CONEG) developed preferred packaging guidelines as a means of coordinating source reduction initiatives in the Northeast. The guidelines were intended to educate different constituencies, including product designers, packaging professionals, government regulators, and consumers, about opportunities to reduce packaging-related waste [20].

In order of priority, the preferred packaging practices are as follows:

1. *No packaging* (bulk or no packaging at retail or wholesale level)
2. *Minimal packaging* (alternative methods of product and packaging design, such as concentrates, streamlining package design, new materials for packaging, lightweighting, single packaging, different modes of shipping requiring less packaging)
3. *Consumable, returnable or refillable/reusable packaging* (e.g., water soluble packets for detergent; returnable shipping containers; refills for original [not secondary] purpose)
4. *Recyclable packaging/recycled material in packaging* (recyclability presupposes viable local collection, processing and marketing of material; recyclability and recycledness most preferred; recyclability alone preferable to recycledness alone)

Table 1. "Environmental Cost" of Packaging Materials: Tellus Method

Materials	Full "Environmental Cost" ($/gram)
Plastic	
HDPE	$0.0006
LDPE	$0.0006
PET	$0.0012
PP	$0.0007
PS	$0.0007
PVC	$0.0058
Paper	
Bleached kraft paperboard	$0.0005
Recycled paperboard	$0.0003
Glass	
Virgin	$0.0002
Recycled	$0.0001
Aluminum	
Virgin	$0.0021
Recycled	$0.0004
Steel	
Virgin	$0.0004
Recycled	$0.0004

Source: Tellus Institute (1992), *CSG/Tellus Packing Study,* Volume I, Chap. 3, Table 3.3.

To apply the guidelines, we made qualitative assessments as to which packaging practices characterized the various product choices within product categories. Product choices could then be ranked from "most preferred" (embodying a higher priority practice and hence more "environmental") to "least preferred" (embodying a lower priority practice). The qualitative nature of these assessments afforded less discrimination between product choices than the other methods and meant that two product choices in some cases shared one ranking.

Educator's Assessment

We also asked an experienced recycling and waste reduction educator in New York State to evaluate the product choices within the product categories from the standpoint of packaging waste reduction. Her assessments should not be interpreted as representative of the concerns or priorities of solid waste educators, in general. Instead, they demonstrate that educators evaluate packaging options within a practice-based understanding of the opportunities and constraints for waste management programs within their specific localities. In this sense, educators may espouse particular waste reduction and/or recycling principles based on a holistic understanding of the larger solid waste field within their geographic area.

We obtained these product evaluations by interviewing the recycling coordinator/educator of the county waste agency cooperating on the project. She explained, "My criteria, like the New York State solid waste hierarchy, are, in the following order, reuse and reduction, recycling and composting, and finally, landfilling or incineration. Waste diversion includes recycling and we should be teaching people to recycle what they can't reuse." In the county under study, materials mandated for recycling included glass bottles and jars; plastic bottles and jugs (all types of plastics); metal cans (steel and aluminum) and metal lids; newspaper, corrugated cardboard, and office paper. Neither plastic bags nor plastic lids were locally recyclable at the time of the study.

RESULTS

Dishwashing Liquid

Within brands, product choices in hand dishwashing liquid generally come in different sizes, but in packaging with identical constituent materials. A comparison of the three methods and the educator's assessment shows that for this product the larger sized container generally, although not uniformly, is ranked as the environmental choice (Table 2). In the case of Dawn™, the container, which is locally recyclable, is made of high density polyethylene (HDPE), while the polypropylene (PP) cap is not recyclable in the locality.

The weight-based Cornell method yields a progressively lower packaging to product ratio as container size increases. Volume-based measures of packaging waste departed from this precise sequence, with the 32 oz. container yielding the same volume of waste as the 96 oz. container. This outcome may reflect the greater difficulty compacting the heavier plastic used in the 96 oz. container, as well as the inherent variability of volume measurements under the system used. The transport ratio also produced the surprising result of the smallest container loading the most product onto a truck. However, the ratios for the 32 oz. and the 96 oz. are

Table 2. Environmental Ranking of Dishwashing Liquid

Product Choices	Packaging Materials	Cornell[a] Weight	Cornell[a] Volume	Cornell[a] Transport	Tellus[a]	CONEG[c]	Educator's Assessment[a]
22 oz. Dawn	Container: HDPE[b] cap: PP	3 (1.6 g/oz.)	2 (10 ml/oz.)	1 (1.00)	3 ($0.00148/oz.)	N.A.	3 (Least preferred)
32 oz. Dawn	Container: HDPE[b] cap: PP	2 (1.4 g/oz.)	1 (8 ml/oz.)	2 (1.02)	2 ($0.00131/oz.)	N.A.	2 (2nd most preferred)
96 oz. Dawn	Container: HDPE[b] cap: PP	1 (0.9 g/oz.)	1 (8 ml/oz.)	2 (1.02)	1 ($0.00080/oz.)	N.A.	1 (Most preferred)

[a]Numbers are ranking from best (1) to worst (3) environmental choice.
[b]Based on non-recovery rate of 62 percent for natural, non-beverage HDPE.
[c]N.A. = Not applicable.

only slightly higher (and the same); this may reflect the fact that these sizes are more rounded bottles and the cylindrical smaller size can be packed more closely together, allowing somewhat less empty space per truckload. The Tellus method reproduces the ranking of the Cornell weight-based method; the "environmental cost" per ounce of dishwashing liquid packaging decreases by nearly a factor of two as the package increases from the 22 oz. to the 96 oz. size.

Strictly interpreted, the CONEG guidelines confer no preference to larger sized versions or a product and thus allow no discrimination between this set of product choices in assessing environmental impacts. In contrast, the educator ranked the dishwashing liquid choices in an order that parallels the Cornell weight measures and the Tellus approach. Her ranking reflects the generally accepted advice to "buy the largest size" on the basis of an expected reduction in packaging to produce ratio with larger sizes.

Fabric Softener

As a product category, fabric softener is more complex than hand dishwashing liquid. Analysis for this product category is presented in Table 3. The category includes both dilute and concentrated options, although many manufacturers are now phasing out their dilute products. In addition, fabric softener comes in different sized containers and in containers made of different materials. Within the Snuggle™ brand we examined, there were two packaging options in the concentrate (a plastic container, where the jug was made of locally recyclable pigmented HDPE and the cap of locally non-recyclable PP, and a plastic film coated paperboard carton which was not locally recyclable). Each of these were available in two sizes. There was also a dilute product choice in one size, whose HDPE container and PP cap involved the same packaging materials as the first concentrate option.

In all methods, the dilute product choice yields the most packaging waste per use, despite local recyclability. Beyond this, however, there is no sweeping agreement among the methods. In the Cornell weight and volume-based measures, the 36 oz. concentrate plastic container and the 40 oz. concentrate gabletop carton closely rival one another for ranking as the environmental choice; they are followed closely by the 20 oz. concentrate gabletop carton, with the 22 oz. concentrate plastic container a bit farther behind. Focusing on the more reliable weight-based measures alone, the differences in the adjusted weight of waste among the concentrates are small. By extension then, the relative rankings of the recyclable concentrate plastic containers and the non-recyclable concentrate gabletop cartons depend on the recovery rates of the locally recyclable material, pigmented HDPE. Since the 30 percent recovery rate used in the calculations for Table 3 is an estimate, we also examined the impact on the relative rankings under the Cornell weight-based analysis when different diversion rates were applied. At a 50 percent recovery rate for HDPE, there is little change in the rankings. The

Table 3. Environmental Ranking of Fabric Softener

Product Choices	Packaging Materials	Cornell[a]			Tellus[a]	CONEG[a]	Educator's Assessment[a]
		Weight	Volume	Transport			
64 oz. Snuggle dilute plastic (23 uses)	Container: HDPE[b] cap: PP	5 (4.9 g/use)	5 (45 ml/use)	5 (2.80)	5 ($0.00393/ use)	3 (Least preferred)	3 (3rd most preferred)
22 oz. ultra Snuggle concentrate plastic (22 uses)	Container: HDPE[b] cap: PP	4 (3.0g/use)	4 (21 ml/use)	4 (1.22)[c]	4 ($0.00245/ use)	1 (Most preferred)	2 (2nd most preferred)
20 oz. ultra Snuggle concentrate gable top carton (20 uses)	Bleached paperboard w/plastic film coating	3 (2.3 g/use)	3 (17 ml/use)	2 (1.10)	2 ($0.00114/ use)	2 (2nd most preferred)	5 (Least preferred)
40 oz. ultra Snuggle concentrate gable top carton (40 uses)	Bleached paperboard w/plastic film coating	2 (2.0 g/use)	1 (15 ml/use)	1 (1.00)	1 ($0.00099/ use)	2 (2nd most preferred)	4 (4th most preferred)
36 oz. ultra Snuggle concentrate plastic (36 uses)	Container: HDPE[b] cap: PP	1 (1.9 g/use)	2 (16 ml/use)	3 (1.13)	3 ($0.00152/ use)	1 (Most preferred)	1 (Most preferred)

[a]Numbers are ranking from best (1) to worst (5) environmental choice.
[b]Based on non-recovery rate of 70 percent for pigmented HDPE.
[c]Transport calculation for 20 oz. HDPE container which replaced discontinued 22 oz. HDPE container late 1993.

36 oz. plastic container remains ranked first, the 40 oz. gabletop carton remains second, while the 22 oz. plastic container and the 20 oz. gabletop carton converge to share the third rank. However, with an increase in diversion to 75 percent, the 36 oz. plastic container still remains first, but is followed by the 22 oz. plastic container, and then by the 40 oz. gabletop carton and the 20 oz. gabletop carton in that order. The transportation measure under the Cornell system provides yet another different ranking, with the paperboard concentrate containers packing more product per truckload than the HDPE concentrate containers. This outcome suggests the greater efficiency of cubed packaging compared to cylindrical forms for transportation and storage.

The Tellus approach produces a product choice ranking identical to the Cornell transportation ratio, with the paperboard concentrate choices achieving lower environmental costs than the HDPE concentrate choices and the dilute version of fabric softener being the most costly of all. This is attributable to the slightly higher environmental cost and greater weight (unadjusted for local recyclability) of plastics relative to paperboard in this product category. Applying the CONEG method, the two HDPE concentrate forms would share most preferred status, because they embody two practices (concentrating and recyclable packaging). The two paperboard cartons would be second most preferred (concentrating) and the dilute form would be least preferred (recyclable packaging only). In contrast, the local educator's assessment disfavors the paperboard concentrate options relative to even the dilute HDPE option, because at present plastic film covered paperboard cartons, despite the alluring "refill" language on these products, are neither truly refillable nor locally recyclable (or compostable). With HDPE recycling programs locally in place, she argues that theoretically no plastic fabric softener containers need end up in the waste system.

Cranberry Juice

Cranberry juice is another product category that reflects choices between concentrated and dilute forms and between different packaging materials and sizes. Table 4 displays the results of comparisons between the product choices. At the grocery stores under study, in the Ocean Spray™ brand, we found two sizes of dilute juice in glass containers with metal lids, a three pack of dilute single serving aseptic juice boxes, a large polyethylene (PET) container of dilute juice with a non-locally recyclable HDPE lid, and a concentrated aseptic box refill. Of the various packaging materials in these product choices, only three were locally recyclable: glass, metal lids, and PET.

Using the Cornell method, the concentrated aseptic refill produces considerably less weight and volume of packaging waste per serving and appears the environmental choice. It also yields a strongly superior transportation ratio relative to the other product choices, since the concentrate choice omits the water characterizing virtually all ready to consume fruit drinks. After the concentrated aseptic refill, the

Table 4. Environmental Ranking of Cranberry Juice

Product Choices	Packaging Materials	Cornell[a] Weight	Cornell[a] Volume	Cornell[a] Transport	Tellus[a]	CONEG[a]	Educator's Assessment[a]
32 oz. Ocean Spray glass dilute (5.3-6 oz. servings)	Glass container[b] metal lid[b]	5 (26.0 g/ serving)	2 Intact = 69 ml/svg; Crushed = 11 ml/svg	5 (5.76)	5 ($0.01156/ serving)[c]	2 (2nd most preferred)	3 (3rd most preferred)
48 oz. Ocean Spray glass dilute (8-6 oz. servings)	Glass container[b] metal lid[b]	4 (24.7 g/ serving)	2 Intact = 69 ml/svg; Crushed = 11 ml/svg	4 (5.73)	4 ($0.01098/ serving)[c]	2 (2nd most preferred)	2 (2nd most preferred)
3-8.45 oz. Ocean Spray dilute aseptic juice boxes (4.2-6 oz. servings)	Aseptic box PP straws PVC shrink wrap	3 (9.8 g/ serving)	3 95 ml/svg	3 (4.44)	2 ($0.00992/ serving)[d]	3 (Least preferred)	5 (Least preferred)
64 oz. Ocean Spray PET dilute (10.7-6 oz. servings)	PET container[b] HDPE lid	2 (6.9 g/ serving)	4 102 ml/svg	2 (4.32)	3 ($0.01038/ serving)	2 (2nd most preferred)	1 (Most preferred)
8.45 oz. Ocean Spray concentrate aseptic refill (7-6 oz. servings)	Aseptic box	1 (1.9 g/ serving)	1 15 ml/svg	1 (1.00)	1 ($0.00122/ serving)[d]	1 (Most preferred)	4 (4th most preferred)

[a]Numbers are ranking from best (1) to worst (5) environmental choice.
[b]Based on non-recovery rates of 31 percent for glass, 34 percent for metal lids, and 78 percent for custom PET.
[c]Tellus calculation assumes glass is 50 percent recycled content, 50 percent virgin content.
[d]Aseptic container was analyzed in Tellus method as containing 70 percent bleached kraft paperboard, 24 percent LDPE and 6 percent virgin aluminum. **Source:** Aseptic Packaging Council

Cornell weight-based system and transportation ratio produce identical rankings, led by the 64 oz. PET container, and followed by the aseptic single serving juice boxes, the 48 oz. glass container and the 32 oz. glass container, in that order. The Cornell volume-based system yields a different sequence, however. Here the two glass containers result in the same volume of waste per serving, which is less adjusted for local recyclability, than either the aseptic single serving juice boxes or the PET container. If volume is measured with the glass containers fully crushed (a condition that probably underestimates volume of waste under current solid waste management practices), the two glass containers yield even less volume of waste than the concentrated aseptic refill box.

Applying the Tellus approach again suggests the environmental superiority of the aseptic concentrate product choice. The "environmental cost" of packaging per serving with the aseptic concentrate refill is less than one-eighth the cost of the next best choice. Despite the greater weight of waste for the aseptic dilute single serving boxes compared to the PET dilute container under the Cornell method, the Tellus method suggests that the aseptic dilute juice boxes and the PET dilute container are fairly close in "environmental cost." This is due to the comparatively high "environmental cost" attributed by the Tellus method to PET in contrast to LDPE and paper, the major components of the aseptic package (see Table 1). Although glass, whether virgin or recycled, has a comparatively low environmental cost per gram under the Tellus method, the two glass juice choices become the most costly due to their very high weight of waste, relative to other product choices.

Under the CONEG guidelines, the aseptic concentrate refill embodies the highest level packaging practice (concentrating), which gives it most preferred status. The PET container and the two glass container choices share second most preferred status, because all are locally recyclable. Finally, the single serving dilute juice boxes are least preferred, as single use, locally unrecyclable, and an overly complex form of packaging.

In contrast, the local educator's assessment again incorporates closer attention to local recycling opportunities and programs in evaluating packaging waste impacts of the product choices. Locally recyclable and a large sized container, the PET dilute container achieves "most preferred status." The 48 oz. dilute glass and the 32 oz. dilute glass follow in descending order, as they too are recyclable, but their packaging to product ratios are assumed to be less favorable. The educator ranks the aseptic refill concentrate as the fourth product choice, which she stresses is a difficult determination. Although concentrating receives high marks, being locally unrecyclable is, in the educator's view, a strong mark against this packaging form. Finally, she gives the aseptic dilute juice boxes least preferred status, for being overly packaged, locally unrecyclable single-serving products and asks, "Why can't concentrated juice be packaged in a small, rectangular HDPE or PET container?"

Pancakes

As with cranberry juice, the product category of pancakes encompasses different product forms, packaging materials and package sizes. Table 5 presents the results of our comparison. In the Aunt Jemima™ brand, we found and analyzed three sizes of boxed pancake mix and one size package of frozen pancakes. We also analyzed a pancake product, the "shake n' pour," in the Bisquik™ brand, because in the view of many environmentalists and waste reduction educators, it epitomizes wasteful packaging. The product is marketed for one time use, so that with the addition of water, the pancake mix can be shaken in the package and poured directly on the griddle. Although the boxed pancake mix package is made of recycled paperboard, no credit is given for this under the Cornell method. Only the "shake n' pour" option, with its HDPE container, uses locally recyclable materials.

The Cornell method results in rankings across the three sub-methods that agree only on the "best" choice. By weight, volume and transport measures, the 5 lb. box of pancake mix appears the clear environmental choice. Although from a volume standpoint the 2 lb. box generates less waste per pancake than the 1 lb. box, there was no difference in weight of waste per pancake between these size choices. Because of the weight advantage conferred by its locally recyclable HDPE container, the "shake and pour" option ranks higher than the frozen pancake package. However under the volume-based system, even with an adjustment for locally recyclable HDPE, the "shake and pour" option ranks below the frozen pancake package. Under the Cornell weight and volume-based systems, the status of the "shake and pour" option is highly dependent on the local recycling recovery rate for HDPE. With improved diversion of HDPE (i.e., a recovery rate of 60 percent or more), the "shake n' pour" option would generate less weight of waste per pancake than the 2 lb. or 1 lb. boxes. With a recovery rate of 70 percent, the "shake n' pour" becomes equivalent to the 5 lb. box under the Cornell weight of waste sub-method.

Under the Cornell transportation method, the "shake and pour" option ranks the most poorly, followed by the 1 lb. and 2 lb. boxes. The frozen pancake option receives the second best rank, because the total package is comparatively light and more units of product can therefore be stacked to "cube out the truck." However, our analysis here does not adjust for the additional environmental and economic costs of freezer truck transport; thus, the transportation ranking for frozen pancakes likely underreports actual environmental impacts.

Using the Tellus approach, the 5 lb. box achieves the lowest environmental cost for packaging in the pancake category, followed by the 2 lb. and the 1 lb. boxes in close succession. The frozen pancake package comes next, with the plastic packaged "shake n' pour" option registering the highest "environmental cost" for its packaging per pancake served, a result again reflecting the "costliness" of plastic packaging when its unadjusted weight corresponds to comparatively few units of usable product.

Table 5. Environmental Ranking of Pancakes

Product Choices	Packaging Materials	Cornell[a]			Tellus[a]	CONEG[a]	Educator's Assessment[a]
		Weight	Volume	Transport			
Aunt Jemima frozen pack (12 pancakes)	Box: bleached paperboard Inner bag: HDPE	4 (4.1 g/ pancake)	4 (27 ml/ pancake)	2 (1.13)	4 ($0.00203/ pancake)	3 (Least preferred)	5 (Least preferred)
Shake-n-Pour Bisquick (9 pancakes)	Container: HDPE[b] plastic lid/foam seal	3 (3.7 g/ pancake)	5 (31 ml/ pancake)	5 (2.39)	5 ($0.00300/ pancake)	1 (Most preferred)	4 (4th most preferred)
Aunt Jemima 1-lb. box (13 pancakes)	Recycled paperboard	2 (2.7 g/ pancake)	3 (14 ml/ pancake)	4 (1.50)	3 ($0.00076/ pancake)	2 (2nd most preferred)	3 (3rd most preferred)
Aunt Jemima 2-lb. box (25 pancakes)	Recycled paperboard	2 (2.7 g/ pancake)	2 (12 ml/ pancake)	3 (1.26)	2 ($0.00074/ pancake)	2 (2nd most preferred)	2 (2nd most preferred)
Aunt Jemima 5-lb. box (62 pancakes)	Recycled paperboard	1 (2.0 g/ pancake)	1 (9 ml/ pancake)	1 (1.00)	1 ($0.00055/ pancake)	2 (2nd most preferred)	1 (Most preferred)

[a]Numbers are ranking from best (1) to worst (5) environmental choice.
[b]Based on non-recovery rates of 70 percent for pigmented HDPE.

Application of the CONEG guidelines arguably confers most preferred status on the "shake and pour" HDPE package choice, because much of it is locally recyclable. Sharing second most preferred status are the 5 lb., 2 lb., and the 1 lb. boxes, all made of recycled material, which is a lower priority, according to the CONEG guidelines, than being recyclable. Since the CONEG guidelines suggest no differentiation on the basis of product choice size, the three boxes share this rank. Finally, the frozen pancake choice would be least preferred, given its lack of recyclable or recycled content packaging.

The waste reduction educator provides a ranking of the product choices, which echoes the Cornell weight-based system and favors the boxes arrayed from largest to smallest. She explains: "The bulk form and recycled content packaging of the 5 lb. box supports recycling markets and helps close the loop. Because it's a dry box and not multi-layered, we may be able to recycle or compost it in the future and that's important from the standpoint of program development." She ranks the plastic "shake n' pour" choice above the frozen pancake option, but with certain reservations, noting "the local recyclability of the 'shake n' pour' option counts for something, although we dislike the fact that this package includes extra, empty space for water to be added. A smaller HDPE container would be more desirable."

Chicken Noodle Soup

The vast soup category increasingly includes ready-to-eat options that offer consumers convenience, as well as more complex packaging. Table 6 presents our comparison of three forms of chicken noodle soup within the Campbell's brand. The microwaveable single serving cup represents a highly complex package, made from an array of unrecycled and locally unrecyclable materials. It includes a mixed plastic cup, a virgin aluminum seal, a polystyrene (PS) label and a low density polyethylene (LDPE) lid. The longstanding canned option is semi-concentrated; its steel can is locally recyclable, although its paper label is not. The dry packet contents can be seen as a form of concentrating, but the packaging material, a mixed plastic, is neither recycled nor locally recyclable.

Based on the Cornell method and the Tellus approach, the dry packet appears the clear environmental choice. The dry packet produced far less weight of packaging waste per serving than the canned, although the canned option produced less volume of packaging waste per serving than the dry. Such an outcome for volume measures, however, may reflect differences in the ease of compacting and maintaining a compacted shape for the two product choices. The dry packet and canned soup were exceedingly close on the transport measure, an outcome which may reflect the greater number of servings in the canned as opposed to the dry packet choice. However, the Tellus ranking clearly identifies the dry packet as the least environmental cost option, at approximately one quarter the cost of the can and less than one tenth the cost of the microwaveable cup. By all measures, the poor ranking of the microwaveable cup was the most

Table 6. Environmental Ranking of Chicken Noodle Soup

Product Choices	Packaging Materials	Cornell[a] Weight	Cornell[a] Volume	Cornell[a] Transport	Tellus[a]	CONEG[a]	Educator's Assessment[a]
Microwaveable cup (0.97-8 oz serving)	Mixed plastic cup[b] virgin aluminum seal PS label LDPE lid	3 (31.6 g/ serving)	3 (270 ml/ serving)	3 (2.38)	3 ($0.02659/ serving)	3 (Least preferred)	3 (Least preferred)
Canned concentrate (2.60-8 oz. servings)	Steel can[c] paper label	2 (7.0 g/ serving)	1 (32 ml/ serving)	2 (1.01)	2 ($0.00736/ serving)	1 (Most preferred)	1 (Most preferred)
Dry packet (2.00-8 oz. servings)	Mixed plastic[b]	1 (2.5 g/ serving)	2 (50 ml/ serving)	1 (1.00)	1 ($0.00186/ serving)	2 (2nd most preferred)	2 (2nd most preferred)

[a]Numbers are ranking from best (1) to worst (3) environmental choice.
[b]Tellus factor applied is average of full "environmental cost" for HDPE, LDPE, PET, PP and PS (see Table 1).
[c]Based on non-recovery rates of 34 percent for steel can.

straightforward, with respect to packaging waste weight and volume, transport, and environmental costs.

Following the CONEG guidelines, the canned option, as a concentrate in a locally recyclable steel can, would be most preferred. The dry packet, although neither recyclable nor made of recycled content, would be second most preferred, because it too is a concentrated product. The microwaveable cup, as a complex package and single use serving, would be least preferred. This ranking corresponds exactly with that offered by the waste reduction educator, who again gives significant weight to local recyclability and the number of uses or servings supported by a given amount of packaging.

DISCUSSION

A comparison of methods for assessing packaging impacts within five grocery product categories reveals some of the challenges for educators and practitioners who seek to guide consumers to an "environmental choice." Given the array of products crowding grocery shelves, it remains unclear how full scale, formal life cycle assessments could be conducted in a useful or cost-efficient manner for even a fraction of those products. However, when we turn to more streamlined methods, such as we have demonstrated in this article, both strengths and weaknesses are evident. With sufficient program resources, the Cornell method, which builds upon a protocol developed by the Minnesota Office of Solid Waste, can be administered for a set of products on which educators wish to focus their environmental shopping education. In its attention to lower weight and volume of waste, the method broadly assumes that less packaging per unit of usable product translates into lower environmental impacts. By "giving credit" for local recycling practices, the method recognizes the value of material recovery through recycling, although as applied here it also discounts any environmental impacts in the manufacture, collection and reprocessing of locally recyclable packaging waste. The transportation component of the Cornell method represents a fairly simple, although coarse way of assigning and comparing environmental impacts in distribution and provides a valuable extension of the solid waste focused assessment of the other two components of the Cornell method.

As discussed previously, the Tellus method has generated considerable controversy. Furthermore, it was not developed to be applied by educators and practitioners for their own program purposes. We have applied the Tellus factors for "full environmental costs" of packaging materials in order to illustrate how the approach works and compare it to other methods. But the derivation and application of these factors have been strongly disputed [2, 10, 19]. In addition, constituent materials of some packaging are difficult to separate and sometimes even to identify, hampering implementation of this type of analysis for complex packages. However, a strength of the Tellus method is its attention to predisposal (e.g., manufacturing) impacts of packaging rather than to disposal impacts exclusively.

Emissions from production of packaging can be more significant than environmental impacts at the stage of waste disposal, especially given improvements in landfill and incinerating technology. Furthermore, the difference between impacts of many materials is small enough that the lightest weight package is often the best "environmental choice" [22]. In this case, source reduction becomes more important than attention to or "credit" for recycling.

The CONEG Preferred Packaging Guidelines offer relative simplicity and hence more immediate utility for busy educators and practitioners needing to assess consumer products. As a qualitative system of packaging evaluation, however, they are open to subjective interpretation (e.g., precisely what constitutes streamlined package design or lightweighting?) Furthermore, unless one interprets preference for "bulk" to include preference for larger sized containers, they omit attention to a source reduction principle, largely confirmed by more quantitative methods—that larger sized products yield less packaging waste per unit of product.

Packaging assessments by a local waste reduction and recycling educator underscore the importance of local context in making attributions about environmental impacts. In this case, the educator emphasized support of existing local recycling programs in assessing packaging. As a result, her rankings sometimes diverged from those of the other three methods. This demonstrates the programmatic challenge of waste reduction education, which may sometimes require different recommendations than recycling education. In short, there is often a tension between source reduction and recycling and the programmatic integration of these priorities may be easier in theory than in practice.

Agreements and disagreements between these packaging assessment approaches highlight some of the issues facing waste reduction educators and practitioners. General agreement between the methods occurs when produce choices within a category involve the same packaging materials with size representing the main difference between product choices, as in hand-dishwashing liquid. Although the Cornell transportation ratio favors the smallest size product choice in this category slightly, all other methods support the familiar educator's assertion to "buy the largest size," in order to obtain a lower packaging-to-product ratio.

Discrepancies between the methods often occur in more complicated product categories, where product choices involve different packaging materials, only some of which are locally recyclable. For example, in the case of fabric softener, the CONEG guidelines, the Cornell weight measures and the local educator all rank the largest size concentrate in a locally recyclable container (HDPE) as the "environmental choice." However, the Cornell volume measures, the Cornell transportation ratio and the Tellus method rank the largest size concentrate in the locally non-recyclable gabletop paperboard carton as the "environmental choice" (although only marginally so for the volume measures). This underscores that weight and volume assessments of packaging sometimes produce different rankings of product choices, and that the comparative importance of either may ultimately depend on a locality's solid waste management situation. It also reflects the greater efficiency of simple, rectangular packaging in transportation and the influence of lower weight in total packaging waste of the carton, when "environmental costs" of HDPE and virgin paperboard (see Table 1), unadjusted for local recyclability, are actually quite similar. For this product category, all methods, except the local educator's assessment, rank the 64 oz. dilute HDPE choice as the least preferred product choice, suggesting a near convergence on the importance of concentrating over any considerations of local recyclability in reducing packaging impacts. For the educator, recyclability again takes precedence over concentration.

Discrepancies also emerge between the methods when evaluating cranberry juice product choices, which include three types of packaging (glass, PET and aseptics) in both concentrate and dilute forms. The three Cornell sub-methods, the CONEG guidelines and the Tellus method rank the aseptic refill concentrate as the "environmental choice," but it was the next to least preferred choice of the local educator, due to lack of local recyclability. The PET dilute container also ranks highly under most methods, except the Cornell volume-based system. The local educator ranks it first (due to size, weight and recyclability), while it achieves the second best Cornell weight-based measure and transportation ratio. It shares second place with the glass containers, also locally recyclable, under the CONEG guidelines. By the Tellus method, it is edged out by the aseptic dilute juice boxes, which incur a somewhat lower environmental cost. Disagreement over the "environmental loser" perhaps epitomizes some of the trade-offs between source reduction and recyclability in assessing packaging impacts. The weight-based quantitative methods (Cornell and Tellus) and the Cornell transportation ratio rank the dilute glass containers as the worst choices. However, they rank much more favorably under the Cornell volume-based system. In addition, the CONEG guidelines and the local educator give the glass containers a higher ranking on the basis of local recyclability, while both see aseptic dilute juice boxes as the "environmental loser," due to the absence of local recycling opportunities and the single serving packaging.

Our comparison of methods for assessing packaging of grocery products demonstrates that attributions about the "environmental choice" are not always clear-cut. More quantitative methods often lead to "less is best" conclusions, where source reduction becomes more important than recycling, even if it means favoring a product in non-locally recyclable packaging. Even using the Cornell weight-based method which effectively assumes that the packaging diverted through recycling results in no "environmental cost," source reduced non-recyclable packaging frequently scores higher than heavier recyclable packaging. More qualitative methods, such as CONEG and the educator's assessment, offer the opportunity to acknowledge and support local recycling efforts, although that sometimes means placing lower priority on lower weight, but non-locally recyclable packaging. It then becomes important to critically evaluate the extent to which achieving local diversion of packaging waste through recycling actually decreases "environmental costs." Among other things, this will depend on the changing impacts and benefits in collecting, processing and remanufacturing locally recycled materials.

CONCLUSIONS

Ubiquitous educational messages on waste reduction that emphasize "buy concentrates," "buy the largest size," "avoid overpackaged products," "buy recyclable packaging," and "buy packaging made of recycled materials" remain appropriate. However, this analysis highlights the difficulty consumers face in applying these messages to products when several of the underlying principles are in conflict. For example, how should consumers evaluate a concentrate in a non-recyclable package in comparison to a dilute product in a recyclable package? In such cases, evaluating the waste reduction implications of the packaging choices depends on the methods used and on assumptions made about recycling rates and impacts.

One clear implication emerging from our comparison of packaging evaluation methods is that source reduced, recyclable packaging of concentrated products represents a very good environmental choice. Manufacturers must move in this direction, where possible, so that consumers and educators are not forced to choose between source reduction and recycling. A further consideration is the role of packaging shape in minimizing transportation impacts. A larger number of rectangular packages will fit into a given space and are thus more efficient than rounded or cylindrical shapes. Finally, to recycle or even compost paperboard and aseptic packaging would improve the environmental profile of these packaging materials and should be addressed by manufacturers and by solid waste practitioners as they set waste management priorities within their localities.

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