LIFE CYCLE ASSESSMENT OF CORRUGATED CONTAINERS AND REUSABLE PLASTIC CONTAINERS FOR PRODUCE TRANSPORT AND DISPLAY

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Study Undertaken on Behalf of:

Corrugated Packaging

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Executive Summary

This report conducted for the Corrugated Packaging Alliance (CPA) is an update to a 2019 ISO-compliant LCA by Quantis that compared corrugated containers (CCs) to reusable plastic containers (RPCs) used to transport and display fresh produce in the U.S.

The analyses described in this study rely on data from 2020 for single-use corrugated fiberboard while the reusable plastic data remained unchanged. Like the earlier study, this LCA seeks to compare the relative environmental performance of these two container systems. The objectives of this study are unchanged from those in the 2019 study, [2] which were outlined as follows:

I. Establish credible and transparent profiles of the life cycle potential environmental impacts of corrugated containers and reusable plastic containers utilizing appropriate and recognized databases and LCIA characterization factors according to ISO 14040 and 14044:2006;
II. Identify the magnitude and confidence of comparative environmental advantages of either system; and
III. Ensure compliance of results with ISO 14044 (clause 6) and ISO 14040 (clause 7) to support a public comparative claim, including critical review by a panel of interested parties.

The functional unit of this study is defined as the provision of containment for 907,185 kg (1,000 short tons) of eight varieties of produce (apples, carrots, grapes, head lettuce, oranges, onions, tomatoes and strawberries) grown and purchased in the United States. The study boundaries include filling the containers, transportation, and display at retail, all while ensuring the produce is maintained at a level suitable for sale and safe for human consumption. The study is "cradle-to-grave," as such, it includes all life cycle stages from raw materials extraction through end-of-life. As in the 2019 Quantis study, most data for this study are based on CPA's own research. Other data sources included published LCAs on CCs and RPCs and confidential information provided by representatives of the CC and RPC industries.

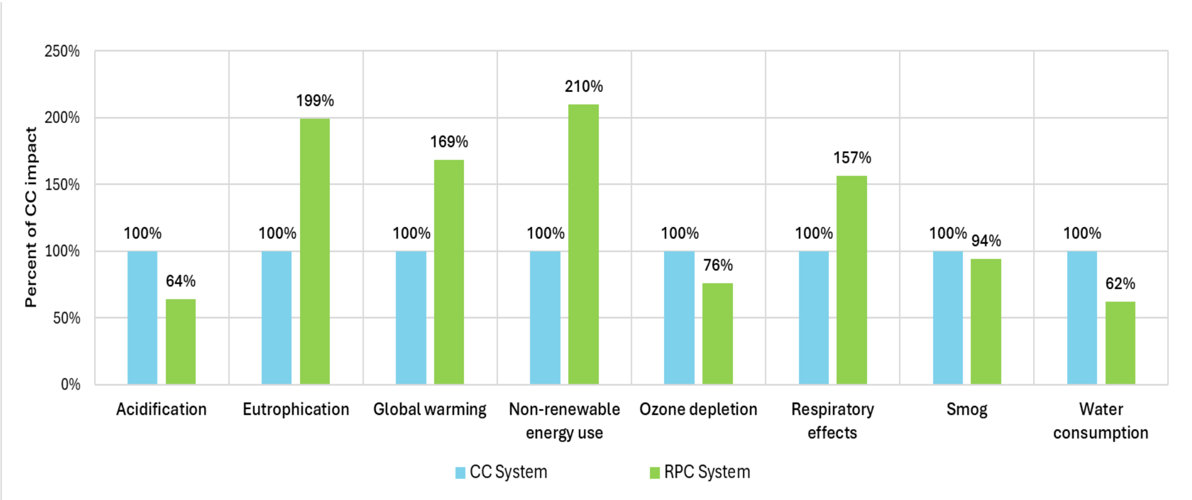
To facilitate comparisons to the 2019 study, the same seven impact categories were evaluated: acidification, eutrophication, global warming, non-renewable energy, ozone depletion, respiratory effects, and smog formation along with an eighth category: water consumption. SimaPro software was employed to perform calculations, and neither normalization nor weighting of results was employed. An external panel has been commissioned to conduct a review in accordance with ISO 14040.

[2] Thorbecke, M., A. Pike, J. Dettling, and D. Eggers. Life cycle assessment of corrugated containers and reusable plastic containers for produce transport and display. Quantis. February 28, 2019.

Results

Market-Weighted Results

Analysis showed that the RPCs create higher impacts in 4 of the 8 damage categories assessed (eutrophication, global warming, non-renewable energy use, and respiratory effects) but lower impacts in 3 categories (acidification, ozone depletion, and water consumption, ES Figure 1). For smog, the difference between CC and RPC systems is less than 10%, which is not significant enough to be considered as an advantage for either system. The magnitude of the difference between the CC and RPC is greatest for the categories of eutrophication, global warming, and non-renewable energy use, where the RPC results are 69-110% larger than those for the CC system.



ES Figure 1: Market-weighted average results for the baseline analysis

Commodity-Specific Results

Commodity-specific results demonstrate similar trade-offs between the container systems (ES Table 1). Regardless of the commodity, RPCs perform better than CCs in three damage categories (acidification, ozone depletion, and water consumption); and CCs perform better than RPCs in four damage categories (eutrophication, global warming, non-renewable energy use, and respiratory effects). For smog formation, RPCs show lower smog impacts for carrots, lettuce, onions, and grapes, no difference for apples, and higher smog impacts for strawberries, tomatoes, and oranges.

ES Table 1. Baseline results for the 8 produce types in this study. Commodities are ordered from the greatest to least functional unit mass ratio. Each bar is shown relative to the system of greatest impact for that impact category and commodity.

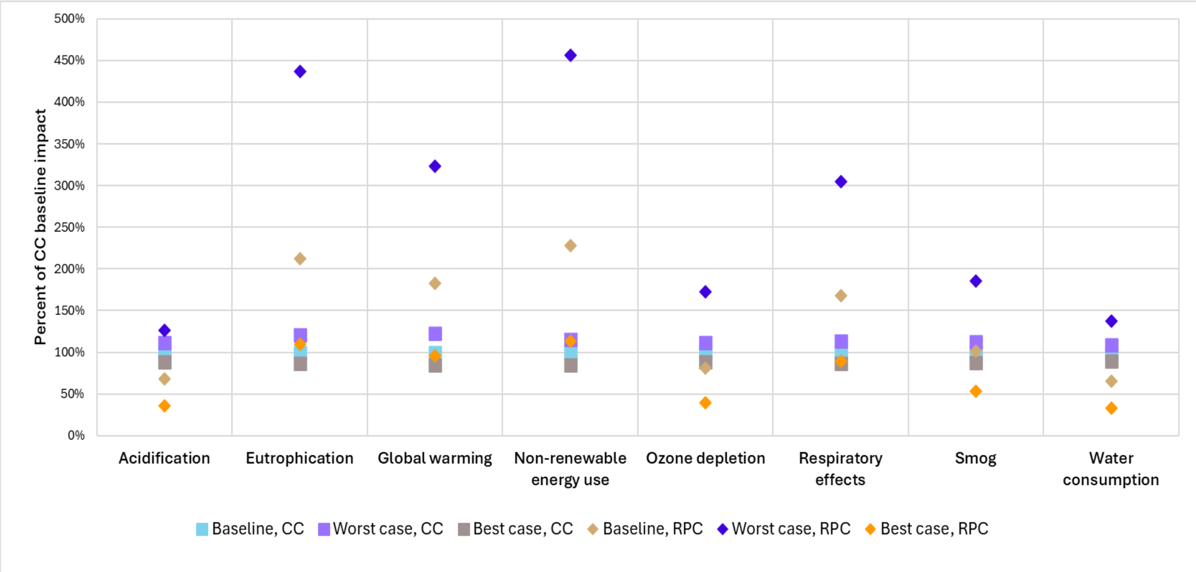
Impact category	Unit	System	Onions	Grapes	Lettuce	Carrot	Apple	Oranges	Tomatoes	Strawberries
Acidification	(kg SO2 eq)	CC	4.9E+02	7.1E+02	4.3E+02	3.5E+02	4.2E+02	4.1E+02	4.3E+02	9.8E+02
		RPC	2.3E+02	4.0E+02	2.4E+02	2.2E+02	2.9E+02	2.9E+02	3.3E+02	7.9E+02
Eutrophication	(kg N eq)	CC	8.4E+01	1.2E+02	7.3E+01	5.9E+01	7.1E+01	7.0E+01	7.3E+01	1.7E+02
		RPC	1.2E+02	2.1E+02	1.3E+02	1.2E+02	1.5E+02	1.5E+02	1.7E+02	4.2E+02
Global warming	(kg CO2 eq)	CC	7.7E+04	1.1E+05	6.7E+04	5.4E+04	6.5E+04	6.5E+04	6.7E+04	1.6E+05
		RPC	9.4E+04	1.6E+05	1.0E+05	9.3E+04	1.2E+05	1.2E+05	1.3E+05	3.3E+05
Non-renewable energy use	(MJ)	CC	1.2E+06	1.7E+06	1.0E+06	8.2E+05	9.8E+05	9.7E+05	1.0E+06	2.4E+06
		RPC	1.8E+06	3.1E+06	1.9E+06	1.7E+06	2.2E+06	2.3E+06	2.5E+06	6.1E+06
Ozone depletion	(kg CFC-11 eq)	CC	3.8E-03	5.5E-03	3.4E-03	2.7E-03	3.3E-03	3.2E-03	3.3E-03	7.7E-03
		RPC	2.1E-03	3.7E-03	2.3E-03	2.1E-03	2.7E-03	2.7E-03	3.0E-03	7.2E-03
Respiratory effects	(kg PM2.5 eq)	CC	4.8E+01	6.9E+01	4.2E+01	3.4E+01	4.1E+01	4.0E+01	4.2E+01	9.8E+01
		RPC	5.5E+01	9.5E+01	5.8E+01	5.4E+01	6.8E+01	6.9E+01	7.8E+01	1.9E+02
Smog	(kg O3 eq)	CC	4.8E+03	6.9E+03	4.2E+03	3.4E+03	4.1E+03	4.0E+03	4.2E+03	9.7E+03
		RPC	3.3E+03	5.7E+03	3.5E+03	3.2E+03	4.1E+03	4.2E+03	4.7E+03	1.1E+04
Water consumption	(m3)	CC	8.5E+02	1.2E+03	7.4E+02	6.0E+02	7.3E+02	7.1E+02	7.4E+02	1.7E+03
		RPC	3.9E+02	6.7E+02	4.0E+02	3.7E+02	4.7E+02	4.8E+02	5.4E+02	1.3E+03

Best- and Worst-Case Results

The best- and worst-case scenarios substantiate these conclusions. In the case of the apple system as depicted in ES Figure 2, the best-case scenario for the RPC system includes the highest reuse rate, lowest break/loss rate, greatest amount of recycled content, shortest transport distances (from growers to retailers, retailers to servicing and servicing back to growers) and state-of-the-art cleaning technology. The worst-case for RPCs applies the opposite ends of these values (e.g., lowest reuse rate), except for the cleaning technology, for which the baseline assumption (composite technology) is used. This is a conservative (favorable) assumption for RPCs.

The best-case for the CC system includes the least container weight, highest recovery rate and shortest transport distances (from growers to retailers); the worst-case evaluates the heaviest container, least amount of recovery and longest transport distances (from growers to retailers). The biogenic carbon accounting scheme and the biogenic carbon storage parameter are excluded from the best- and worst-case scenarios because the purpose of the test is to understand the relative results of RPCs and CCs under varying industry conditions, and the biogenic carbon topics are methodological choices, rather than industry variables.

The results offer a sense for the range of results that could be obtained under various combinations of the different assumptions. One system's worst-case scenario doesn't necessarily have to be preferable to the others' best-case scenario for conclusions to be drawn.



ES Figure 2: Baseline, best and worst-case scenarios for RPCs and CCs containing apples. For each indicator, a score higher than 100% indicates greater impact than the CC baseline results.

Conclusions

In line with the 2019 report which concluded "without prioritizing types of impact, it is not possible to say from the present assessment that one of these systems is an overall better environmental performer than the other in the US market," results from the current study do not indicate that either system is clearly a superior overall environmental performer. It remains true that it is not appropriate to use a count of the number of indicators in which a container system shows less impact to determine the comparative advantage between container types and that the only overarching conclusion that can be made is that there are trade-offs between the systems.

The same opportunities for improvement for the container systems studied exist today as when the 2019 study was undertaken. Impacts from the CC system can be reduced by lowering container weight and enhancing recovery rates. Impacts from the RPC system can be reduced by increasing reuse, incorporating recycled content, minimizing breakage and losses, and reducing transport distances. Reducing transportation distances would reduce impacts for both CCs and RPCs.

Among the factors analyzed, CC weight and RPC transportation distances emerge as the most significant in determining the relative performance of the two container systems. However, even under market conditions that might appear to favor one system over the other, the findings suggest that neither system demonstrates a definitive environmental advantage for most commodity systems.

The findings indicate that variations exist in the comparative results across the assessed impact categories. For a given commodity, the environmental trade-offs between container systems can be predicted based on analyzing the ratio of the container masses required to fulfill the functional unit for each container system. The disparity in container mass needed to transport a specific quantity of produce determines which environmental indicators favor one system over the other.

Both container systems present opportunities for environmental improvement. The CC system can reduce its impact by lowering container weight and enhance recovery rates. Similarly, the RPC system can improve its environmental performance by increasing reuse and recycled content, minimizing breakage and losses, and reducing transport distances.

This study assumes a steady-state market where the containers under evaluation maintain consistent weights and dimensions throughout their functional use. However, it is important to acknowledge that these characteristics may change over time. Furthermore, while not analyzed in this study, custom container designs tailored for specific retailers can lead to inventories of containers with remaining service life when the designs are no longer required. If a system stops operating before the containers reach their useful service lifespan, a larger share of the production and disposal impacts is attributed to that system. Consequently, the impact per container increases, as the associated environmental and resource costs are distributed across fewer usage cycles.

A significant knowledge gap pertains to the proportion of RPCs in the float[3] system. This study adopts a conservative approach, assuming that float constitutes a minimal share (<1%) of the total crate mass in the system. Under this assumption, the environmental impact attributed to float is considered negligible. However, if float represents a substantially larger proportion of the total mass, its contribution to environmental impact could become significant and should be accounted for in studies of this nature.

When integrating the findings of this study with those of other LCAs comparing CCs and RPCs, the overarching conclusion is that environmental trade-offs do indeed exist between the RPC and CC systems. Additionally, market characteristics- subject to regional variations- play a crucial role in shaping these trade-offs. Given the close alignment of outcomes between the two systems in certain impact categories and the sensitivity of the results to certain factors, it is clearly important to model in detail the specific market in question.

[3] Float refers to the quantity of excess RPCs that exist in the total system. These excess RPCs are required to assure the flexibility to respond to surges in system demand or extended time in the return loop.