Research Shows Which PET Water Bottle Design Attributes Impact Recycling

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Overview

Polyethylene terephthalate (PET) water bottles are everywhere. However, brand owners continue to commercialize water in packaging that oftentimes does not meet consumer expectations for convenience and price, nor does it minimize the carbon footprint. The most common strategy deployed by many to meet sustainability initiatives has been to significantly lightweight the PET bottle.

For the first time ever, Beverage Marketing Corp. reported in 2017 that Americans consume more bottled water than carbonated soft drinks. Water is marketed in the lightest PET bottles found on store shelves. Technological enhancements have enabled cost reduction and contributed to positive environmental impact. Many assume that lighter weight will have only positive benefits, but is that the reality?

Since the early 2000s, the weight of a 0.5 L (16.9oz.) water bottle has been reduced in half, possibly pushing acceptance limits for most consumers.

While PET resin suppliers have benefited greatly from the growth of single-serve water bottles, significant research has not been focused on the performance impact and the validation of sustainability assumptions. With industry knowledge and experience being limited in this area, PTI wanted to provide brand owners with additional information to facilitate the decision making process.

What follows are the findings of PTI's research project which help shed more light on performance attributes and recyclability assumptions.

Executive Summary

The study found a wide variation in performance, weight and recyclability in the bottles it examined. All of the packages were commercially-produced for consumers and procured from retail store shelves.

Lighter weight, design and label choices have an impact on post-consumer recovery. The decisions made during the design phase not only have to meet physical performance requirements but also should not negatively impact current recycling systems. While weight reduction results in a lower carbon footprint, it was found that ultra-lightweight bottles can negatively impact the effectiveness of post-consumer packaging waste sorting and recycling systems.

The study showed that many of the samples did not factor in generally-accepted recyclability guidelines during the design process. In some scenarios, the PET package design had strong shelf presence and met the functional requirements. However, the bottle color, label, glue or ink components had a significant impact on package recyclability.

Research Overview

The study was divided into two parts. The first was to analyze how weight affects performance, cost and environmental impact. The second part explores how other design decisions impact recyclability.

The study includes data from the highest bottled water consumption regions where market-leading global brands are sold. These include North America, Latin America (represented by Mexico) Europe and India. The bottle size selected for performance review across all regions was 500mL, sold individually at room temperature.

Performance Evaluation

The bottles were then evaluated for weight, pressure, product volume, fill point, top load, thickness, section weights, color and closure types.

The study showed that there are wide variations in water bottle weights and product volumes, even in small sample sets. Some premium brands prefer to use heavier package, while others continue to lower their bottle weights. However, the performance was not a direct correlation to the weight of the package. All of the samples were procured from the store shelf and showed no obvious signs of leaking or damage.

Although lightweighting seems to have approached the technical limit, new technologies are being used to further reduce weight, compensating structural rigidity with pressurization by nitrogen dosing, overfilling or improved secondary packaging. (Please refer to the chart for pressure data.)

- All of the samples passed the standard performance specifications for water bottles as established by industry recognized guidelines.
- Package weights. Packages evaluated from the United States fell into three categories. There were two premium packages sold in 6-packs. The bottles for these products were still around 22-23 g. Bottles for mid-range priced 24-pack case packages were in the 13 – 17g range. The value-priced bottles sold in 24-pack cases were in the 7.5 – 8.5g range.
    - India bottles were closest to the mid-range U.S. bottles, with weights in the 11.5 – 14.5g range.
    - Europe bottles were also in the mid-range, with weights primarily in the 12 – 16g range. (One of the brands used bottles just under 10g.)
    - Mexico bottles were also in the mid-range, with weights primarily in the 13 – 16g range, although one of them was just under 8g.
- Wall thickness. This attribute generally tracked with bottle weight, although finish size did have some impact, as wall thickness was sometimes traded for a larger finish.
- Pressurization. Most of the U.S. bottles were pressurized. All of the India bottles were pressurized.
- Volumes. Almost all of the bottles had overflow volumes approximately 20 – 30ml higher than their nominal volumes.
- Optical quality. All bottles from all regions were for the most part quite similar in their b values. Bottles without blue tint had b values around 0.5, while those with tint were slightly-to-extremely negative (blue) depending on intensity of the color. There was some variation in haze values across bottles.

Data Tables

The following tables summarize key performance test results by country/continent of bottle sample origin.

Table 1: Testing Summary - U.S. Samples

Sample ID	Closure Wt. (g) Avg.	Bt. Wt. (g) Avg.	Wall Thickness (mm)	Pressure (psi) Avg.	ETLV pk (lb) Avg.	OF Vol. (ml) Avg.	Fill Vol. (ml) Ave.	Color b Avg.	Haze Ave.
A	1.96	13.24	0.150	0.7	12.0	524	507	-0.14	1.45
B	2.56	16.92	0.198	2.0	25.0	517	505	0.65	1.70
C	1.03	8.40	0.130	0.1	4.8	531	519	0.62	2.34
D	0.87	7.69	0.108	4.2	3.7	534	495	0.48	1.46
E	0.85	7.61	0.103	3.8	3.8	537	500	0.53	1.57
F	2.49	23.10	0.316	3.5	54.0	534	522	-0.64	1.64
G	2.65	21.95	0.333	0	31.0	527	517	0.56	1.64

Table 2: Testing Summary - India Samples

Sample ID	Closure Wt. (g) Avg.	Bt. Wt. (g) Avg.	Wall Thickness (mm)	Pressure (psi) Avg.	ETLV pk (lb) Avg.	OF Vol. (ml) Avg.	Fill Vol. (ml) Ave.	Color b Avg.	Haze Ave.
A	NA[1]	14.1	0.11	7.4	13.4	522	516	0.54	3.2
B	NA[1]	11.3	0.08	8.3	4.0	530	507	0.49	1.9
C	NA[1]	13.4	0.07	7.1	9.9	512	503	0.54	3.2
D	NA[1]	14.6	0.12	8.1	12.3	509	503	0.59	2.9

[1]*Closure weights were not available.*

Table 3: Testing Summary - Europe Samples

Sample ID	Closure Wt. (g) Avg.	Bt. Wt. (g) Avg.	Wall Thickness (mm)	Pressure (psi) Avg.	ETLV pk (lb) Avg.	OF Vol. (ml) Avg.	Fill Vol. (ml) Ave.	Color b Avg.	Haze Ave.
A	1.30	9.33	0.090	NA[2]	4.3	527	NA	NA	NA
B	1.83	15.85	0.187	NA[2]	18.2	533	NA	NA	NA
C	2.05	14.34	0.157	NA[2]	11.5	537	NA	NA	NA
D	1.41	12.14	0.152	NA[2]	12.8	534	NA	NA	NA
E	2.06	14.17	0.157	NA[2]	10.4	536	NA	NA	NA
F	1.31	12.77	0.152	NA[2]	13.6	531	NA	NA	NA
G	1.38	13.42	0.147	NA[2]	12.7	527	NA	NA	NA
H	1.39	14.74	0.185	NA[2]	19.2	525	NA	NA	NA
I	2.09	14.90	0.166	NA[2]	17.0	519	NA	NA	NA

[2]The bottles from Europe were shipped to PTI's U.S. lab empty, therefore no pressure or fill volume data is available.

Table 4: Testing Summary - Mexico Samples

Sample ID	Closure Wt. (g) Avg.	Bt. Wt. (g) Avg.	Wall Thickness (mm)	Pressure (psi) Avg.	ETLV pk (lb) Avg.	OF Vol. (ml) Avg.	Fill Vol. (ml) Ave.	Color b Avg.	Haze Ave.
A (600ml)	NA[3]	15.5	0.143	6	7.0	630	597	0.55	3.0
B (600ml)	NA[3]	13.9	0.145	0	9.5	625	608	0.73	3.3
C (500ml)	NA[3]	12.8	0.144	0	10.8	522	508	0.52	2.0
D (600ml)	NA[3]	14.5	0.135	10	8.1	645	598	0.46	2.4
E (500ml)	1.72	14.0	0.163	NA[3]	NA[3]	NA[3]	NA[3]	0.73	5.6
F (600ml)	2.42	26.4	0.336	NA[3]	NA[3]	NA[3]	NA[3]	NA[3]	NA[3]
G (500ml)	0.84	7.7	0.109	NA	NA	NA	NA	0.12	2.8
H (500ml)	2.12	15.6	0.199	NA	NA	NA	NA	-2.96	3.8w
I (600ml)	2.35	19.6	0.214	NA	NA	NA	NA	NA	NA

[3]The bottles from Mexico were mostly 600ml instead of 500ml. Bottles were shipped empty so there are no pressures or fill volumes. Some bottles were damaged in transit, therefore no top load data points were available for those specific samples. Some bottles were missing closures.

Recycling Performance

Following Association of Plastic Recyclers (APR) guidelines, this evaluation showed significant issues with the majority of the bottles tested.

- Five out of the seven U.S. bottle samples and four out of the six European samples will have some issue during the recycling process.
- All of the label samples studied in this research caused color and clarity change in the wash.
- Label bleed was the most common issue observed.
- The substrates chosen for labels varied and paper labels will have more issues with elutriation/air separation.

U.S. Bottle Details

Brand Name	Label Material	Label Type	Label Discolors PET	Adhesive Dissolves	Closure Floats	Label Sinks	Wash Water Discolors
A	Polymer	Wrap Around	N	Y	Y	N	N
B	Polymer	Wrap Around	N	Y	Y	N	N
C	Paper	Wrap Around	N	Y	Y	Y	N
D	Polymer	Wrap Around	Y	Y	Y	N	Y
E	Polymer	Wrap Around	Y	Y	Y	N	Y
F	Polymer + Paper	Adhered Label	N	N	Y	Y	N
G	Polymer	Adhered Label	Y	N	Y	Y	Y

European Bottle Details

Brand Name	Label Material	Label Type	Label Discolors PET	Adhesive Dissolves	Closure Floats	Label Sinks	Wash Water Discolors
H	Polymer	Wrap Around	Y	Y	Y	N	Y
I	Polymer	Wrap Around	N	Y	Y	N	Y
J	Polymer	Wrap Around	Y	Y	Y	N	Y
K	Polymer	Wrap Around	Y	Y	Y	N	Y
L	Polymer	Wrap Around	Y	Y	Y	N	Y
M	Paper	Wrap Around	N	Y	Y	Y	Y

The cells highlighted in yellow are considered to be less favorable for recycling.

The samples that had less than favorable ratings can be improved by the proper choice of ink and adhesive. The use of soluble inks and glues and the specification of the label substrate could have resulted in much better recyclability scores.

There are resources available to designers and brand managers to assist in improving sustainability. APR (Association of Plastic Recyclers), EPBP (European PET Bottle Platform) and SPC (Sustainable Packaging Coalition) have tools and guidelines which can improve the recyclability and sustainability of the package. APR and EBPB have critical guidance protocols and design for recycling guidelines. SPC's Compass(Comparative Packaging Assessment) has tools that provide comparative environmental profiles of packaging alternatives based on life cycle assessment metrics and design attributes.

Conclusion

As mentioned in the executive summary, lightweight bottles can help communicate a positive environmental position. However, the decisions made in the design phase not only have to meet the physical performance but also should not negatively impact the yields realized via current recycling systems. Bottlers must look beyond the bottle itself and include components such as labels, inks and closures to truly understand their impact on the waste stream. For additional information on the research study (expanded findings, data, etc.) please contact: +1-419-867-5400.

About PTI

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