

DO THE BULK AREA AND THE EXTERIOR SURFACE OF MODERN GLASS CONTAINERS EXHIBIT DIFFERENCES IN REFRACTIVE INDEX MEASUREMENTS?

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INTRODUCTION

Refractive index (RI) is a prime property of glass that is measured in the context of comparative examinations between unknown and reference fragments.

A critical aspect of RI measurements is the evaluation of intra-source variation. RI is known to vary at different locations of a given glass object. In addition to spatial heterogeneity, previous studies indicate that differences in RI values could be observed between the external surface and the bulk area of a glass object (Davis *et al.*, 1980; Locke and Hayes, 1984; Zoro *et al.*, 1988; Suzuki *et al.* (2000).

Considering the improvements of modern glass manufacturing processes, this study aims to compare RI data from the external surfaces of glass containers with those collected from their bulk in order to determine if a significant difference exists.

Hypothesis:

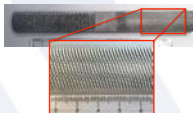
The bulk area and the exterior surface of glass containers exhibit differences in refractive index values.

Objectives:

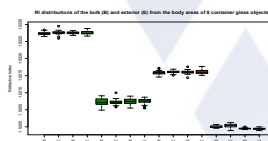
1. Develop a simple and rapid method that properly separates the exterior surface layer from the internal bulk layer.
2. Generate representative RI data from the selected glass containers.
3. Apply a basic statistic that reliably informs about a potential difference between RI data from bulk and exterior of a given glass container.

MATERIALS AND METHODS

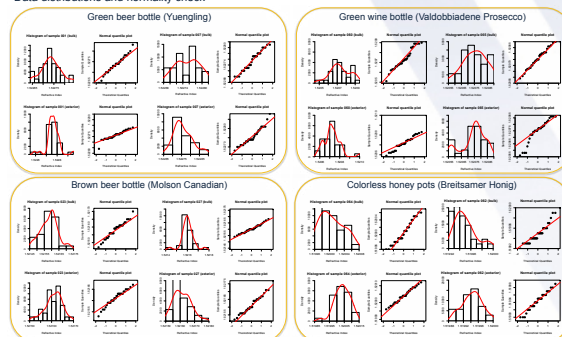
- Eight containers were selected:
 - 2 green beer bottles (Yuengling)
 - 2 green wine bottles (Valdobbadiene Prosecco)
 - 2 brown beer bottles (Molson Canadian)
 - 2 colorless honey pots (Breitsamer Honig)
- Glass objects were smashed: the body area (as opposed to neck, shoulder and base) was considered for this study.
- Separation of bulk and exterior surface of glass object:
 - ⇒ Mortar and pestle for bulk glass
 - ⇒ File for scraping external surface glass (FOG – filing of glass – method)
- RI Measurements carried out using GRIM 3 instrument from Foster & Freeman:
 - 14 fragments selected for each container:
 - 7 from bulk;
 - 7 from exterior;
 - 5 RI measurements per fragment:
 - ⇒ 70 RI measurements per container;
 - ⇒ TOTAL of 560 RI measurements.



RESULTS



Data distributions and normality check



- **Welch's statistic** used to test the differences between RI data between bulk and external surface glass samples:

- a) the number of RI measurements for each glass container relatively small;
- b) known to be robust to deviations from normality (case of our data);
- c) Commonly used for glass RI comparisons.

Hypotheses: $H_0: \mu_b - \mu_e = 0$ and $H_1: \mu_b - \mu_e \neq 0$

Sample	p-value from Welch test	p-value interpretation considering verbal scale in Curran (2010):
Green beer bottle #001	0.0358	
Green beer bottle #007	0.7700	
Green wine bottle #060	0.6401	
Green wine bottle #065	0.6616	
Brown beer bottle #023	0.0254	
Brown beer bottle #027	0.4126	
Colorless honey pot #062	0.3095	
Colorless honey pot #064	0.0036	

If p-value > 0.1
0.05 < p-value < 0.1
0.01 < p-value < 0.05
p-value < 0.001

"There is no evidence against H_0 ."
"There is weak evidence against H_0 ."
"There is evidence against H_0 ."
"There is strong evidence against H_0 ."
"There is very strong evidence against H_0 ."

Differences were observed between:

- a) bulk and exterior from body areas of some of the collected glass containers
- b) glass objects of same type and manufacturer

DISCUSSION

- Although a small number (8) of samples was collected in this study, data obtained show that the glass analyst shall expect variations between the bulk and the external surface of glass containers.
- Glass objects were selected in pairs (same type and manufacturer): in three pairs out of four, one container did not exhibit differences between bulk and exterior while its similar object did. This indicates that RI differences between bulk and exterior may not be predictable given a particular container.
- The relatively low number of 14 fragments per container measured in this study is comparable to the number of fragments that may be recovered in casework. The number of recovered fragments affects the number of reference fragments to be sampled if t-test or Welch tests are to be used, in the sense that if an unbalanced number of questioned and reference fragments are measured, then the standard error in the denominator of the Welch statistic would be biased (Curran *et al.*, 2000). This implies the necessity to collect an adequate number of reference fragments and a desideratum of this study is that glass analysts would consider bulk and exterior while sampling from reference glass.

CONCLUSION

- This study showed the RI differences between bulk and exterior areas from glass containers.
- A method for isolating micro-fragments from a glass surface was developed.
- It is recommended that sampling from both bulk and exterior is sampled from reference glass sources.

REFERENCES

- Curran J.M., Hicks T., Buckleton J. Forensic Interpretation of Glass Evidence. Taylor & Francis, CRC Press, Boca Raton, FL (2000).
- Curran J.M. Introduction to Data Analysis with R for Forensic Scientists. CRC Press, Boca Raton, FL (2010).
- Davies M.M., Dudley R.J., Smalton K.W. An investigation of bulk and surface refractive indices for flat window glasses, patterned window glasses and windscreen glasses. Forensic Science International 1980, 16(2):125-137.
- Locke J., Hayes C.A. Refractive index variations across glass objects and the influence of annealing. Forensic Science International 1984, 26(2):147-157.
- Suzuki Y., Sugita R., Suzuki S., Marumo Y. Forensic discrimination of bottle glass by refractive index measurement and analysis of trace elements with ICP-MS. Analytical Sciences – The Japan Society for Analytical Chemistry 2000(16): 1156-1158.
- Zoro J.A., Locke J., Day R.S., Badmus O., Perryman A.C. An investigation of refractive index anomalies at the surfaces of glass objects and windows. Forensic Science International 1988, 38(2):127-141.

