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Quantitative divergence between refractometric total soluble solids (°Brix) and label-declared values in commercial fruit beverages: implications for screening

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ABSTRACT

Refractometric determination of total soluble solids (°Brix) is widely used as a rapid analytical tool in fruit beverage quality control. However, °Brix represents the cumulative concentration of all soluble constituents, rather than sugars alone, and therefore is not directly comparable to label-declared sugar or carbohydrate values. This study aimed to quantify the magnitude, direction, and variability of divergence between refractometrically determined °Brix values and label-declared sugar or carbohydrate values in commercial non-carbonated fruit beverages and to evaluate the analytical behavior of °Brix as a screening indicator across different beverage categories. Thirty commercially available fruit beverages (local and imported) were sampled from retail markets in Peja, Kosovo. Total soluble solids were measured using a calibrated digital refractometer, and declared nutritional values were extracted from product labels. Measured soluble solids ranged from 2.7 to 13.2 g/100 mL, while declared sugar or carbohydrate values ranged from 5.9 to 13.3 g/100 mL. The mean measured °Brix value was 9.47 ± 2.83 g/100 mL, compared with 8.72 ± 2.09 g/100 mL for declared values. The mean bias (°Brix − label value) was +0.75 ± 2.31 g/100 mL, with with wide dispersion (−6.3 to +4.4 g/100 mL). A moderate positive correlation was observed ($r = 0.608$). Bland–Altman analysis demonstrated substantial and formulation-dependent divergence rather than analytical agreement between the variables. Because °Brix and label-declared sugar or carbohydrate values represent non-equivalent analytical constructs, the results should be interpreted as exploratory screening data rather than method-comparison outcomes. Refractometric °Brix measurement is useful as a rapid compositional screening tool but cannot independently assess labelling accuracy without complementary chemical analyses.

Keywords: fruit juice, sugar content, °Brix, refractometry

INTRODUCTION

Refractometric determination of total soluble solids (TSS), expressed as °Brix, is one of the most widely applied rapid analytical tools in fruit juice quality control and industrial processing **[1]**, and **[2]**. Originally developed to estimate sucrose concentration in aqueous solutions, refractometry is now routinely used for monitoring fruit maturity, concentration processes, and batch consistency in fruit-based beverages and juices **[3]**, **[4]**, and **[5]**. Its widespread use is primarily due to rapid measurement, minimal sample preparation, and non-destructive operation.

In fruit matrices, however, °Brix reflects the cumulative refractive contribution of all dissolved solids rather than sugars alone. In addition to glucose, fructose, and sucrose, several other soluble components including organic acids, soluble pectins, amino acids, and mineral ions—contribute to refractive index measurements, **[6]**, **[7]**, and **[8]**. Consequently, °Brix values represent total soluble solids and are not chemically equivalent to sugar concentration. The magnitude of divergence between °Brix and actual sugar content depends on fruit composition, processing conditions, and beverage formulation **[9]**. At the same time, regulatory and nutritional labelling frameworks require declaration of sugars or total carbohydrates rather than total soluble solids. For example, Codex Alimentarius standards define minimum °Brix values primarily as indicators of juice authenticity rather than nutritional composition **[10]**, while European Union food information regulations mandate the reporting of sugars or carbohydrates on product labels **[11]**. As a result, refractometric measurements and label-declared nutritional values represent related but fundamentally non-equivalent analytical constructs. Most previous studies in fruit beverage analyses have focused on precise quantification of individual sugars using chromatographic techniques such as high-performance liquid chromatography (HPLC) or gas chromatography (GC) **[12]**, **[13]**, and **[14]**, or on authenticity and adulteration detection using isotopic or spectroscopic methods **[15]**, **[16]**, and **[17]**. While these approaches provide high analytical precision, they often require sophisticated instrumentation and extensive sample preparation. In contrast, relatively little research has explored the use of refractometry as a rapid screening method to evaluate the relationship between °Brix values and declared sugar content across heterogeneous commercial beverage categories.

Modern beverage markets include a wide range of formulations, including 100% fruit juices, nectars, fruit drinks and beverages produced from concentrate. **[18]**, **[19]**, and **[20]**. These products differ substantially in composition, dilution, and ingredient structure, which may influence the relationship between measured °Brix values and declared nutritional parameters. Importantly, divergence between these variables is analytically expected and does not in itself indicate labelling inaccuracy.

The knowledge gap addressed in this study is therefore not whether °Brix equals sugar content, but how large, variable, and formulation-dependent the divergence between refractometric measurements and label-declared values is under real market conditions. Understanding this relationship is important for evaluating the practical use of refractometry as a rapid screening tool in quality control and market surveillance contexts, particularly in resource-limited analytical environments.

In the present study, refractometric °Brix values were compared with nutritional information obtained from product labels. Most products reported sugar content, while a small number reported total carbohydrates. For analytical consistency, these values were treated as a unified label-declared variable, while acknowledging their non-equivalence.

Scientific Hypothesis

There is a measurable divergence between refractometrically determined total soluble solids (°Brix) and label-declared values in commercial fruit beverages, and the magnitude and direction of this divergence vary according to beverage formulation.

Objectives

This study aimed to quantify the magnitude, direction, and variability of divergence between refractometrically determined °Brix and label-declared values in commercial non-carbonated fruit beverages and to evaluate the behaviour of °Brix as a rapid screening indicator across different beverage categories.

MATERIAL AND METHODS

Samples

Samples description: Thirty commercial non-carbonated fruit beverage products representing different formulation categories were purchased from retail markets. Products were selected to reflect the diversity of beverages available to consumers, including locally produced and imported brands. Beverages were grouped into three categories based on label description: (i) 100% fruit juices, (ii) fruit nectars/fruit beverages, and (iii) juices from concentrate. These categories reflect market labelling and product positioning rather than strictly standardized analytical classifications and were used as pragmatic groupings for exploratory comparison. The distribution of analyzed beverage samples by category and labelling information is shown in Table 1.

Table 1 Distribution of analyzed beverage samples by category and labelling information.

Beverage category	Number of samples	Label parameter reported	Typical fruit types
100% fruit juices	12	Sugars (g/100 mL)	Apple, orange, sour cherry
Fruit nectars / fruit beverages	8	Sugars (g/100 mL)	Peach, strawberry, mixed fruit
Juices from concentrate	10	Sugars (8 samples); carbohydrates (2 samples)	Apple, orange, mixed fruit
Total	30	Sugars (28); Carbohydrates (2)	Multiple fruit types

In 28 products, the nutritional label reported sugars (g/100 mL), while in two products only total carbohydrates were declared. Because sugars represent a subset of total carbohydrates, these variables are not chemically equivalent. For statistical comparison, they were combined into a single label-declared variable to allow comparison across all samples; however, this simplification was considered in the interpretation of results. Where available, additional label information (e.g., fruit content, presence of added sugars, stabilizers, or concentrates) was recorded qualitatively to support interpretation of compositional differences between products. Examples of representative products analysed in the present study are shown in Figure 1.

Figure 1 Representative commercial fruit beverage products included in the study prior to refractometric analysis.

Samples collection: Samples were purchased from retail supermarkets and food stores in Kosovo. All products were stored at room temperature and analysed within their recommended shelf-life period.

Samples preparation: Samples were homogenised by gentle shaking before analysis. Approximately 10 mL of each beverage sample was used for refractometric measurement.

Number of samples analysed: A total of 30 beverage samples were analysed.

Chemicals

No additional chemical reagents were required for refractometric determination of soluble solids.

Animals, Plants and Biological Materials

Fruit beverages derived from plant sources including *Malus domestica* (apple), *Citrus sinensis* (orange), *Prunus persica* (peach), and mixed fruit preparations were analysed.

Instruments

Total soluble solids were measured using a digital refractometer (ATAGO pr-32 alpha, Tokyo, Japan) with automatic temperature compensation.

Laboratory Methods

Total soluble solids were determined according to the ISO 2173:2003 refractometric method for fruit and vegetable products **[1]**. Measurements were performed at 20 °C using a digital refractometer with automatic temperature compensation.

Description of the Experiment

Study flow: The study consisted of three sequential phases:

1. collection of commercial fruit beverage samples from retail markets,
2. determination of total soluble solids using refractometry,
3. statistical evaluation of divergence between measured °Brix values and label-declared values.

Quality Assurance

Number of repeated analyses: Each sample was measured in triplicate using independent aliquots, and the mean value was used for statistical evaluation.

Number of experiment replication: The measurement procedure was repeated independently for each sample.

Reference materials: The refractometer was calibrated with distilled water (0 °Brix) prior to each measurement session and verified against commercial sucrose calibration standards within the expected measurement range, according to manufacturer recommendations**.**

Calibration: Calibration was performed before each measurement session. Instrument performance was verified using sucrose reference solutions across the expected analytical range (5–15 °Brix).

Laboratory accreditation: The analyses were conducted in a university laboratory following standard analytical procedures; however, the laboratory is not formally accredited.

Data Access

Data supporting the findings of this study are available from the corresponding author upon reasonable request.

Statistical Analysis

Statistical analysis was performed using IBM SPSS Statistics version 26 (IBM Corp., USA). Descriptive statistics included mean values, standard deviations, and ranges for both refractometric °Brix measurements and label-declared values. Linear regression analysis was used to evaluate the association between refractometrically measured °Brix values and label-declared value. The strength of the relationship was expressed using the Pearson correlation coefficient (r) and coefficient of determination (R^2).

Distribution of differences and magnitude of divergence between the variables were explored using Bland–Altman analysis **[21]**, **[22]**. This approach allows visualization of systematic bias and dispersion between two quantitative measurements. In the present study, Bland–Altman analysis was used as an exploratory method to evaluate divergence patterns rather than to imply analytical equivalence between the two variables. Bias between measurements was calculated as Bias = °Brix − label-declared value

Positive bias indicates higher measured soluble solids relative to declared values, while negative bias indicates the opposite. Ninety-five percent confidence intervals (95% CI) were calculated for the mean bias and limits of agreement. Each sample was analyzed in triplicate (technical replicates) and the mean value was used for statistical analysis. Statistical significance was set at $p < 0.05$.

Reporting and transparency statement

The sample size was determined by the market availability of commercial products. Triplicate measurements represent technical replication of each sample. No samples were excluded from analysis. No data transformation or post-hoc data modification was performed. Randomization and blinding were not applicable because the study involved analytical measurements of commercial products.

A sensitivity analysis was performed by excluding the two products that reported total carbohydrates instead of sugars to assess their influence on overall bias estimates. This exclusion did not materially change the observed patterns of divergence.

RESULTS AND DISCUSSION

A total of 30 fruit beverages (20 local and 10 imported) were analyzed. As shown in Table 2, measured soluble solids content (°Brix) ranged from 2.7 to 13.2 g/100 mL, while label-declared values ranged from 5.9 to 13.3 g/100 mL. The overall mean measured °Brix was 9.47 ± 2.83 g/100 mL, whereas the mean label-declared value was 8.72 ± 2.09 g/100 mL. The mean difference (bias) between measured and declared values was +0.75 ± 2.31 g/100 mL. Across all samples, divergence ranged from −6.3 to +4.4 g/100 mL, indicating substantial variability between refractometric measurements and label-declared values.

Table 2 Overall descriptive statistics of measured °Brix and label-declared values (n = 30).

Parameter	Mean	SD	Minimum	Maximum
Measured °Brix (g/100 mL)	9.47	2.83	2.7	13.2
Label-declared values (g/100 mL)	8.72	2.09	5.9	13.3
Bias (°Brix − Label-declared value)	0.75	2.31	−6.3	4.4

When stratified by beverage type, 100% juices generally showed relatively narrow dispersion positive bias (°Brix > label-declared value). Nectars and fruit beverages showed moderate variability, while juices from concentrate showed wider dispersion and included both positive and negative divergence.

These observations suggest that the magnitude and direction of divergence are influenced by formulation characteristics; however, given the limited subgroup sizes, these patterns should be interpreted as descriptive tendencies rather than definitive category-level differences.

Subgroup descriptive statistics by beverage category are presented in Table 3.

Table 3 Subgroup descriptive statistics of refractometric °Brix and label-declared values by beverage category.

Beverage category	n	Mean °Brix (g/100 mL)	Mean label-declared value (g/100 mL)	Mean bias (°Brix − label-declared) (g/100 mL)
100% fruit juices	10	11.52 ± 0.72	9.57 ± 1.06	+1.95 ± 0.72
Fruit nectars / beverages (including products from concentrate)	20	8.45 ± 3.03	8.30 ± 2.24	+0.16 ± 2.61
Total	30	9.47 ± 2.83	8.72 ± 2.09	+0.75 ± 2.31

100% fruit juices exhibited higher mean °Brix values and a more consistent positive bias (+1.95 g/100 mL), whereas fruit nectars and beverages showed lower mean °Brix values and substantially greater variability in bias. These findings support the formulation-dependent nature of divergence between refractometric and label-declared values.

Bias explanation: Positive bias indicates higher measured total soluble solids relative to label-declared values, while negative bias indicates the opposite. The presence of both positive and negative divergence confirms that the relationship between °Brix and label-declared values is not unidirectional.

Regression analyses: The relationship between refractometric °Brix measurements and label-declared values is presented in Figure 2. A moderate positive correlation was observed (r = 0.608, $R^2 = 0.37$), indicating that beverages with higher declared values tend to exhibit higher °Brix measurements. However, the relatively low coefficient of determination ($R^2 = 0.37$) indicates that a substantial proportion of variability remains unexplained, suggesting that additional compositional factors influence refractometric readings. Several samples deviated from the general trend, including beverages with lower °Brix values relative to their label-declared values, highlighting the influence of formulation and matrix composition.

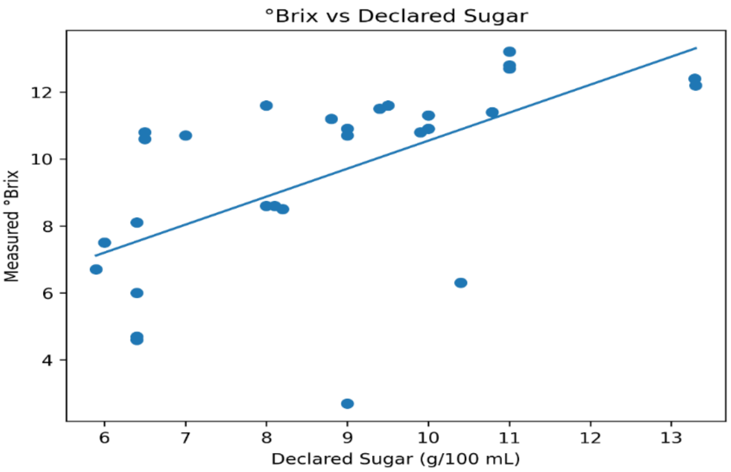

Figure 2 Relationship between measured °Brix values and label-declared values in analyzed beverages. The scatter plot demonstrates a moderate positive correlation between the two parameters (r = 0.608, $R^2 = 0.37$).

Bland–Altman Comparison analysis: To further examine agreement between refractometric measurements and label-declared values, a Bland–Altman analysis was performed (Figure 3). The plot illustrates the distribution of differences (°Brix − label-declared value) against the mean of the two variables. The mean bias was +0.75 g/100 mL, with approximate 95% limits of divergence ranging from −3.8 to +5.3 g/100 mL. The analysis demonstrates substantial dispersion across the measurement range, indicating that divergence between the variables is variable and formulation-dependent revealed that most beverages were distributed around the mean difference. Because the two variables represent non-equivalent analytical constructs, this analysis should be interpreted as a visualization of divergence patterns rather than analytical agreement.

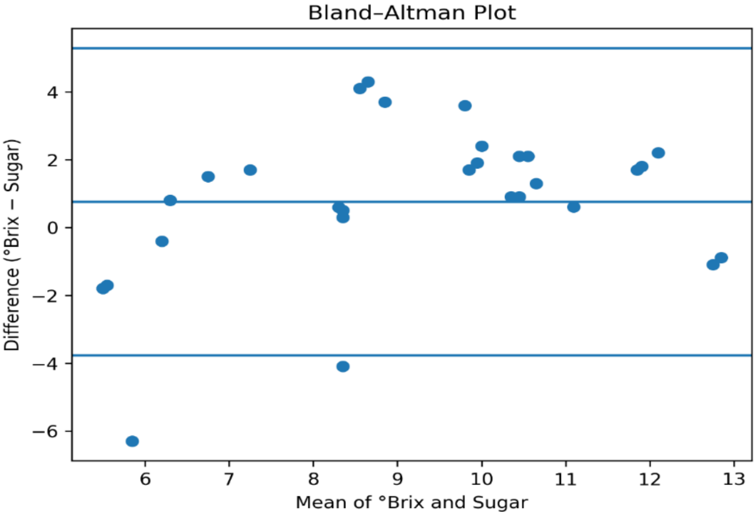

Figure 3 Bland–Altman plot showing agreement between measured °Brix values and label-declared values.

Origin comparison: The distribution of difference according to product origin is shown in Figure 4. Local beverages appeared to exhibit greater variability and a wider range of divergence compared with imported beverages. However, this observation is descriptive and may be influenced by differences in beverage category, formulation, and product composition. Therefore, no causal interpretation can be drawn from this comparison

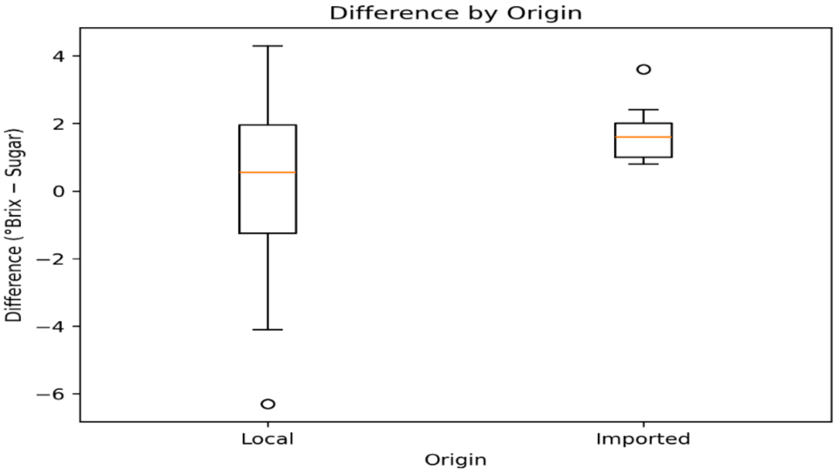

Figure 4 Distribution of the difference between °Brix and label-declared values in local and imported beverages.

Analytical Interpretation of Divergence: The present findings demonstrate that divergence between refractometric °Brix measurements and label-declared values is heterogeneous and strongly dependent on beverage formulation. In most 100% fruit juices included in the study, measured °Brix values exceeded label-declared values, which is consistent with the compositional principle that refractometric measurements represent total soluble solids rather than sugars alone. In addition to mono- and disaccharides, fruit-based matrices contain organic acids, soluble pectins, amino acids, and mineral constituents, all of which contribute to refractive index measurements **[6]**, and **[23]**. Published compositional studies indicate that non-sugar soluble components may contribute approximately 0.3–1.5 °Brix units, depending on fruit type, maturity, and processing conditions **[24]**, **[25]**, and **[26]**. The magnitude of positive divergence observed in the present dataset falls within this range and is therefore consistent with expected compositional characteristics of fruit beverages rather than indicative of analytical inconsistency.

At the same time, negative divergence (label-declared value exceeding °Brix) was observed in several samples. This finding highlights that divergence is not unidirectional and may arise from multiple factors, including formulation differences, dilution practices, label rounding tolerances, and the intrinsic limitations of refractometric measurements in complex sugar–acid systems. Nutritional labelling regulations permit rounding of declared values, which may contribute to small discrepancies when expressed per 100 mL **[11]**. These observations reinforce that °Brix and label-declared values represent related but non-equivalent analytical constructs.

Matrix effects and compositional complexity: The relationship between refractometric measurements and sugar content is further influenced by matrix effects inherent to fruit beverages. Refractometry is based on the measurement of refractive index, which is affected not only by solute concentration but also by the chemical nature of dissolved compounds. Different sugars (glucose, fructose, sucrose) and organic acids exhibit distinct refractive properties, and their combined presence results in non-linear contributions to °Brix values. In addition, the conversion of refractive index to °Brix assumes sucrose equivalence, which introduces systematic uncertainty when applied to mixed sugar systems typical of fruit beverages. The presence of pulp, stabilizers, and other soluble or colloidal components may further influence light propagation and refractive index measurements. These factors collectively contribute to variability in the relationship between °Brix and actual sugar concentration and help explain the dispersion observed in the present study.

Category-Dependent Behaviour: Differences observed between beverage categories further support the formulation-dependent nature of refractometric measurements. While 100% fruit juices tended to show relatively consistent positive divergence, beverages such as nectars and products derived from concentrate exhibited greater variability. These products often differ in fruit content, dilution level, and ingredient composition, which may alter both the concentration and the type of soluble constituents. Codex Alimentarius establishes minimum °Brix standards for certain fruit juices as indicators of authenticity and compositional integrity **[10]**. In the present study, several beverages labelled as 100% fruit juices exhibited °Brix values within the ranges commonly reported for fruit juices such as apple and orange in compositional studies **[27]**, and **[28]**. This supports the interpretation that refractometric measurements broadly reflect expected soluble solids levels for these products.

Unlike natural fruit juices, beverages such as nectars and products derived from concentrate, may contain lower concentrations of naturally occurring soluble solids and additional ingredients that influence refractive index measurements.

The inclusion of multiple beverage categories in the present study therefore reflects the diversity of commercial fruit beverages and strengthens the practical relevance of the findings. At the same time, the results highlight the importance of formulation-specific interpretation when using refractometric measurements for rapid compositional screening. Previous compositional studies have reported that soluble solids measurements in fruit beverages are influenced by fruit variety, processing conditions, and the presence of additional soluble constituents such as organic acids and phenolic compounds **[3]**, **[7]**, **[9], **and **[23]**. It is important to note that the category definitions used in this study reflect market labelling rather than strictly standardized analytical classifications. Consequently, the observed category-level differences should be interpreted as descriptive tendencies rather than definitive compositional distinctions.

Method-Comparison Interpretation and Statistical Considerations: Regression analysis demonstrated a clear association between measured °Brix values and label-declared values, however, the relatively low coefficient of determination ($R^2 = 0.37$) indicates that a substantial proportion of variability remains unexplained. This finding suggests that refractometric measurements have limited predictive value for estimating label-declared values in heterogeneous beverage matrices.

Similarly, Bland–Altman analysis revealed wide limits of divergence, indicating that differences between the two variables vary considerably across the measurement range. Because °Brix and label-declared values do not measure the same analytical parameter, this analysis should not be interpreted as evidence of agreement, but rather as a visualization of divergence structure. This interpretation is consistent with the original methodological framework of Bland–Altman analysis **[21]** and **[22]**. Refractometric measurements provide an integrated estimate of total soluble solids, whereas chromatographic methods such as high-performance liquid chromatography remain the preferred analytical techniques for precise quantification of individual sugars in fruit beverages **[12]**, and **[13]**. Nevertheless, refractometry remains widely used in food analysis due to its rapid measurement time, minimal sample preparation, and low operational cost.

Practical and methodological relevance: The present study provides applied evidence that °Brix cannot be directly equated with nutritional sugar values across diverse beverage formulations. Rather than proposing a new analytical method, the study characterizes the magnitude and variability of divergence under real market conditions. This distinction is particularly relevant for laboratories operating in resource-limited environments, where refractometry is widely used due to its rapid measurement, minimal sample preparation, and low operational cost. The results indicate that °Brix measurements may serve as an initial screening indicator to identify samples that deviate substantially from expected compositional ranges and may warrant further investigation using more specific analytical methods.

Public Health and Quality-Control Relevance: Although the present study does not assess regulatory compliance, the findings highlight the importance of appropriate interpretation of rapid analytical measurements in food quality control. Refractometry may support preliminary screening and market surveillance activities, but results must be interpreted in the context of formulation and matrix composition.

Limitations

The present study has several limitations that should be considered when interpreting the findings. First, the analysis relied exclusively on refractometric measurements without confirmatory chromatographic profiling of individual sugars. High-performance liquid chromatography would provide more precise characterization of sugar composition and enable direct comparison with refractometric measurements. Second, only a single batch of each product was analysed, which does not allow assessment of potential batch-to-batch variability during industrial production. In addition, the relatively small subgroup sizes within beverage categories limit the statistical robustness of category-level comparisons. Third, the study relied on label-declared values obtained from product packaging. These values may be influenced by permitted rounding tolerances (typically ±0.5 g/100 mL) and therefore may not exactly reflect true compositional values. Another limitation relates to the geographic scope of sampling, as all beverages were obtained from a single national retail market, which may limit the generalizability of the findings to broader international contexts. Finally, refractometric measurements assume sucrose equivalence when converting refractive index to °Brix values, which may introduce additional variability in beverages containing mixed sugar systems and other soluble constituents **[14]**.

CONCLUSION

Refractometric determination of °Brix provides a rapid and accessible estimate of total soluble solids in commercial fruit beverages. In the present study, measured °Brix values ranged from 2.7 to 13.2 g/100 mL, whereas label-declared values ranged from 5.9 to 13.3 g/100 mL, with a mean bias of +0.75 ± 2.31 g/100 mL (range −6.30 to +4.40 g/100 mL). The results of the present study demonstrate that divergence between measured °Brix values and label-declared values occurs across beverage categories and is strongly influenced by formulation. This divergence is analytically expected, as refractometric measurements reflect total soluble solids rather than sugar content alone. These findings confirm that °Brix measurements have limited predictive value for estimating label-declared values but can serve as a practical screening tool for rapid compositional assessment. However, refractometric results must be interpreted in the context of beverage formulation and matrix composition and cannot be used independently to assess labelling accuracy or regulatory compliance. More specific analytical techniques, such as chromatographic sugar profiling, remain necessary for precise quantification and regulatory verification. Nevertheless, refractometry represents a useful first-line analytical approach for identifying samples that may require further investigation in heterogeneous beverage markets. Future studies incorporating chromatographic sugar profiling alongside refractometric measurements would provide a more detailed understanding of the relationship between total soluble solids and individual sugar components. In addition, larger datasets and standardized category definitions would improve the robustness of formulation-specific interpretations.

REFERENCES

1. ISO. (2003). ISO 2173: Fruit and vegetable products—Determination of soluble solids—Refractometric method. Geneva: International Organization for Standardization.
2. International Fruit and Vegetable Juice Association (IFU). (2020). Determination of soluble solids (°Brix) in fruit juices (IFU Method No. 8). Paris: IFU.
3. Magwaza, L. S., & Opara, U. L. (2015). Analytical methods for determination of sugars and sweetness of horticultural products—A review. Scientia Horticulturae, 184, 179–192. https://doi.org/10.1016/j.scienta.2015.01.001
4. Jaywant, S. A., Singh, H., & Arif, K. M. (2022). Sensors and instruments for Brix measurement: A review. Sensors, 22(6), 2290. https://doi.org/10.3390/s22062290
5. AOAC International. (2019). Official methods of analysis (21st ed.). Gaithersburg, MD: AOAC International.
6. Lee, H. S., & Coates, G. A. (2003). Relationship between soluble solids and fruit juice quality. Journal of Food Science, 68(4), 1424–1428.

7. Kelebek, H., & Selli, S. (2011). Determination of sugars, organic acids, and phenolic compositions of orange juice. Food Chemistry, 127(2), 709–715. https://doi.org/10.1016/j.foodchem.2010.12.024
8. Chen, L., Zhao, J., Zhang, H., & Liu, Y. (2018). Determination of individual sugars in fruit juices using HPLC-RID. Food Analytical Methods, 11(4), 1132–1140. https://doi.org/10.1007/s12161-017-1099-4
9. Iglesias, I., & Echeverría, G. (2009). Differential effect of cultivar and harvest date on fruit quality and sensory attributes of apple juice. Postharvest Biology and Technology, 52(3), 258–265. https://doi.org/10.1016/j.postharvbio.2008.11.009
10. Codex Alimentarius Commission. (2005). General standard for fruit juices and nectars (CODEX STAN 247-2005). Rome: FAO/WHO.
11. European Parliament and Council. (2011). Regulation (EU) No 1169/2011 on the provision of food information to consumers. Official Journal of the European Union, L304, 18–63.
12. Walker, R. W., Dumke, K. A., & Goran, M. I. (2014). Fructose content in popular beverages made with and without high-fructose corn syrup. Nutrition, 30(7–8), 928–935. https://doi.org/10.1016/j.nut.2014.04.003
13. Ventura, E. E., Davis, J. N., & Goran, M. I. (2011). Sugar content of popular sweetened beverages based on objective laboratory analysis: Focus on fructose content. Obesity, 19(4), 868–874. https://doi.org/10.1038/oby.2010.255
14. Sadeghi, F., Mohammadi, A., & Javidipour, I. (2021). Evaluation of sugar content in commercial fruit juices and beverages. Food Chemistry, 343, 128468. https://doi.org/10.1016/j.foodchem.2020.128468
15. Kelly, S., Heaton, K., & Hoogewerff, J. (2005). Tracing the geographical origin of food: The application of multi-element and multi-isotope analysis. TrAC Trends in Analytical Chemistry, 24(3), 212–221. https://doi.org/10.1016/j.trac.2004.11.006
16. Rossmann, A. (2001). Determination of fruit juice authenticity by isotope ratio mass spectrometry. Food Reviews International, 17(3), 347–381. https://doi.org/10.1081/FRI-100104705
17. Cordella, C., Moussa, I., Martel, A. C., Sbirrazzuoli, N., & Lizzani-Cuvelier, L. (2002). Recent developments in food characterization and adulteration detection using spectroscopic techniques. TrAC Trends in Analytical Chemistry, 21(6–7), 487–497. https://doi.org/10.1016/S0165-9936(02)00608-9
18. Popkin, B. M., & Hawkes, C. (2020). Sweetening of the global diet, particularly beverages: Patterns, trends, and policy responses. The Lancet Diabetes & Endocrinology, 8(2), 174–186. https://doi.org/10.1016/S2213-8587(19)30377-1
19. Malik, V. S., Popkin, B. M., Bray, G. A., Després, J. P., & Hu, F. B. (2010). Sugar-sweetened beverages and risk of metabolic syndrome and type 2 diabetes. Diabetes Care, 33(11), 2477–2483. https://doi.org/10.2337/dc10-1079
20. World Health Organization. (2015). Guideline: Sugars intake for adults and children. Geneva: WHO.
21. Bland, J. M., & Altman, D. G. (1986). Statistical methods for assessing agreement between two methods of clinical measurement. The Lancet, 327(8476), 307–310. https://doi.org/10.1016/S0140-6736(86)90837-8
22. Giavarina, D. (2015). Understanding Bland–Altman analysis. Biochemia Medica, 25(2), 141–151. https://doi.org/10.11613/BM.2015.015
23. Rydén, P., Andersson, R., & Åman, P. (2019). Comparison of refractometry and chromatographic methods for sugar determination in fruit juices. Journal of Food Composition and Analysis, 77, 1–7.
24. Kader, A. A. (2002). Fruit maturity indices. In A. A. Kader (Ed.), Postharvest technology of horticultural crops (pp. 39–47). University of California Agriculture and Natural Resources.
25. Wrolstad, R. E., Acree, T. E., Decker, E. A., Penner, M. H., Reid, D. S., Schwartz, S. J., Shoemaker, C. F., Smith, D. M., & Sporns, P. (2005). Handbook of food analytical chemistry. Wiley. https://doi.org/10.1002/0471709085
26. Nielsen, S. S. (2017). Food analysis (5th ed.). Springer. https://doi.org/10.1007/978-3-319-45776-5
27. Kowalczyk, A., Jeżowski, P., Sęczyk, Ł., et al. (2020). Physicochemical properties of commercial apple juices. Processes, 8(11), 1457. https://doi.org/10.3390/pr8111457
28. Bates, R. P., Morris, J. R., & Crandall, P. G. (2001). Principles and practices of small- and medium-scale fruit juice processing. FAO Agricultural Services Bulletin No. 146. Rome: Food and Agriculture Organization of the United Nations.

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AI Statement:

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