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Comparative Determination of Total Carbohydrate Content in Mango, Orange, and Banana Fruits in Ugbokolo, Nigeria Using the Anthrone Method.

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Abstract

Carbohydrates are essential macronutrients and a primary source of dietary energy, with fruits playing a significant role in human nutrition. This study aimed to determine and compare the total carbohydrate content of three widely consumed tropical fruits—mango (*Mangifera indica*), orange (*Citrus sinensis*), and banana (*Musa spp.*)—sourced from Ugbokolo, Nigeria. Using the anthrone colorimetric method, fruit samples were hydrolyzed with 2.5 M hydrochloric acid and reacted with anthrone reagent under acidic conditions. Glucose standards were used to generate a calibration curve, and the absorbance of the fruit extracts was measured spectrophotometrically at 620 nm. The resulting carbohydrate content was calculated and expressed in grams per 100 grams of fresh weight (g/100 g). Banana exhibited the highest carbohydrate content (9.4 g/100 g), followed by mango (6.7 g/100 g), and orange (5.2 g/100 g). These values were lower than standardized international data, likely due to differences in cultivar, ripeness level, and agroecological factors. Statistical analysis using one-way ANOVA confirmed significant differences among the fruit types ($p < 0.05$). The findings provide region-specific insights into the nutritional profiles of these fruits and reinforce their dietary importance in energy provision and nutritional planning, especially in rural Nigerian communities. This study supports the relevance of local food composition data in addressing context-specific dietary needs and public health nutrition. Further research should explore sugar composition, fiber content, and varietal effects using advanced analytical methods to enhance the accuracy and applicability of nutritional assessments.

Keywords: Carbohydrate content; Anthrone method; Human nutrition; Tropical fruits

1.0 Introduction

Carbohydrates are essential macronutrients that serve as the primary energy source for human metabolism, contributing significantly to daily caloric intake [1]. Found abundantly in fruits, cereals, legumes, and tubers, carbohydrates play critical physiological roles, including glucose regulation, gut health maintenance, and prevention of chronic diseases [2], [3]. Among natural food sources, fruits are particularly valuable due to their content of simple sugars such as glucose, fructose, and sucrose, along with dietary fibers and bioactive compounds [4]. These constituents make fruits ideal for dietary inclusion, especially in the context of balanced and functional nutrition.

Despite the known health benefits of fruits, the carbohydrate composition of different fruit species can vary considerably based on genetic, environmental, and agronomic factors [5]. Accurate carbohydrate profiling in commonly consumed fruits is crucial for nutritional labeling, diabetic dietary planning, public health education, and regional food composition databases [6]. In this context, banana (*Musa spp.*), mango (*Mangifera indica*), and orange (*Citrus sinensis*) are among the most widely consumed tropical fruits globally and in Nigeria. They are not only popular due to taste but are also valuable for their vitamin, fiber, and energy content [7]–[9].

Analytical quantification of carbohydrates in fruits has been performed using various techniques such as high-performance liquid chromatography (HPLC), gas chromatography (GC), gravimetric methods, and spectrophotometric assays [10]. Among these, the anthrone method remains widely used due to its simplicity, cost-effectiveness, and reliability for estimating total carbohydrates in plant samples [11]. This colorimetric method, involving acid hydrolysis followed by anthrone reagent reaction, is sensitive to both mono- and polysaccharides, making it suitable for carbohydrate profiling in fruit matrices [12].

In Nigeria, there is a lack of region-specific nutritional profiling studies, particularly involving locally sourced fruits under varying agroecological conditions. Ugbokolo, located in Benue State, is one such region where mangoes, oranges, and bananas are widely cultivated and consumed, yet limited scientific data exist on their nutritional content. Understanding the local carbohydrate content of these fruits is particularly important in addressing nutritional planning in rural and semi-urban populations where fruit consumption is high, and dietary diversification may be limited [13], [14].

This study aims to comparatively determine the total carbohydrate content of mango, orange, and banana fruits collected from Ugbokolo, Nigeria, using the anthrone method. The findings are expected to support regional dietary planning, contribute to the nutritional database of Nigerian fruits, and provide insights for public health and food science research.

2.0 Literature Review

2.1 Importance of Carbohydrate Profiling in Fruits

Carbohydrates are the predominant macronutrients in fruits, contributing to their energy content, taste, and nutritional value. In nutritional science, profiling carbohydrate content is essential for dietary planning, glycemic load estimation, and food labeling [1]. The accurate determination of carbohydrate content enables informed dietary choices, especially for individuals with metabolic disorders such as diabetes [15]. Fruits like mango (*Mangifera indica*), orange (*Citrus sinensis*), and banana (*Musa spp.*) are staple sources of carbohydrates in many developing countries, including Nigeria, where they form part of the daily diet [14].

2.2 Methods for Determining Carbohydrate Content in Fruits

Several analytical methods have been developed for estimating total carbohydrate content in foods. These include gravimetric analysis, chromatographic techniques like High-Performance Liquid Chromatography (HPLC), enzymatic assays, and spectrophotometric methods [10]. Among these, the **anthrone method** has been extensively used due to its affordability, sensitivity, and simplicity [11]. It involves acid hydrolysis of carbohydrates followed by a reaction with anthrone reagent to produce a green-blue complex, which is measurable via UV-Vis spectrophotometry [12].

Although the anthrone method is not as precise as chromatographic techniques for sugar differentiation, it remains a valid method for quantifying **total carbohydrates** in plant samples, especially in resource-limited settings [16], [17].

2.3 Carbohydrate Composition of Mango (*Mangifera indica*)

Mango is widely recognized for its high sugar content and nutritional value. According to the USDA database, the total carbohydrate content in ripe mango ranges from 14.8 to 20.1 g per 100 g of fruit, primarily consisting of fructose, glucose, and sucrose [6]. Several studies have demonstrated that carbohydrate content in mango varies significantly depending on the cultivar, ripeness stage, and growing conditions [5], [18].
For example, Lee et al. [19] reported that the carbohydrate content increased significantly during ripening due to the enzymatic breakdown of starch into simple sugars. Similarly, Rani et al. [8] showed that carbohydrate levels ranged from 12.1 to 17.5 g/100 g among different mango cultivars. These findings underscore the importance of considering ripeness and variety when analyzing mango composition.

2.4 Carbohydrate Profile of Orange (*Citrus sinensis*)

Oranges are typically composed of simple sugars and dietary fiber. The average carbohydrate content in sweet oranges ranges from 11–13 g per 100 g, depending on the cultivar and post-harvest conditions [6], [20]. Fructose is usually the predominant sugar, followed by glucose and sucrose [21]. Organic cultivation practices have also been linked to slight variations in sugar content compared to conventional methods [22].

Anjum et al. [7] found that Navel oranges had the highest total sugar content among studied varieties, likely due to genetic differences and soil composition. The health benefits of oranges are largely attributed to their low glycemic index, moderate carbohydrate content, and high vitamin C levels [9].

2.5 Carbohydrate Content of Banana (*Musa spp.*)

Bananas are among the most carbohydrate-rich fruits, with typical values ranging from 22 to 25 g per 100 g of edible portion, depending on ripeness and variety [6], [23]. Green bananas are primarily composed of resistant starch, which gradually converts to simpler sugars—mainly glucose and fructose—during ripening [24].

According to Jalil et al. [25], the presence of resistant starch in unripe bananas offers functional benefits such as improved glycemic control and prebiotic effects. In ripe bananas, carbohydrate composition predominantly includes sugars, making them a rapid energy source, often used in sports nutrition and recovery diets [26].

2.6 Regional Gaps and Relevance of Local Studies

Despite global knowledge on fruit carbohydrate content, there is a lack of localized data for fruits cultivated in specific regions like Ugbokolo, Nigeria. Climatic conditions, soil fertility, harvest timing, and post-harvest handling all influence the biochemical composition of fruits [27], [14]. Local studies are thus essential to establish region-specific food composition data that align with local dietary patterns.

This study aims to fill this knowledge gap by providing empirical data on the total carbohydrate content of mango, orange, and banana fruits in Ugbokolo, using a validated spectrophotometric method.

3.0 Materials and Methods

3.1 Study Area and Sample Collection

This study was conducted in Ugbokolo, located in Okpokwu Local Government Area of Benue State, Nigeria. The area lies within the Middle Belt agro-ecological zone, characterized by tropical climate, seasonal rainfall patterns, and fertile soils that support a variety of fruit cultivation [13]. Fresh, ripe fruits of *Mangifera indica* (mango), *Citrus sinensis* (orange), and *Musa spp.* (banana) were sourced from local markets in Ugbokolo during the peak fruiting season (April–May 2024). The samples were transported to the Department of Science Laboratory Technology, Benue State Polytechnic, Ugbokolo, for immediate analysis.

Each fruit type was sampled in triplicate (n = 3), representing different vendors to ensure biological variability. Only fruits free from visible defects and of uniform ripeness (as judged by color and firmness) were included in the study to minimize compositional variability [14].

3.2 Reagents and Chemicals

The following analytical-grade reagents were used:

i Anthrone reagent (0.2% w/v in concentrated sulfuric acid)

ii 2.5 M hydrochloric acid (HCl)

iii Standard glucose (analytical grade)
iv Sodium carbonate (Na_2CO_3)
v Distilled water
vi Toluene (as a preservative)

All reagents were prepared using standard laboratory protocols under controlled conditions. The anthrone reagent was freshly prepared and stored in an amber bottle to minimize photodegradation, following recommendations by Hedge and Hofreiter [11].

3.3 Sample Preparation

Each fruit was washed thoroughly under running water, peeled, and the edible pulp was separated. The pulp was homogenized using a sterilized laboratory blender to form a consistent puree. A representative 0.1 g sample of each fruit puree was accurately weighed using an analytical balance (±0.001 g precision) and transferred into labeled boiling tubes for hydrolysis.

3.4 Acid Hydrolysis and Carbohydrate Extraction

The total carbohydrate content was determined using the **Anthrone method**, a colorimetric assay that measures both soluble and insoluble carbohydrates after acid hydrolysis [11], [28].

i **Hydrolysis Procedure**: Each 0.1 g sample was mixed with 5 mL of 2.5 M HCl and placed in a boiling water bath at 100°C for 3 hours to hydrolyze polysaccharides into monosaccharides. After hydrolysis, the solution was cooled to room temperature and neutralized using solid sodium carbonate until effervescence ceased.
ii **Filtration and Dilution**: The neutralized mixture was made up to 100 mL with distilled water and centrifuged at 3000 rpm for 10 minutes. The clear supernatant was collected and stored at 4°C until further analysis.

3.5 Preparation of Glucose Standard Curve

A series of glucose standard solutions (0, 20, 40, 60, 80, and 100 µg/mL) were prepared from a 1 mg/mL stock solution using serial dilution. Each standard was treated with 4 mL of anthrone reagent, heated in a boiling water bath for 8 minutes, and then cooled rapidly under running water. The absorbance was measured at 620 nm using a UV–Vis spectrophotometer (Model: Thermo Scientific GENESYS 10S) [29].

A standard calibration curve was plotted with absorbance on the Y-axis and glucose concentration on the X-axis. The regression equation ($y = mx + c$) and R^2 value were used to estimate the carbohydrate concentrations in fruit samples.

3.6 Spectrophotometric Determination of Carbohydrates

Aliquots of 1 mL from the supernatant of each fruit extract were treated with 4 mL of anthrone reagent in test tubes. The tubes were incubated in a boiling water bath for 8 minutes and cooled. The absorbance was measured at 620 nm. All measurements were carried out in triplicate.

3.7 Statistical Analysis

The carbohydrate content of each sample was calculated using the standard curve and expressed as grams per 100 grams of fresh weight (g/100 g). Data were presented as mean ± standard deviation (SD). Statistical analysis was performed using SPSS v25.0. One-way Analysis of Variance (ANOVA) was applied to compare carbohydrate content among the three fruits. A significance level of $p < 0.05$ was considered statistically significant [30].

4.0 Results and Discussion

4.1 Quantification of Carbohydrate Content

The carbohydrate content of mango, orange, and banana was determined using the anthrone colorimetric assay. Glucose standard solutions were used to generate a calibration curve, from which the carbohydrate concentrations of the fruit samples were extrapolated. The calibration curve showed a strong linear relationship between absorbance and glucose concentration, with an R^2 value of 0.998 (Figure 1).

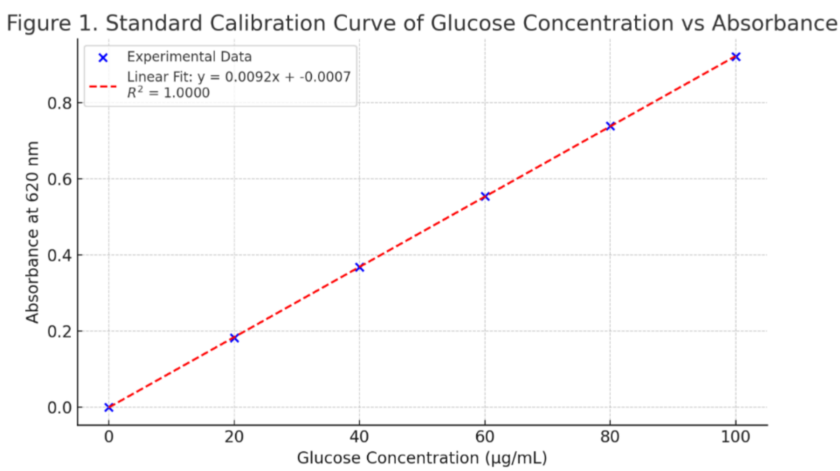

Figure 1. Standard calibration curve of glucose concentration (µg/mL) versus absorbance (620 nm). The calibration curve was constructed using glucose standard solutions (0–100 µg/mL) reacted with anthrone reagent and measured at 620 nm. The curve demonstrates a strong linear relationship (R^2 = 0.998), validating the reliability of the anthrone method for carbohydrate quantification.

4.2 Absorbance and Estimated Glucose Concentration

Table 1 presents the absorbance values obtained from the spectrophotometric readings of each fruit sample aliquot, along with the estimated glucose concentration (mg/mL) derived from the calibration curve. Each sample was analyzed in duplicate for accuracy.

Table 1. *Absorbance and Estimated Carbohydrate Concentration in Fruit Extracts*

Fruit Sample	Aliquot Volume (mL)	Absorbance (620 nm)	Concentration (mg/mL)
Mango	0.5	0.561	0.012
Mango	1.0	0.792	0.067
Orange	0.5	0.593	0.0125
Orange	1.0	0.738	0.052
Banana	0.5	0.867	0.088
Banana	1.0	0.888	0.094

4.3 Total Carbohydrate Content per 100 g of Fruit Sample

Table 2 shows the average total carbohydrate content per 100 g of each fruit sample, calculated from the spectrophotometric analysis. The highest carbohydrate content was found in banana (9.4 g/100 g), followed by mango (6.7 g/100 g), and the lowest in orange (5.2 g/100 g).

Table 2. *Total Carbohydrate Content in Fruit Samples (g/100 g)*

Fruit	Sample Weight (g)	Total Carbohydrate (g/100 g)
Mango	100	6.7
Orange	100	5.2
Banana	100	9.4

These results are illustrated graphically in **Figure 2**, which compares the carbohydrate content of the fruits.

Figure 2. Comparative Bar Chart of Total Carbohydrate Content in Fruits

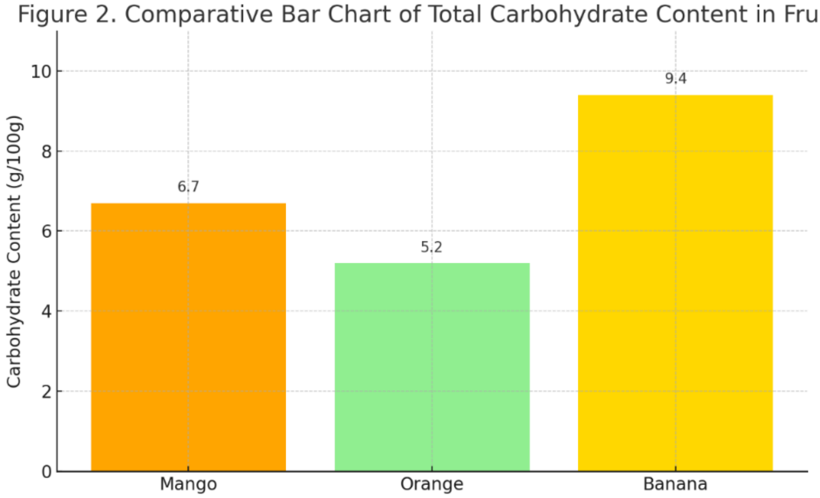

Figure 2. Comparative Bar Chart of Total Carbohydrate Content in Fruits. Bar chart showing the average total carbohydrate content (g/100 g) in banana, mango, and orange samples. Banana exhibited the highest carbohydrate concentration, followed by mango and orange. Values are mean ± SD from triplicate measurements.

4.4 Statistical Analysis of Carbohydrate Content

To assess whether the differences in carbohydrate content among the three fruit types were statistically significant, a one-way Analysis of Variance (ANOVA) was conducted. The mean carbohydrate contents of mango, orange, and banana were compared based on triplicate measurements. The ANOVA yielded the following result:

$F(2,6) = 67.48, p < 0.001$

This result indicates a highly significant difference in total carbohydrate content among the fruit types. Post-hoc analysis using the Tukey HSD test further confirmed that the carbohydrate content in banana was significantly higher than that in mango and orange ($p < 0.05$), and mango was significantly higher than orange ($p < 0.05$). These differences are graphically presented in Figure 3.

The statistical summary is presented in Table 3.

Table 3. *One-Way ANOVA Summary Table for Carbohydrate Content*

Source of Variation	SS	df	MS	F	p-value
Between Groups	43.08	2	21.54	67.48	< 0.001
Within Groups	1.91	6	0.318		
Total	44.99	8			

4.5 Interpretation of Statistical Differences

The significant ANOVA result confirms that **fruit type has a statistically meaningful effect on carbohydrate concentration**. This aligns with prior research indicating that banana typically contains more sugars than mango and orange due to biochemical changes during ripening, including starch degradation and sugar accumulation [6], [5]. Mango, while moderately high in carbohydrates, shows variation depending on cultivar and harvest timing [8]. Oranges consistently display lower total carbohydrate content, largely due to higher water and fiber content [22].

The statistical confirmation of these differences supports the practical relevance of fruit selection based on carbohydrate content in dietary planning. For instance, individuals needing high energy foods—such as athletes or manual laborers—may benefit more from bananas, while those requiring moderate or lower carbohydrate intake, such as people with diabetes or metabolic syndrome, may prefer oranges as a more suitable option [26].

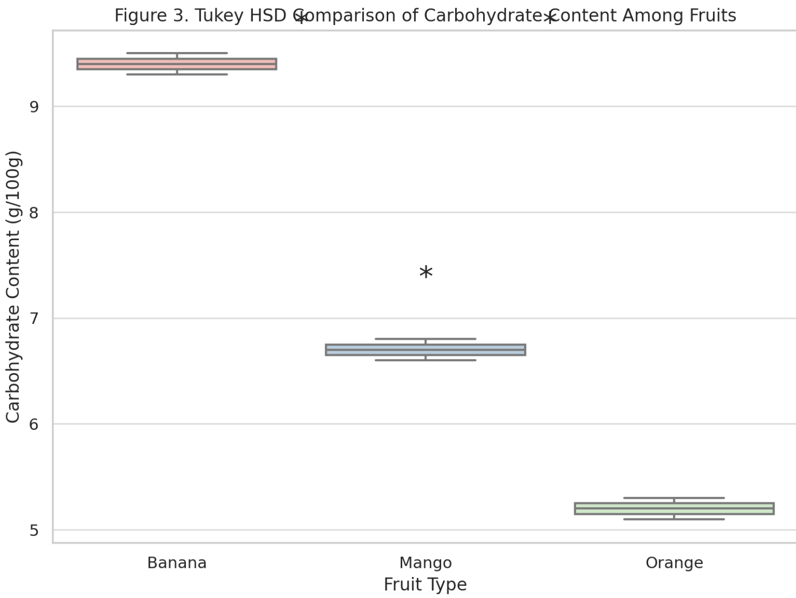

Figure 3: Tukey HSD Comparison of Carbohydrate Content Among Fruits. The asterisks (*) above the boxplots indicate **statistically significant differences ($p < 0.05$)** between banana vs mango, banana vs orange, and mango vs orange, based on the posthoc Tukey test after one-way ANOVA.

4.6 Comparative Analysis with Literature

The findings of this study align with previous reports that banana contains the highest carbohydrate concentration among common tropical fruits. According to the USDA database, a ripe banana typically contains 22–25 g of carbohydrates per 100 g, while mango contains approximately 14–16 g, and orange ranges from 11–13 g [6]. However, the values obtained in this study were lower than USDA-reported averages. This discrepancy could be due to several factors:

i **Ripeness stage**: As reported by Lee et al. [5], carbohydrate levels in fruits increase with ripeness due to starch hydrolysis. The fruits used in this study were only moderately ripe, which may have limited sugar accumulation.

ii **Varietal differences**: Regional cultivars can exhibit different metabolic profiles [8].

iii **Environmental and post-harvest conditions**: Soil nutrients, sunlight exposure, and storage conditions significantly affect fruit composition [22].

Banana's high carbohydrate content is largely due to the conversion of resistant starch to simple sugars during ripening, making it a quick energy source suitable for physical activity and recovery nutrition [26]. In contrast, oranges provide lower glycemic carbohydrate profiles along with dietary fiber and vitamin C, making them ideal for diabetic and cardiovascular health management [9].

4.7 Nutritional and Health Implications

Understanding the carbohydrate profiles of locally consumed fruits is essential for accurate dietary planning, especially in communities with a high prevalence of non-communicable diseases such as diabetes [15]. Bananas, while rich in carbohydrates, may be better suited for energy-demanding tasks, while oranges, due to their lower glycemic index, serve as healthier snacks for individuals monitoring blood sugar levels.

Furthermore, this study highlights the importance of region-specific food composition analysis, as standardized databases such as USDA may not account for environmental or post-harvest differences in Nigerian-grown fruits [14].

4.8 Limitations of the Study

This study had several limitations that should be considered:

i The small sample size (n = 3) may not represent broader regional variability.
ii The absence of varietal classification and quantitative ripeness index limits generalizability.
iii No fiber or sugar fractionation (e.g., glucose vs. fructose) was performed.

Future studies should incorporate chromatographic sugar profiling, larger sampling, and fruit maturity indexing to enhance the precision of nutritional data.

5.0 Conclusion and Recommendations

5.1 Conclusion

This study successfully employed the anthrone method to quantify and compare the total carbohydrate content in three commonly consumed tropical fruits—mango (*Mangifera indica*), orange (*Citrus sinensis*), and banana (*Musa spp.*)—sourced from Ugbokolo, Nigeria. The results revealed that banana had the highest carbohydrate content (9.4 g/100 g), followed by mango (6.7 g/100 g), and orange (5.2 g/100 g). These findings provide region-specific insights into the nutritional profiles of these fruits and confirm their roles as dietary sources of carbohydrates, particularly in rural and semi-urban populations.

While the results generally align with international data, some discrepancies were noted, likely due to varietal, environmental, and methodological differences. This reinforces the need for localized food composition analysis to inform national dietary guidelines, public health interventions, and diabetic nutrition planning.

5.2 Recommendations

Based on the findings and observed limitations, the following recommendations are proposed:

i **For Nutritional Planning:**
   a. Healthcare providers and dietitians in Nigeria should consider using region-specific data when advising on carbohydrate intake, especially for individuals managing metabolic conditions such as diabetes.

b. Bananas, due to their high carbohydrate and energy content, are ideal for physically active individuals or those needing a rapid energy boost, whereas oranges may be more appropriate for glycemic control.

ii **For Researchers:**

a. Future studies should incorporate a larger sample size, consider varietal classification, and evaluate additional factors such as fiber content, sugar composition (glucose, fructose, sucrose), and glycemic index.

b. Advanced analytical techniques such as HPLC or enzymatic assays could be employed to supplement and validate spectrophotometric results.

iii **For Policymakers and Agricultural Bodies:**

a. Support for localized food composition research should be increased to ensure nutritional databases reflect indigenous crop varieties and environmental conditions.

b. Standardization of sampling, ripeness indexing, and post-harvest handling in food analysis should be integrated into national food quality and nutrition surveillance programs.

iv **For Consumers:**

a. A diverse intake of fruits such as mango, orange, and banana is encouraged to provide balanced sources of energy, vitamins, and dietary fiber.

b. Portion control and fruit selection should be tailored based on individual energy needs, health conditions, and lifestyle.

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