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Supplementary Information

Using cotton thread-based colorimetric sensor modified by

carboxymethylcellulose and cuprizone with Smartphone detection for

quantification of copper

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https://drive.google.com/file/d/1KmG4cJ03Q9FjyA0S4CDwgSLBblIA0F_5/view?usp=sh aring.

Video S1 - Demonstrative video showcasing the operation of μ TAD in the detection of cupric ions:

Choice of Cotton Thread

The choice of a suitable substrate material is a critical factor that affects the analytical response of the sensor and the cost of producing the microdevice for fluid analysis (μ TAD). In the present study, cotton thread was chosen as the substrate material for the proposed μ TAD due to its suitable properties, including high hydrophobicity and capillarity through the cotton thread lumen, which make it highly desirable for use in the construction of μ TAD.¹ For the choice of the most suitable cotton thread, initially, two types of commercial cotton thread were tested with and without pretreatment using hot sodium carbonate saline: surgical cotton thread (F₁) and crochet cotton thread (F₂), along with their respective treated versions F₁T and F₂T. This analysis was performed in order to find out which cotton thread exhibits the best capillarity and offers the greatest color intensity for CPZ-Cu complex solution.

The results obtained from the analysis showed that the pretreatment of the cotton thread with hot saline solution improved the hydrophobicity of the material, allowing better penetration of the sample through the cotton thread and greater speed of displacement of the colored solution throughout the cotton thread. The F₂T cotton thread exhibited relatively higher capillarity and greater color variation compared to the F₁T (Figure S1). In view of that, F₂T was chosen as the most suitable material for the construction of the proposed µTAD. In addition, as illustrated in Figure S1, the results obtained from the analysis of the RGB channels related to the color of the CPZ-Cu complex product showed that the R channel exhibited the most significant impact, since it provided a relatively greater variation in color intensity compared to the G and B channels. Thus, the R channel was chosen for the conduct of further experiments.



Figure S1. Variation in the RGB channel intensity observed for the CPZ-Cu complex solution in the cases of F_1T and F_2T . Insets show the flow speed due to capillary action, quantified as the average time required for the solution to traverse a 50 mm length of the treated cotton thread. Experimental conditions: A 30 μ L aliquot of the CPZ-Cu complex solution with a pH of 8.



Figure S2. Micrograph of (a) F_1T (100x); (b) F_1T (1000x); (c) F_1T -CPZ-CMC (200x); and (d) F_1T -CPZ-CMC (1000x). (0.1 μ L of CPZ (2.0 g L⁻¹), 15 μ L of CMC (1%)).



Figure S3. TG and DTG curves related to the thermal decomposition of the proposed μ TAD. Conditions applied: 0.1 μ L of CPZ (2.0 g L⁻¹), 15 μ L of CMC (1%), and 5 μ L of buffer solution with pH 8.



Figure S4. Selectivity assessment of sensor system for analyzing metal ions. Experimental Conditions: 0.1 μ L of CPZ (2.0 g L⁻¹), 15 μ L of CMC (1%), 5 μ L of buffer solution with pH 8, 20 μ L of metal ions solution (5.0 mg L⁻¹), and time = 10 min.



Figure S5. Percentage relative error obtained for the analytical signal in the determination of 5.0 mg L⁻¹ of cupric ions in the presence of potential interfering metal ions in the ratio of 1:1. Conditions applied: 0.1 μ L of CPZ (2.0 g L⁻¹), 15 μ L of CMC (1%), 5 μ L of buffer solution with pH 8, 20 μ L of sample, and time = 10 min.

Table S1. Results obtained from the recovery experiments conducted using samples of water and samples of cachaça, both enriched with cupric ions, based on the application of the proposed digital imaging-based colorimetric sensor (μ TAD + DIB) (n = 3).

Sample	Added/ mg L ⁻¹	Recovered/ mg L ⁻¹	Recovery/%
	1.00	1.07 ± 0.13	107
Tap water	2.00	1.94 ± 0.08	96.5
	4.00	4.09 ± 0.13	102
	1.00	0.97 ± 0.19	97.5
Mineral water	2.00	1.97 ± 0.02	98.5
	4.00	3.40 ± 0.14	84.9
	1.00	0.88 ± 0.31	88.1
Pond water	2.00	1.83 ± 0.03	91.5
	4.00	3.80 ± 0.53	95.0
Cachaça 1	2.00	2.06 ± 0.19	103
	5.00	4.58 ± 0.48	91.7
	7.00	6.81 ± 0.29	97.3
Cachaça 2	2.00	2.09 ± 0.32	105
	5.00	4.69 ± 0.21	93.8
	7.00	6.79 ± 0.14	97.0
	2.00	2.10 ± 0.19	105
Cachaça 3	5.00	4.42 ± 0.34	88.5
	7.00	6.88 ± 0.37	98.2



Figure S6. Analytical curves for the determination of cupric ions in samples of water based on the application of the proposed μ TAD with and without preconcentration n=3). Conditions applied: 0.1 μ L of CPZ (2.0 g L⁻¹), 15 μ L of CMC (1%), 5 μ L of buffer solution with pH 8, and 20 μ L of cupric ions solution.



Figure S7: Visual representation of colorimetric reactions for the determination of cupric ions in a standard water solution using the proposed μ TAD with CMC. The color changes, which occur linearly in response to these reactions, are observable to the naked eye. Conditions applied: 0.1 μ L of CPZ (2.0 g L⁻¹), 15 μ L of CMC (1%), 5 μ L of buffer solution with pH 8, and 20 μ L of cupric ions solution (1, 2, 5, 7 e 10 mg L⁻¹).



Figure S8. Analytical curves for the determination of cupric ions alcoholic beverage (cachaça) based on the application of the proposed μ TAD with preconcentration (n=3). Conditions applied: 0.1 μ L of CPZ (2.0 g L⁻¹), 15 μ L of CMC (1%), 5 μ L of buffer solution with pH 8, 20 μ L of cupric ions solution, and time =10 min.

Table S2. Comparison of the analytical performance of colorimetric sensor with digital image-based detection (μ TAD + DIB) and other colorimetric methodologies applied in the detection of cupric ions.

Substrate	Sample	Linear range ^a	R ²	Detector	LD ^a	Reference
	-					
μPAD + DIB	Cachaça	2.0 – 7.22	0.999	Camera/ smartphone	0.2	2
μPAD + DIB	Cachaça	2 – 13	0.997	Camera/ smartphone	0.03	3
μPAD + DIB	Cachaça	3 – 25	0.990	Scanner	1.6	4
μPAD + naked eye	Water	1-6	0.991	Length/ ruler	-	5
μTAD+ DIB	Water	1-10	0.987	Camera /smartphone	0.23	This work
μTAD+ DIB	Cachaça	1 – 12	0.986	Camera /smartphone	0.21	This work

^a in mg L⁻¹; μ PAD: microfluidic paper-based analytical device; R²: regression coefficient; LD: limit of detection.

Reference

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