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Correction: Chemical analysis in saliva and the search for salivary biomarkers – a tutorial review

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Correction for 'Chemical analysis in saliva and the search for salivary biomarkers – a tutorial review' by Kamonwad Ngamchuea, *et al.*, *Analyst*, 2018, **143**, 81–99.

In the published article some errors were present in Tables 1, 2 and 4.

The concentrations of blood glucose were misplaced into the 'Saliva' column. They are now moved to the correct 'Other biological fluids' column. A full, corrected Table 1 is reproduced here.



Table 1 Components of authentic human saliva and a comparison of the normal range of the concentrations between saliva and other biological fluids

Real saliva composition		Normal range		Ref.		
		Saliva	Other biological fluids			
1. Inorganic compounds	Na ⁺	20–80 mmol L ⁻¹	Plasma 145 mmol L ⁻¹	11		
	K ⁺	20 mmol L ⁻¹	4 mmol L ⁻¹			
	Ca ²⁺	1–4 mmol L ⁻¹	2.2 mmol L ⁻¹			
	Cl ⁻	30–100 mmol L ⁻¹	120 mmol L ⁻¹			
	HCO ₃ ⁻	15–80 mmol L ⁻¹	25 mmol L ⁻¹			
	Phosphate	4 mmol L ⁻¹	1.2 mmol L ⁻¹			
	Mg ²⁺	0.2 mmol L ⁻¹	1.2 mmol L ⁻¹			
	SCN ⁻	2 mmol L ⁻¹	<0.2 mmol L ⁻¹			
	NH ₃	3 mmol L ⁻¹	0.05 mmol L ⁻¹			
	2. Organic compounds (non-protein and lipids)	Uric acid	3.38 ± 0.21 mg dL ⁻¹ 217.2 ± 110.3 mol L ⁻¹ 0.1–7.5 mg dL ⁻¹		Serum 6.31 ± 0.24 mg dL ⁻¹	21–23
Bilirubin		0.5–5.0 μmol L ⁻¹	Serum 0.2–1.2 mg dL ⁻¹			
Creatinine		0.12 ± 0.06 mg dL ⁻¹ 0.05–0.2 mg dL ⁻¹	Serum 0.89 ± 0.17 mg dL ⁻¹ Serum 0.6–1.5 mg dL ⁻¹			
Glucose		4–13 mg dL ⁻¹	Blood 80–120 mg dL ⁻¹ Blood 88.6 ± 8.0 mg dL ⁻¹			
Cholesterol		0.02–5.46 μmol L ⁻¹	Serum <5 mmol L ⁻¹			
Lactate		0.3–1.8 mM	Serum 0.5–1.0 mM			
3. Protein/polypeptide compounds		α-Amylase	0.1 to 2.5 mmol L ⁻¹ 19–308 U mL ^{-1 a} 93 ± 62 U L ^{-1 a} 2.64 ± 1.8 mg mL ⁻¹	Serum 0.05–0.125 U mL ^{-1 a}	23 and 30	
		Albumin	0.2 ± 0.1 mg mL ⁻¹	Serum 3.5–5.5 g dL ⁻¹		
		Secretory-IgA	80–717 mg dL ⁻¹ 124.3–333.5 μg mL ⁻¹	Serum 70–400 mg dL ⁻¹		
		Mucin group	MUC5B: 2.4 ± 1.7 U mL ⁻¹ 1.19 ± 0.17 mg mL ⁻¹	Serum 9.9 ± 0.8 ng mL ⁻¹		
	Lysozyme	3–50 μg mL ⁻¹ 59.7 to 1062.3 μg mL ⁻¹	Serum 7.4 ± 1.8 mg mL ⁻¹ Serum 4–9 μg mL ⁻¹			
	Total proteins	7.1–223.2 mg dL ⁻¹ 0.9 ± 0.2 mg mL ⁻¹	Serum 6–8 g dL ⁻¹			
	4. Hormones	Cortisol	3.5–27.0 mg dL ⁻¹	Serum 2–25 mg dL ⁻¹		35
Testosterone		32–55 pg mL ⁻¹	Serum 320–600 ng dL ⁻¹			
Progesterone		Luteal phase 436 ± 34 pmol L ⁻¹ Follicular phase 22.1 ± 2.7 pmol L ⁻¹	Serum male: <1 ng mL ⁻¹ Serum female: 0.1–20 ng mL ⁻¹			
Estrogen (Estradiol)		Luteal phase 20.6 ± 0.4 pmol L ⁻¹	Serum male: 15–60 pg mL ⁻¹ Serum female: 15–370 pg mL ⁻¹			

^a U mL⁻¹: enzymatic activity per unit (mL) of saliva.

The concentration of CaCl₂·2H₂O (ref. Fusayama-Meyer¹⁶) was given incorrectly. The concentration of NH₄Cl (ref. SAGF^{17,18}) was missing. A full, corrected Table 2 is reproduced here.



Table 2 Compositions of different artificial saliva recipes

Artificial saliva compositions		Concentration (g L ⁻¹)				
		AFNOR ^{14,15}	Fusayama-Meyer ¹⁶	SAGF ^{17,18}	Klimek ¹⁹	Shellis ¹²
1. Inorganic compounds	NaCl	6.70	0.40	0.13	0.58	—
	KCl	1.20	0.40	0.96	1.27	1.16
	Na ₂ HPO ₄	0.26	—	—	0.34	0.375
	KH ₂ PO ₄	0.20	—	0.66	0.33	0.35
	NaHCO ₃	1.50	0.10	0.63	—	0.54
	KSCN	0.33	—	0.19	0.16	0.22
					(NaSCN)	
	CaCl ₂ ·2H ₂ O	—	0.795	0.23	0.17	0.21
	Na ₂ S·9H ₂ O	—	0.005	—	—	—
	Urea	—	1.00	0.20	0.20	0.17
	NaH ₂ PO ₄ ·H ₂ O	—	0.69	—	—	—
	NH ₄ Cl	—	—	0.18	0.16	0.233
	Na ₂ SO ₄ ·10H ₂ O	—	—	0.76	—	—
	MgCl ₂ ·6H ₂ O	—	—	—	—	0.043
Sodium citrate	—	—	—	—	0.013	
2. Organic compounds	Ascorbic acid	—	—	—	0.002	—
	Glucose	—	—	—	0.03	—
	Uric acid	—	—	—	—	0.0105
	Creatinine	—	—	—	—	0.0001
	Choline	—	—	—	—	0.013
	Mixture of vitamins	—	—	—	—	0.0008
	3. Protein/polypeptide compounds	Mucin	—	—	—	2.70 ^a
Glycoprotein		—	—	—	—	2.5
Alpha amylase		—	—	—	—	3 × 10 ⁵ Somogyi's unit L ⁻¹ ^b
Albumin		—	—	—	—	0.025
Mixture of amino acids		—	—	—	—	0.041

^a Bacto-Mucin bacteriological. ^b Somogyi's unit/L is a measure of the level of activity of amylase in blood serum. One Somogyi unit is defined as the amount of amylase required to produce the equivalent of 1 mg of glucose when acting on a standard starch solution under a defined condition.³⁸

Incorrect values were given for linear ranges, LOD and the pH of the buffers for some of the detection methods in Table 4. The specific changes relate to Phosphate (linear range and buffer pH), caffeine (LOD for the molecularly imprinted electrode and linear range for the SWNCT/CC electrode), glutathione (medium for the Prussian blue/SPE electrode and linear range for the caffeic acid/GC electrode) and uric acid (LOD). A full, corrected Table 4 is reproduced here.



Table 4 Examples of methods of electroanalytical detection available for possible salivary biomarkers (listed in Table 3)

Biomarkers	Methods	Electrodes	Linear range	LOD	Medium	Ref.
Chemicals						
Calcium	ISE	Calcium-specific electrode	2.2–8 mg per 100 mL	—	Aqueous, serum	179
Potassium	ISE	Potassium electrode with polymer membrane	115 mM–180 mM ^a	—	Whole blood, serum	180
Phosphate	AMP, CV	Molybdate anions in chitosan/GC	0.79 μ M–3.96 μ M 19 μ M–95 μ M	—	Deaerated Tris buffer (pH 7.2)	187
Cotinine	MPA	BDD	0.5 μ M–100 μ M	0.06 μ M	PBS (pH 7.0), saliva	188
Nicotine	SWV	Anti-cotinine antibody/C-SPE	1–100 ng mL ⁻¹	1.0 ng mL ⁻¹	Serum	189
	AMP, CV	MWCNT/alumina-coated silica nanocomposite	—	1.42 μ M	PBS (pH 8)	190
	AMP	TiO ₂ /GC	0 μ M–5000 μ M	4.9 μ M	PBS (pH 7.4)	191
	CV	MWCNT/BPPG	up to 1 mM	1.5 μ M	BR (pH 8)	192
Nitrate (NO ₃ ⁻)	CV	CNT/SPE	10 μ M–1000 μ M	2 μ M	Buffer (pH 7), artificial saliva	193
	DPV	BDD	0.5 μ M–200 μ M	0.3 μ M	BR (pH 8)	194
	EIS	Polydopamine imprinted film	1 μ M–25 μ M	0.5 μ M	PBS (pH 7.4), serum	195
	LSV	Cu plated-/BDD microelectrode array	1.2 μ M–124 μ M	0.76 μ M	0.1 M Na ₂ SO ₄ (pH 3)	196
Nitrite (NO ₂ ⁻)	AMP	Cellulose acetate membrane/Pt	1 μ M–100 μ M	0.5 μ M	Acetate buffer (pH 4.0)	197
	AMP	Poly(1,8-diaminonaphthalene) film/Pt	0.5 μ M–100 μ M	0.1 μ M	Acetate buffer (pH 4.0)	198
Caffeine	DPV, LSV	Carbon black paste electrode	0.01 μ M–4 μ M	0.005 μ M	Acetate buffer (pH 4.6)	199
	CV	Carbon black SPE	0.1 μ M–8.8 μ M	0.097 μ M	Saliva, urine	200
	DPV, LSV	GC	4 mM–80 mM	6 μ M	PBS (pH 7.0)	201
	CV, SWV	Nafion/GC	up to 7.0 mM	0.04 μ M	PBS (pH 7.0)	202
	CV, SWV	Pseudo CP	1 μ M–1 mM	0.348 μ M	PBS (pH 7.0)	203
	DPV	Molecularly imprinted polymer	0.5 nM–0.16 μ M	90 pM	PBS (pH 6.5)	204
	DPV	SWCNT/CC	0.25 μ M–0.1 mM	0.12 μ M	0.01 M H ₂ SO ₄ (pH 1.7)	205
Thiocyanate (SCN ⁻)	SWV	EPPG	0.02 μ M–100 μ M	0.008 μ M	PBS (pH 7.2), urine	206
	CV, DPV	Ag-MWCNT/GC	2.5 nM–50 nM	1.0 nM	PBS (pH 6.0), saliva, urine	207
	CV, AMP	Ag@Cu nanorods/GC	50 nM–1.0 μ M	10 nM	PBS (pH 6.0)	208
	CV, AMP	Ag@Cu nanorods/GC	1 mM–10 mM	10 nM	PBS (pH 6.0)	209
Anti-oxidants						
Glutathione (GSH) ^b	CV	Copper hydroxide/CILE	1 μ M–50 μ M	30 nM	PBS (pH 7.0)	210
	CV, AMP	Ordered mesoporous carbon	0.1 mM–1.8 mM	0.09 μ M	PBS (pH 7.16)	211
	CV, AMP	Carbon microfiber	0 mM–2.5 mM ^a	0.09 μ M	PBS (pH 7.5)	212
	CV	Poly(caffeic acid) nanocarbon composite/GC	5 μ M–65 μ M ^a	0.5 μ M	PBS (pH 7.0)	213
	CV	GC	0.5 μ M–5.0 mM	0.5 μ M	PBS (pH 7.0)	214
	CV	GC	6 μ M–59 μ M	1 μ M	Tissue media (pH 7)	215
	CV	Prussian blue/SPE	2 μ M–0.5 mM	2.0 μ M	PBS (pH 7.4), blood	216
	CV	Nanocarbon paste	2 μ M–120 μ M ^a	2.0 μ M	PBS (pH 7.5)	217
Glutathione disulfide (GSSG)	CV	Caffeic acid/GC	>1.0 mM	2.2 μ M	PBS (pH 7.0)	218
	CV, SWV	CNT-SPE	10 μ M–60 μ M ^a	3.0 μ M	PBS (pH 7.0), saliva	219
	CV	Copper hydroxide/CIL	0.4 μ M–120 μ M	15 nM	PBS (pH 7.0)	220
	CV	Graphene-Pt/GC	0.15 μ M–34 μ M	0.15 μ M	PBS (pH 7.0)	221
	DPV	Nitrogen doped graphene	5.0 μ M–1.3 mM	2.2 μ M	PBS (pH 6.0)	222
Ascorbic acid	CV, LSV	SWCNH/GC	30 μ M–400 μ M	5 μ M	PBS (pH 7.0)	223
	CV, DPV	Poly(acid chrome blue K)/GC	50.0–1000.0 μ M	10.0 μ M	PBS (pH 4.0), urine	224
	CV, DPV	Graphene-Pt/GCE	0.05 μ M–12 μ M	0.05 μ M	PBS (pH 7.0)	225
	CE/AMP	Poly(dimethylsiloxane) (PDMS)/glass microchip	15 μ M–110 μ M	1 μ M	MES (pH 5.5), urine	226
	DPV	Nitrogen doped graphene	0.1 μ M–20 μ M	45 nM	PBS (pH 6.0)	227
Uric acid	SWV	Clay colloids/GC	0.5 μ M–10 μ M	0.2 μ M	Citrate buffer (pH 1.0)	228
	DPV	CIL	10 μ M–100 μ M	1.0 μ M	PBS (pH 6.8), urine	229
	CV, DPV	Poly(acid chrome blue K)/GC	2.0 μ M–0.2 mM	1.0 μ M	PBS (pH 6.8), urine	230
	CV, DPV	Poly(acid chrome blue K)/GC	1.0 μ M–120 μ M	0.5 μ M	PBS (pH 4.0),	231



Table 4 (Contd.)

Biomarkers	Methods	Electrodes	Linear range	LOD	Medium	Ref.
	CV, LSV	SWCNH/GC	0.06 μM –10 μM	20 nM	PBS (pH 7.0)	216
	SWV	Electrochemically activated GC	0.04 μM –2.0 μM	9 nM	0.5 M H_2SO_4 , urine	221
Therapeutic drugs						
Theophylline	CV	MWCNT/GC	0.3 μM –10.0 μM	50 nM	PBS (pH 5.8)	222
	DPV	Graphene/Nafion/GC	10 nM –1.0 μM	6.0 nM	0.1 M H_2SO_4	223
Acetaminophen (paracetamol)	DPV	Cobalt phthalocyanine NP/CP	0.4 μM –0.1 mM	0.14 μM	PBS (pH 7.4)	224
	DPV	Urchin-like CdSe microparticles/ GC	μM –40 μM	0.4 μM	PBS (pH 6.0)	225
	SWV	Nafion/lead–ruthenium oxide pyrochlore	40 μM –700 μM up to 100 μM	0.1 μM	PBS (pH 3)	226
	CV	Nafion/ TiO_2 -graphene/GC	1 μM –100 μM	0.21 μM	PBS (pH 7.0)	227
	DPV	Pd/graphite oxide/GC	5 nM–0.5 μM	2.2 nM	PBS (pH 6.8)	228
	DPV	BiO/graphite SPE	0.5 μM –1.250 μM	30 nM	BR buffer (pH 2.0), saliva	229
	DPV	SWCNT–graphene/GC	0.05 μM –65 μM	38 nM	PBS (pH 7.0), serum	230
	DPV	Functionalized MWCNT	0.45 μM –90.0 μM	0.35 μM	PBS (pH 7.0), saliva	231
	SWV	CoNP/MWCNT	5.2 nM–0.45 μM	1.0 nM	PBS (pH 7.0)	232
	SWV	MWCNT/BPPG	μM –2 μM	10 nM	PBS (pH 7.5)	233
SWV	Graphene/GC	2 μM –20 μM 0.1 μM –20 μM	32 nM	$\text{NH}_3 \cdot \text{H}_2\text{O}$ – NH_4Cl (pH 9.3)	234	
pH						
pH	CV	Carbon fibre microelectrode	pH 2.5–8 (buffer), pH 4–8.5 (artificial saliva)	Sensitivity: –61 mV/pH (buffer) –73 mV/pH (artificial saliva)	Buffer, artificial saliva, saliva	235
	EIS	Iridium oxide	pH 4–8	Sensitivity: –47 mV/pH (artificial saliva)	Artificial saliva	236
	ISE	Poly(3-octylthiophene-2,5-diyl) regiorandom/SPCE	pH 4–8	Sensitivity: –53.4 mV/pH (buffer)	Buffer, saliva	237
	ISE	Poly(terthiophene benzoic acid)/ AuZnO_x /SPCE	pH 2–13	Sensitivity: 59.2 \pm 0.5 mV/pH (buffer)	Buffer, saliva, urine	238

The methods highlighted in grey and blue have been validated in artificial saliva and real saliva, respectively. **Methods:** AMP: amperometry, CA: chronoamperometry, CE: capillary electrophoresis, CV: cyclic voltammetry, DPV: differential pulse voltammetry, EIS: electrochemical impedance spectroscopy, ISE: ion-selective electrode, LSV: linear sweep voltammetry, MPA: multiple-pulse amperometry, SWV: square wave voltammetry. **Electrodes:** BDD: boron-doped diamond, BPPG: basal plane pyrolytic graphite, CC: carbon ceramic, CIL: carbon ionic liquid, CNF: carbon nanofiber, CP: carbon paste, EPPG: edge plane pyrolytic graphite, GC: glassy carbon electrode, MWCNT: multi-walled carbon nanotube, NP: nanoparticle, SPE: screen-printed electrode, SWCNT: single-walled carbon nanotube, SWCNH: single-walled carbon nanohorn.^a Not stated in the text – values are taken from calibration curves present in the papers.



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