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

Kamonwad Ngamchuea, Korbua Chaisiwamongkhol,
Christopher Batchelor-McAuley and Richard G. Compton*

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	Serum 6.31 ± 0.24 mg dL ⁻¹	21–23
		217.2 ± 110.3 mol L ⁻¹		
		0.1–7.5 mg dL ⁻¹		
	Bilirubin	0.5–5.0 μmol L ⁻¹	Serum 0.2–1.2 mg dL ⁻¹	24
	Creatinine	0.12 ± 0.06 mg dL ⁻¹	Serum 0.89 ± 0.17 mg dL ⁻¹	25
		0.05–0.2 mg dL ⁻¹	Serum 0.6–1.5 mg dL ⁻¹	
	Glucose	4–13 mg dL ⁻¹	Blood 80–120 mg dL ⁻¹	22 and 26
			Blood 88.6 ± 8.0 mg dL ⁻¹	
	Cholesterol	0.02–5.46 μmol L ⁻¹	Serum <5 mmol L ⁻¹	27
	Lactate	0.3–1.8 mM	Serum 0.5–1.0 mM	28 and 29
3. Protein/polypeptide compounds	α-Amylase	0.1 to 2.5 mmol L ⁻¹		23 and 30
		19–308 U mL ⁻¹ ^a	Serum 0.05–0.125 U mL ⁻¹ ^a	
		93 ± 62 U L ⁻¹ ^a		
		2.64 ± 1.8 mg mL ⁻¹		
	Albumin	0.2 ± 0.1 mg mL ⁻¹	Serum 3.5–5.5 g dL ⁻¹	31
	Secretory-IgA	80–717 mg dL ⁻¹	Serum 70–400 mg dL ⁻¹	23 and 32
		124.3–333.5 μg mL ⁻¹		
	Mucin group	MUC5B: 2.4 ± 1.7 U mL ⁻¹	Serum 9.9 ± 0.8 ng mL ⁻¹	31 and 33
		1.19 ± 0.17 mg mL ⁻¹		
	Lysozyme	3–50 μg mL ⁻¹	Serum 7.4 ± 1.8 mg mL ⁻¹	23, 32 and 34
4. Hormones		59.7 to 1062.3 μg mL ⁻¹	Serum 4–9 μg mL ⁻¹	
	Total proteins	7.1–223.2 mg dL ⁻¹	Serum 6–8 g dL ⁻¹	
		0.9 ± 0.2 mg mL ⁻¹		23 and 31
	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	36
	Progesterone	Luteal phase 436 ± 34 pmol L ⁻¹	Serum male: <1 ng mL ⁻¹	37
		Follicular phase 22.1 ± 2.7 pmol L ⁻¹	Serum female: 0.1–20 ng mL ⁻¹	37
	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 μM–3.96 μM 19 μM–95 μM	—	Deaerated Tris buffer (pH 7.2)	187	
Cotinine	MPA	BDD	0.5 μM–100 μM	0.06 μM	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 μM	PBS (pH 8)	190	
	AMP	TiO ₂ /GC	0 μM–5000 μM	4.9 μM	PBS (pH 7.4)	191	
	CV	MWCNT/BPPG	up to 1 mM	1.5 μM	BR (pH 8)	192	
	CV	CNT/SPE	10 μM–1000 μM	2 μM	Buffer (pH 7), artificial saliva	193	
	DPV	BDD	0.5 μM–200 μM	0.3 μM	BR (pH 8)	194	
	EIS	Polydopamine imprinted film	1 μM–25 μM	0.5 μM	PBS (pH 7.4), serum	195	
Nitrate (NO ₃ [−])	LSV	Cu plated-/BDD microelectrode array	1.2 μM–124 μM	0.76 μM	0.1 M Na ₂ SO ₄ (pH 3)	196	
Nitrite (NO ₂ [−])	AMP	Cellulose acetate membrane/Pt	1 μM–100 μM	0.5 μM	Acetate buffer (pH 4.0)	197	
		Poly(1,8-diaminonaphthalene) film/Pt	0.5 μM–100 μM	0.1 μM			
Caffeine	AMP, DPV	Carbon black paste electrode	0.01 μM–4 μM	0.005 μM	Acetate buffer (pH 4.6)	198	
	DPV, LSV	Carbon black SPE	0.1 μM–8.8 μM	0.097 μM	Saliva, urine	199	
	CV	GC	4 mM–80 mM	6 μM			
	CV	Nafion/GC	up to 7.0 mM	0.04 μM	PBS (pH 7.0)	200	
	CV, SWV	Pseudo CP	1 μM–1 mM	0.348 μM	PBS (pH 7.0)	201	
	DPV	Molecularly imprinted polymer	0.5 nM–0.16 μM	90 pM	PBS (pH 6.5)	202	
	DPV	SWCNT/CC	0.25 μM–0.1 mM	0.12 μM	0.01 M H ₂ SO ₄ (pH 1.7)	203	
	SWV	EPPG	0.02 μM–100 μM	0.008 μM	PBS (pH 7.2), urine	204	
Thiocyanate (SCN [−])	CV, DPV	Ag-MWCNT/GC	2.5 nM–50 nM 50 nM–1.0 μM	1.0 nM	PBS (pH 6.0), saliva, urine	205	
	CV, AMP	Ag@Cu nanorods/GC	1 mM–10 mM	10 nM	PBS (pH 6.0)	206	
Anti-oxidants							
Glutathione (GSH) ^b	CV	Copper hydroxide/CILE	1 μM–50 μM 0.1 mM–1.8 mM	30 nM	PBS (pH 7.0)	207	
	CV, AMP	Ordered mesoporous carbon	0 mM–2.5 mM ^a	0.09 μM	PBS (pH 7.16)	208	
	CV, AMP	Carbon microfiber	5 μM–65 μM ^a	0.5 μM	PBS (pH 7.5)	158	
	CV	Poly(caffeic acid) nanocarbon composite/GC	0.5 μM–5.0 mM	0.5 μM	PBS (pH 7.0)	209	
	CV	GC	6 μM–59 μM	1 μM	Tissue media (pH 7)	210	
	CV	Prussian blue/SPE	2 μM–0.5 mM	2.0 μM	PBS (pH 7.4), blood	211	
	CV	Nanocarbon paste	2 μM–120 μM ^a	2.0 μM	PBS (pH 7.5)	212	
	CV	Caffeic acid/GC	>1.0 mM	2.2 μM	PBS (pH 7.0)	213	
Glutathione disulfide (GSSG)	CV, SWV	CNT-SPE	10 μM–60 μM ^a	3.0 μM	PBS (pH 7.0), saliva	156	
	CV	Copper hydroxide/CIL	0.4 μM–120 μM	15 nM	PBS (pH 7.0)	207	
	Ascorbic acid	CV, DPV	Graphene–Pt/GC	0.15 μM–34 μM	0.15 μM	PBS (pH 7.0)	214
		DPV	Nitrogen doped graphene	5.0 μM–1.3 mM	2.2 μM	PBS (pH 6.0)	215
		CV, LSV	SWCNH/GC	30 μM–400 μM	5 μM	PBS (pH 7.0)	216
CV, DPV		Poly(acid chrome blue K)/GC	50.0–1000.0 μM	10.0 μM	PBS (pH 4.0), urine	217	
Uric acid	CV, DPV	Graphene–Pt/GCE	0.05 μM–12 μM	0.05 μM	PBS (pH 7.0)	214	
	CE/AMP	Poly(dimethylsiloxane) (PDMS)/glass microchip	15 μM–110 μM	1 μM	MES (pH 5.5), urine	218	
	DPV	Nitrogen doped graphene	0.1 μM–20 μM	45 nM	PBS (pH 6.0)	215	
	SWV	Clay colloids/GC	0.5 μM–10 μM 10 μM–100 μM	0.2 μM	Citrate buffer (pH 1.0)	219	
	DPV	CIL	2.0 μM–0.2 mM	1.0 μM	PBS (pH 6.8), urine	220	
	CV, DPV	Poly(acid chrome blue K)/GC	1.0 μM–120 μM	0.5 μM	PBS (pH 4.0),	217	



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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