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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 <sup>+</sup>	20–80 mmol L <sup>-1</sup>	Plasma 145 mmol L <sup>-1</sup>	11
K <sup>+</sup>	20 mmol L <sup>-1</sup>	4 mmol L <sup>-1</sup>	
Ca <sup>2+</sup>	1–4 mmol L <sup>-1</sup>	2.2 mmol L <sup>-1</sup>	
Cl <sup>-</sup>	30–100 mmol L <sup>-1</sup>	120 mmol L <sup>-1</sup>	
HCO <sub>3</sub> <sup>-</sup>	15–80 mmol L <sup>-1</sup>	25 mmol L <sup>-1</sup>	
Phosphate	4 mmol L <sup>-1</sup>	1.2 mmol L <sup>-1</sup>	
Mg <sup>2+</sup>	0.2 mmol L <sup>-1</sup>	1.2 mmol L <sup>-1</sup>	
SCN <sup>-</sup>	2 mmol L <sup>-1</sup>	<0.2 mmol L <sup>-1</sup>	
NH <sub>3</sub>	3 mmol L <sup>-1</sup>	0.05 mmol L <sup>-1</sup>	
2. Organic compounds (non-protein and lipids)			
Uric acid	3.38 ± 0.21 mg dL <sup>-1</sup> 217.2 ± 110.3 mol L <sup>-1</sup> 0.1–7.5 mg dL <sup>-1</sup>	Serum 6.31 ± 0.24 mg dL <sup>-1</sup>	21–23
Bilirubin	0.5–5.0 µmol L <sup>-1</sup>	Serum 0.2–1.2 mg dL <sup>-1</sup>	24
Creatinine	0.12 ± 0.06 mg dL <sup>-1</sup> 0.05–0.2 mg dL <sup>-1</sup>	Serum 0.89 ± 0.17 mg dL <sup>-1</sup> Serum 0.6–1.5 mg dL <sup>-1</sup>	25
Glucose	4–13 mg dL <sup>-1</sup>	Blood 80–120 mg dL <sup>-1</sup> Blood 88.6 ± 8.0 mg dL <sup>-1</sup>	22 and 26
Cholesterol	0.02–5.46 µmol L <sup>-1</sup>	Serum <5 mmol L <sup>-1</sup>	27
Lactate	0.3–1.8 mM 0.1 to 2.5 mmol L <sup>-1</sup>	Serum 0.5–1.0 mM	28 and 29
3. Protein/polypeptide compounds			
α-Amylase	19–308 U mL <sup>-1</sup> <sup>a</sup> 93 ± 62 U L <sup>-1</sup> <sup>a</sup> 2.64 ± 1.8 mg mL <sup>-1</sup>	Serum 0.05–0.125 U mL <sup>-1</sup> <sup>a</sup>	23 and 30
Albumin	0.2 ± 0.1 mg mL <sup>-1</sup>	Serum 3.5–5.5 g dL <sup>-1</sup>	31
Secretory-IgA	80–717 mg dL <sup>-1</sup> 124.3–333.5 µg mL <sup>-1</sup>	Serum 70–400 mg dL <sup>-1</sup>	23 and 32
Mucin group	MUC5B: 2.4 ± 1.7 U mL <sup>-1</sup> 1.19 ± 0.17 mg mL <sup>-1</sup>	Serum 9.9 ± 0.8 ng mL <sup>-1</sup>	31 and 33
Lysozyme	3–50 µg mL <sup>-1</sup> 59.7 to 1062.3 µg mL <sup>-1</sup>	Serum 7.4 ± 1.8 mg mL <sup>-1</sup>	23, 32 and 34
Total proteins	7.1–223.2 mg dL <sup>-1</sup> 0.9 ± 0.2 mg mL <sup>-1</sup>	Serum 4–9 µg mL <sup>-1</sup> Serum 6–8 g dL <sup>-1</sup>	23 and 31
4. Hormones			
Cortisol	3.5–27.0 mg dL <sup>-1</sup>	Serum 2–25 mg dL <sup>-1</sup>	35
Testosterone	32–55 pg mL <sup>-1</sup>	Serum 320–600 ng dL <sup>-1</sup>	36
Progesterone	Luteal phase 436 ± 34 pmol L <sup>-1</sup> Follicular phase 22.1 ± 2.7 pmol L <sup>-1</sup>	Serum male: <1 ng mL <sup>-1</sup> Serum female: 0.1–20 ng mL <sup>-1</sup>	37
Estrogen (Estradiol)	Luteal phase 20.6 ± 0.4 pmol L <sup>-1</sup>	Serum male: 15–60 pg mL <sup>-1</sup> Serum female: 15–370 pg mL <sup>-1</sup>	37

<sup>a</sup> U mL<sup>-1</sup>: enzymatic activity per unit (mL) of saliva.

The concentration of CaCl<sub>2</sub>·2H<sub>2</sub>O (ref. Fusayama-Meyer<sup>16</sup>) was given incorrectly. The concentration of NH<sub>4</sub>Cl (ref. SAGF<sup>17,18</sup>) was missing. A full, corrected Table 2 is reproduced here.



**Table 2** Compositions of different artificial saliva recipes

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

<sup>a</sup> Bacto-Mucin bacteriological. <sup>b</sup> 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.<sup>38</sup>

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.
<b>Chemicals</b>						
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 <sup>a</sup>	—	Whole blood, serum	180
Phosphate	AMP, CV	Molybdate anions in chitosan/GC	0.79 μM–3.96 μM 19 μM–95 μM	—	Dearated 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 <sup>-1</sup>	1.0 ng mL <sup>-1</sup>	Serum	189
	AMP, CV	MWCNT/alumina-coated silica nanocomposite	—	1.42 μM	PBS (pH 8)	190
	AMP	TiO <sub>2</sub> /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 <sub>3</sub> <sup>-</sup> )	LSV	Cu plated-/BDD microelectrode array	1.2 μM–124 μM	0.76 μM	0.1 M Na <sub>2</sub> SO <sub>4</sub> (pH 3)	196
Nitrite (NO <sub>2</sub> <sup>-</sup> )	AMP	Cellulose acetate membrane/Pt Poly(1,8-diaminonaphthalene) film/Pt	1 μM–100 μM 0.5 μM–100 μM	0.5 μM 0.1 μM	Acetate buffer (pH 4.0)	197
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	Nafion/GC	4 mM–80 mM	6 μM	PBS (pH 7.0)	200
	CV, SWV	Pseudo CP	up to 7.0 mM	0.04 μM	PBS (pH 7.0)	201
	DPV	Molecularly imprinted polymer	1 μM–1 mM	0.348 μM	PBS (pH 6.5)	202
	DPV	SWCNT/CC	0.5 nM–0.16 μM	90 pM	0.01 M H <sub>2</sub> SO <sub>4</sub> (pH 1.7)	203
	SWV	EPPG	0.25 μM–0.1 mM	0.12 μM	PBS (pH 7.2), urine	204
	CV, DPV	Ag-MWCNT/GC	0.02 μM–100 μM	0.008 μM	PBS (pH 6.0), saliva, urine	205
Thiocyanate (SCN <sup>-</sup> )	CV, AMP	Ag@Cu nanorods/GC	2.5 nM–50 nM 50 nM–1.0 μM	1.0 nM	PBS (pH 6.0)	206
<b>Anti-oxidants</b>						
Glutathione (GSH) <sup>b</sup>	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 <sup>a</sup>	0.09 μM	PBS (pH 7.16)	208
	CV, AMP	Carbon microfiber	5 μM–65 μM <sup>a</sup>	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 <sup>a</sup>	2.0 μM	PBS (pH 7.5)	212
Glutathione disulfide (GSSG)	CV	Caffeic acid/GC	>1.0 mM	2.2 μM	PBS (pH 7.0)	213
	CV, SWV	CNT-SPE	10 μM–60 μM <sup>a</sup>	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	0.2 μM	Citrate buffer (pH 1.0)	219
	DPV	CIL	10 μM–100 μM	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 SWV	SWCNH/GC Electrochemically activated GC	0.06 μM–10 μM 0.04 μM–2.0 μM	20 nM 9 nM	PBS (pH 7.0) 0.5 M H <sub>2</sub> SO <sub>4</sub> , urine	216 221
<b>Therapeutic drugs</b>						
Theophylline	CV DPV	MWCNT/GC Graphene/Nafion/GC	0.3 μM–10.0 μM 10 nM –1.0 μM 2.0 μM–30 μM	50 nM 6.0 nM	PBS (pH 5.8) 0.1 M H <sub>2</sub> SO <sub>4</sub>	222 223
	DPV DPV	Cobalt phthalocyanine NP/CP Urchin-like CdSe microparticles/ GC	0.4 μM–0.1 mM μM–40 μM 40 μM–700 μM	0.14 μM 0.4 μM	PBS (pH 7.4) PBS (pH 6.0)	224 225
	SWV	Nafion/lead–ruthenium oxide pyrochlore	up to 100 μM	0.1 μM	PBS (pH 3)	226
Acetaminophen (paracetamol)	CV DPV	Nafion/TiO <sub>2</sub> –graphene/GC Pd/graphite oxide/GC	1 μM–100 μM 5 nM–0.5 μM 0.5 μM–80.0 μM	0.21 μM 2.2 nM	PBS (pH 7.0) PBS (pH 6.8)	227 228
	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 2 μM–20 μM	10 nM	PBS (pH 7.5)	233
	SWV	Graphene/GC	0.1 μM–20 μM	32 nM	NH <sub>3</sub> ·H <sub>2</sub> O–NH <sub>4</sub> Cl (pH 9.3)	234
<b>pH</b>						
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-diy) regiorandom/SPCE	pH 4–8	Sensitivity: –53.4 mV/pH (buffer)	Buffer, saliva	237
	ISE	Poly(terthiophene benzoic acid)/ AuZnO <sub>x</sub> /SPCE	pH 2–13	Sensitivity: 59.2 ± 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.<sup>a</sup> Not stated in the text – values are taken from calibration curves present in the papers.



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