Using bio-impedance for rapid screening of water injection into chicken filets

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Abstract. *Injecting chicken products with water has emerged as a considerably spread method for increasing the weights of the product in order to increase profits. Due to the huge number of products that are retailed daily, it is out of reach to test them with conventional methods for water injection. Here we present results for rapid screening of water amount in chicken filets done by electrical bio-impedance, a technique that is easy to implement, rapid, portable. Electrical impedance depends on structure and composition of the sample, and as such, its values correlate with water amount. We present results for values of electrical bio-impedance for 50 samples from the Dutch market and compare them with values of bio-impedance obtained with chicken filets injected with tap water, salty water, and with moisture retaining agents. Results demonstrate that, after proper calibration, bio-impedance is a convenient method for a rapid screening of meat products.*

Introduction. To increase their weight, and to flavour them, chickens meats are sometimes injected with seawater. This adulteration disrupts the quality of the product, defrauds consumers, and increases the content of sodium of the chickens. A rapid assay for the authenticity of chicken meat would protect consumers, and the reputation of retailers by constantly monitoring the products on the shelves. To this goal, we propose a rapid physical-chemical assays based on the measurements of the electrical impedance[1-7] of chicken samples. Electrical impedance, in fact, depends on the composition, and structure of a sample. A useful feature of electrical bio-impedance is the opportunity to determine the impedance of the extra-cellular matrix of a tissue, and the cumulative impedance of extra- and intra-cellular matrix together with the contribution of the cellular membrane. Intra- and extra- cellular matrixes conduct current via ionic motion and give an ohmic contribution to the impedance (Figure 1, component R); by contrast, cellular membrane conduct current by polarization and, as such, contribute with a capacitive term which depends on the frequency of the voltage source (Figure 1, component C[2, 3]). By measuring the impedance at different frequencies, these terms can be quantified.

Conventional methods of analysis of water content of meats require long times, trained personnel, and the destruction of the sample Measuring electrical impedance of chicken samples is simple and rapid and does not require a long preparation of the sample; indeed, it can be performed directly on a chicken cut.

By contrast,. As such, values of electrical impedance can be used for a rapid screening of the state of a sample by comparing measured values with reference values collected for authentic samples.

For the present study, we took advantage of recent development of equipment and designed a impedance-meter by using portable hardware available on the market.

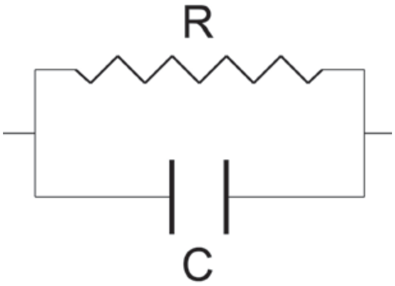

Figure 1. Components of the impedance Z. R= ohmic contribution mainly due to ionic conduction. C= capacitive term due to the cellular membrane.

This strategy made it possible to develop a cheap, yet reliable reader of values of electrical impedance of chickens filets. This instrument was able to detect injection of tap water, salty water, and moisture retaining proteins. We also present results for values of electrical impedance of chicken filets across 50 samples analysed during six months. These results represents a reference data-archive for future testing of not declared injection of water.

Experimental. For measuring the impedance of chicken filets we used a 4-electrodes probe.[2, 7] With this design, two electrodes were used to inject the current coming from a digital function-generator, and two electrodes were used to measure the voltage drop localized exclusively within the portion of the chicken filet under investigation. This design minimizes the influence of the interfaces and removes the impedance of the external circuit. As electrodes, we used stainless steel needles which could penetrate the sample. As voltage source we used a portable function generator Vellman HPG1. We measured the voltage drop with a portable oscilloscope Vellmann HPS140i, and we read the current flowing through the circuit with a bench amperometer by Gw-Instek GDM 8245. For measuring the impedance we used a sinusoidal voltage signal with an amplitude of 0.5V and of variable frequency.

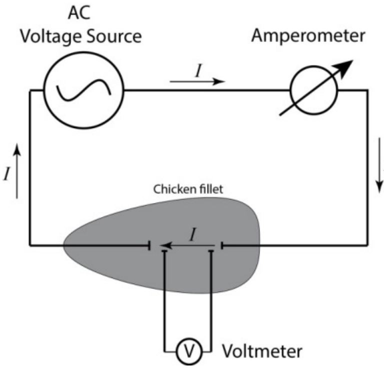

Figure 2. *Conceptual circuit used for measuring the impedance Z of a chicken filet. As AC voltage source we used a portable function generator; As voltmeter we used a portable oscilloscope, while we measured the current with a common bench amperometer. With this design, we measured the impedance Z within the two electrodes connected to the oscilloscope and that were inserted into the chicken fillet.*

The modulus of the impedance Z was calculated as:

$$|Z| = \frac{|V|}{|I|}$$

where V was the voltage drop, measured with the voltmeter, within the sample, and I is the current flowing through the entire circuit (measured with the amperometer.)

This study measured the value of Z for 50 chicken filets from the Dutch market over a period of three months, from June 2015 to August 2015. Samples specifications are listed in Table 1. The values of Z for these 50 samples served to estimate the range of the values of Z for genuine products. For each samples, we measured 15 values of Z. Successively, we measured the values of Z for 15 chicken filets which were injected with increasing amounts of tap water; 15 which were injected with a solution of 2 g/L NaCl in tap water; 15 filets treated with protein retaining protein. Measurements were repeated at 200 Hz and 45 KHz.

Results. Figure 3 summarizes the values of Z measured for the 50 samples listed in table 1. Measurement at 45 KHz were more stable than at 200 Hz and values of Z resulted less dispersed. We did not observe any variation over the three months. These measurements allowed us to estimate an average value of Z expected for genuine sample as Z= 160 Ω with standard deviation SD = 27 Ω at 45 KHz, and Z= 180 Ω with standard deviation SD = 40 Ω.

The small difference between the values at 200 Hz and at 45 KHz suggests that most of the current flows through the extra-cellular matrix as it can be expected because of the high amount of water held by the chicken filets (~78%) which makes the contribution of the non-conductive, polarizable cellular membrane very small.

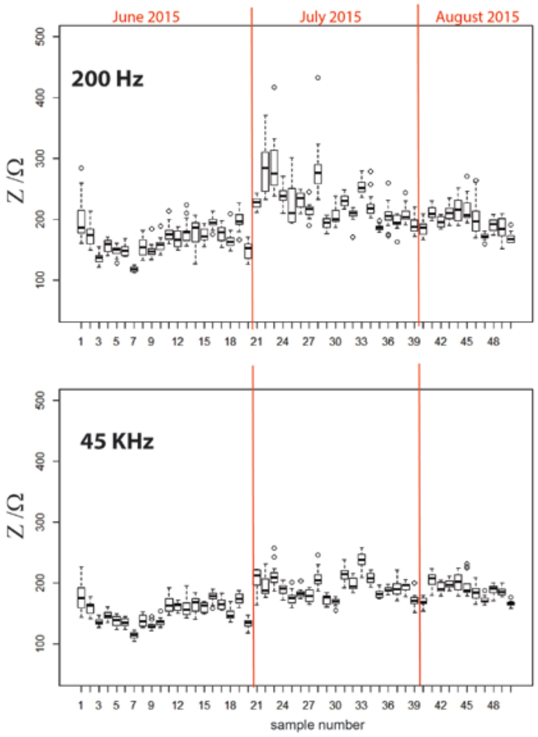

Figure 3. *Values of Z measured at 200 Hz (top), and at 45 KHz (bottom) for the 50 samples listed in Table 1.*

After the screening of chicken filets from the market, we measured the values of Z for a series of samples that we injected with different amount of tap water. Results are reported in Figure 4. We observed that the progressive increase of water injected into the samples led to a correspondent increase in the value of Z.

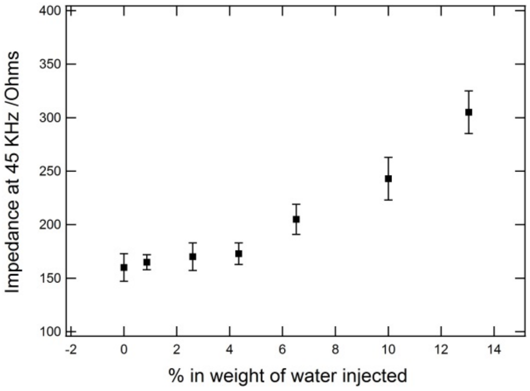

Figure 4. *Values of Z measured at 45 KHz for chicken filets injected with increasing amounts (expressed as % in weight) of tap water.*

This result is compatible with the low conductivity of the tap water. We observed that the value of Z for a chicken injected with 14% (in weight) of water fell beyond the range of the variation reported in figure 3, and the high value of Z resulted from injection of water. We did not observe any difference in Z between values measured at 200 Hz and 45 KHz; indeed, injection of water modified the composition of the extra-cellular matrix.

We measured also the effect on the value of Z of injecting salty water in to the chicken filets. Results are shown in Figure 5. Both at 200 Hz and at 45 KHz the values of Z decreased from 160 Ω to ~135 Ω when salty water was injected. We observed that the value of Z dropped at once and did not decrease further by injecting more water. The conductivity of the salty water, in fact, dominates the impedance of the chicken filet, which are less conductive than the salty solution. Again, the behaviour was the same at 200 Hz and at 45 KHz, indicating that the alteration involved only the extra-cellular matrix. From comparison of the results reported in Figure 5 and Figure 3, we see that values of Z lower than 130 Ω are due to artificial modification of the composition and should not be expected for genuine chicken filets.

Because the amount of water that can be injected is limited, some producers have been found adding water retaining agents, such as pork proteins, to increase the volume of water that a chicken filet can hold. These protein turn the water into a gel, preventing from any leaking, and increasing the weight of the product.

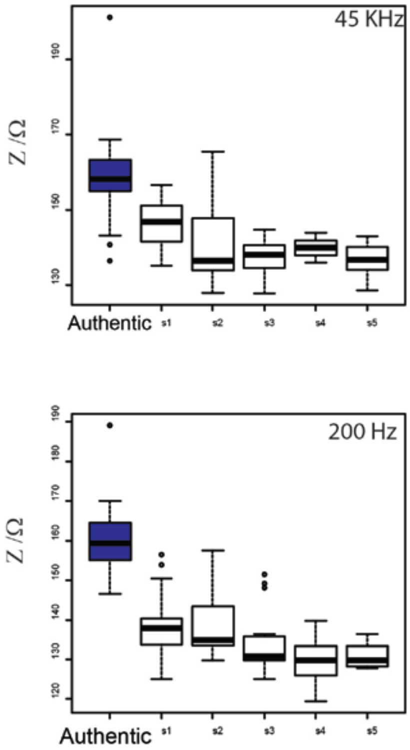

Figure 5. *Values of Z for chicken filets injected with salty water. For comparison, the values of Z for the same chicken filets before injection are also shown (authentic).*

Figure 6 shows the values of Z for fresh samples and for samples to which a gelifying agent was added.

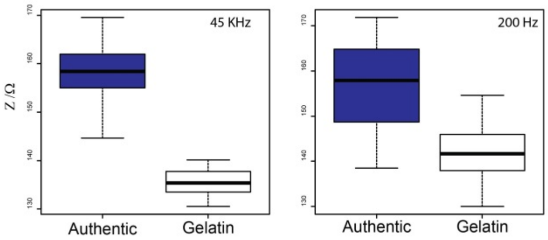

Figure 6. *Values of Z for fresh chicken filets and for filets injected with a solution containing gelifying agents.*

We observed, for the injected samples, a big variation of Z between 200 Hz and 45 KHz, much bigger than the variation of Z at the two frequencies for not-injected samples. In the case of Figure 6, in fact, the gelifycation of the extracellular matrix changed the mobility of ions within it, leading to a different response depending of the frequency of the voltage signal. From Figure 6 we observe a ΔZ of ~100 Ω.

Based on this experiment, we can conclude that a substantial variation of Z going from 200 Hz to 45 KHz indicates an extracellular matrix where the motion of ions is not the same as that observed for fresh samples.

Conclusion. Measuring bio-impedance resulted a valuable method for a rapid screening of water injected into chicken products. The work described in this article might serve, in the future, as a background to develop the method even further. Values of Z reported here represent a reference background for rapid testing.

Table 1. Samples of chicken filets used in the study

Sample number	Description	Producer
1	Hollandse kip, Kipfilet 1 stuk, eigen merk	Albert Heijn, Renkum
2	Kipfilet, 1 stuk, eigen merk	Plus, Renkum
3	Kipfilet, 2 stuks, eigen merk	Spar, Heelsum
4	Kipfilet, 2 stuks, Storteboom Brink B.V.	Aldi, Oosterbeek
5	Kipfilet, 1 stuk, eigen merk	COOP, Oosterbeek
6	Nieuwe standaard kip, Kipfilet, 1 stuk, eigen merk	Jumbo, Doorwerth
7	Biologisch kippen vlees, Kipfilet, 1 stuk, eigen merk	Jumbo, Doorwerth
8	Kipfilet, 2 stuks, Landjonker	LIDL, Doorwerth
9	Kipfilet, 1 stuk	Natuurslagerij Keijzer & van Santen, Wageningen
10	Kipfilet, 1 stuk	Keurslager H.E. Elings, Wageningen
11	Kipfilet, 1 stuks, eigen merk	Hoogvliet, Wageningen
12	Kipfilet, 3 stuks, Pure Halal	Hoogvliet, Wageningen
13	Kipfilet, 1 stuks, eigen merk, Actie	C1000, Wageningen
14	Kipfilet, 1 stuks, de betere kip, eigen merk	EMTE, Ede
15	Kipfilet, 2 stuks, Vleesspecialiteiten, Scharrel kipfilet, vrije uitloop	EMTE, Ede
16	Kipfilet "Tante Door", 1 stuks	Keurslager de Haas, Stadspoort, Ede
17	Hollandse kip, Kipfilet 1 stuk, eigen merk	Albert Heijn XL, Ede
18	Kipfilet, 1 stuk, Scharrel kip, eigen merk	Albert Heijn XL, Ede
19	Kipfilet 3 stuks, grote kipfilet, eigen merk	Albert Heijn XL, Ede
20	Kipfilet 1 stuk, Odin	Estafette de biologische eetwinkel, Ede
21	Kipfilet 1 stuk, eigen merk, nieuwe AH kip	Albert Heijn, Renkum
22	Kipfilet, 1 stuk, eigen merk	Plus, Renkum
23	Kipfilet, 1 stuk, eigen merk	Spar, Heelsum
24	Kipfilet, 2 stuks, Storteboom Brink B.V.	Aldi, Oosterbeek
25	Kipfilet, 1 stuk, eigen merk	COOP, Oosterbeek
26	Kipfilet, 2 stuks, eigen merk	Jumbo, Doorwerth
27	Kipfilet, 2 stuks, Scharrel kip, eigen merk	Jumbo, Doorwerth
28	Kipfilet, 2 stuks, Landjonker	LIDL, Doorwerth
29	Kipfilet, 1 stuk	Natuurslagerij Keijzer & van Santen, Wageningen
30	Kipfilet, 1 stuk	Keurslager H.E. Elings, Wageningen
31	Kipfilet, 2 stuks, Biologische kip 3 sterren, eigen merk	Albert Heijn, Renkum
32	Kipfilet, 1 stuk, Scharrel kip, Beter leven 1 ster, eigen merk	Albert Heijn, Renkum

33	Kipfilet, 3 stuks, Scharrel kip, Beter leven 1 ster, Landjonker	LIDL, Doorwerth
34	Kipfilet, 2 stuks, Scharrel kip, eigen merk	Jumbo, Doorwerth
35	Biologisch kippen vlees, Kipfilet, 1 stuk, eigen merk	Jumbo, Doorwerth
36	Kipfilet, 2 stuks, Hollandse Beter Leven kip, 1 ster, eigen merk	Plus, Renkum
37	Kipfilet 1 stuk, Bio+, Beter Leven 3 sterren	Plus, Renkum
38	Kipfilet, 1 stuk	Keurslagerij Gert Budding, Renkum
39	Kipfilet, 1 stuk	Slager & Worstmaker van de Bovenkamp
40	Kipfilet, 1 stuk	Ambachtelijke slager Reijers, Renkum
41	Kipfilet, 1 stuk	Natuurslagerij Keijzer & van Santen, Wageningen
42	Kipfilet, 1 stuk	Keurslager H.E. Elings, Wageningen
43	Kipfilet, 2 stuks, Scharrel kip, Beter leven 1 ster, eigen merk	Albert Heijn, Renkum
44	Kipfilet, 2 stuks, Biologische kip 3 sterren, eigen merk	Albert Heijn, Renkum
45	Kipfilet, 1 stuk, eigen merk	Plus, Renkum
46	Kipfilet, 2 stuks, Hollandse Beter Leven kip, 1 ster, eigen merk	Plus, Renkum
47	Kipfilet 1 stuk, Bio+, Beter Leven 3 sterren	Plus, Renkum
48	Kipfilet, 3 stuks, Scharrel kip, Beter leven 1 ster, Landjonker	LIDL, Doorwerth
49	Kipfilet, 2 stuks, Scharrel kip, eigen merk, 1 ster	Jumbo, Doorwerth
50	Biologisch kippen vlees, Kipfilet, 1 stuk, eigen merk	Jumbo, Doorwerth

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