

Determination of the electrical conductivity of gluten-free dough during ohmic baking

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INTRODUCTION & AIM

During ohmic cooking an electrical current passes through a food. The resistance of the food to the electrical current generated heat in a volumetric way, heating the food quickly, efficiently and uniformly. The heating velocity depends, among other factors, on the food electrical conductivity σ (Siemens/m).

This study aimed to estimate σ for gluten-free batters during ohmic baking tests.

METHOD

The baking tests were performed at 50 Hz electrical current, with voltage difference of 135, 180 or 220 V. Fig. 1 show an image of one baking test.

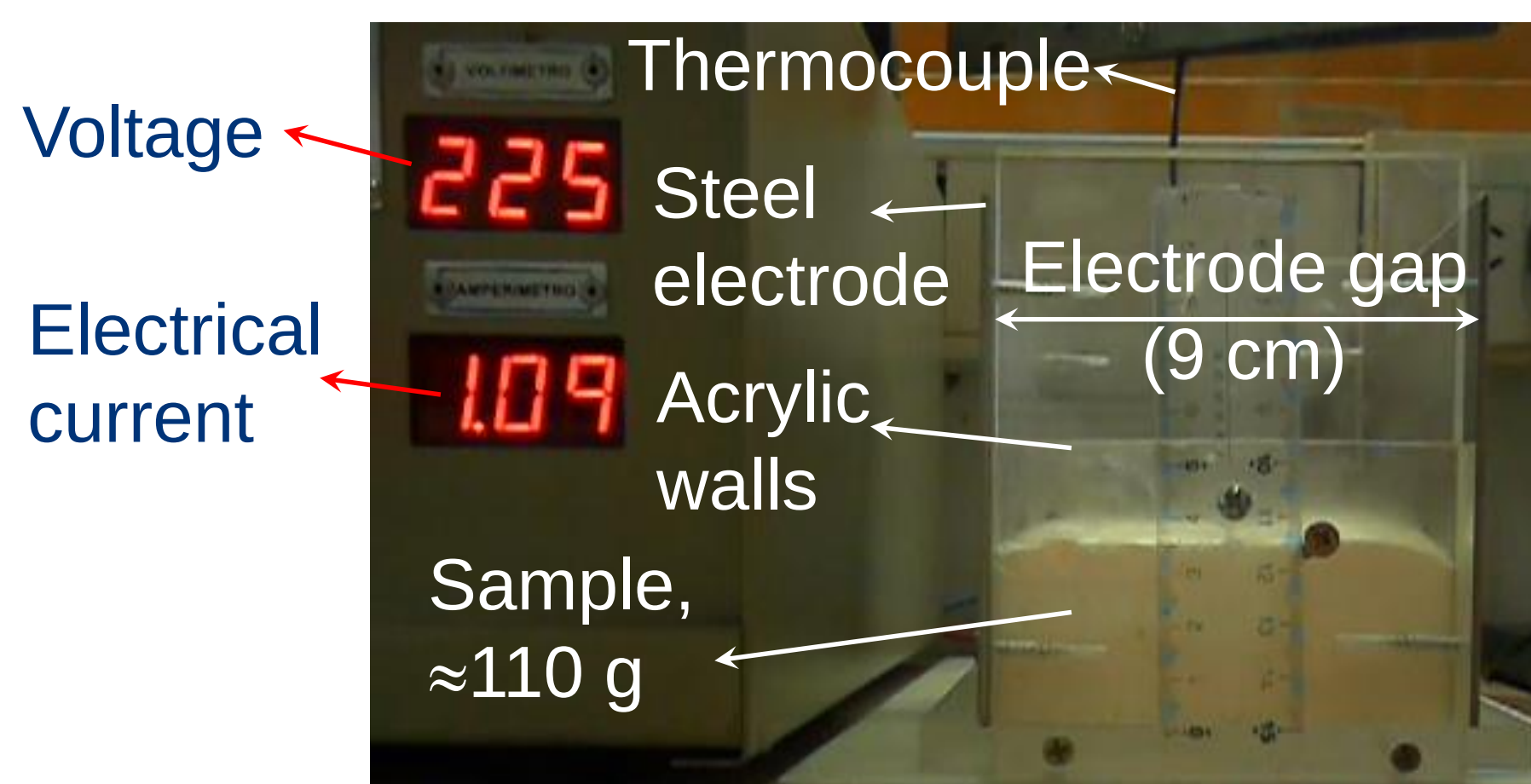


Figure 1. Gluten free premix, ohmic baked at 225 V, 50 Hz

During tests, current, voltage, sample height, and internal temperature, were obtained. Data with temperatures below 60°C was used, before starch gelatinization.

σ estimation from capacitor formula:

$$\sigma = (I \cdot L) / (U \cdot A) \quad (1)$$

I is current (A), L is the electrode gap (m), U is the voltage (V) difference, and A is the electrode area (m²). Since area change with time and height profile is not uniform, the initial height was used. σ vs. T were fitted to polynomials:

$$\sigma = a + b \cdot T + c \cdot T^2 \quad (2)$$

and used to solve a simple macroscopic energy balance to estimate batter temperature evolution (E is electric field, U/L):

$$\rho C_p \frac{dT}{dt} = \sigma E^2 \quad (3)$$

Since the initial height was used, a constant density was assumed.

σ estimation from temperature profiles: an inverse problem was solved to estimate parameters of Eq. (2); the energy balance (3) was solved using 4th-order Runge-Kutta method, coupled to a nonlinear fitting method to minimize the difference between predicted and experimental temperature profiles.

RESULTS & DISCUSSION

Fig. 2 show σ predicted using Eq. (1).

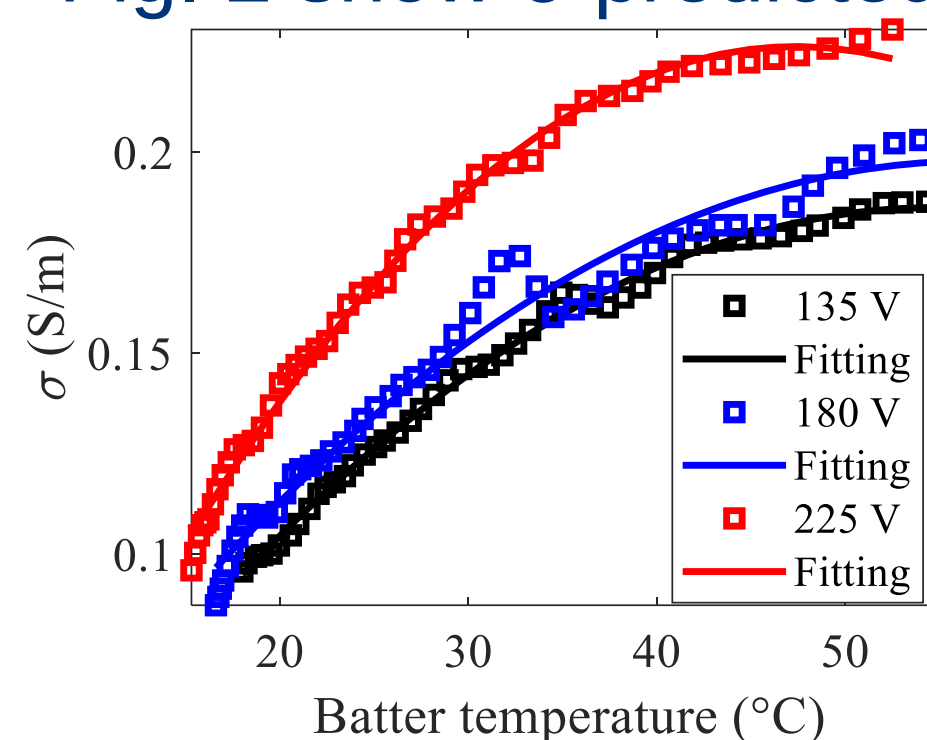


Figure 2. Experimental data and fitting of Eq. (2)

σ predicted was used to solve the macroscopic energy balance to estimate batter temperature evolution: comparing the predicted vs. experimental batter temperature profiles (Fig. 3a), the errors were 3.3, 9.8, and 28.2%, for the three voltages. Using the temperature profiles to solve the inverse problem lead to prediction errors of 0.32, 0.38, and 0.97%, respectively (Fig. 3b).

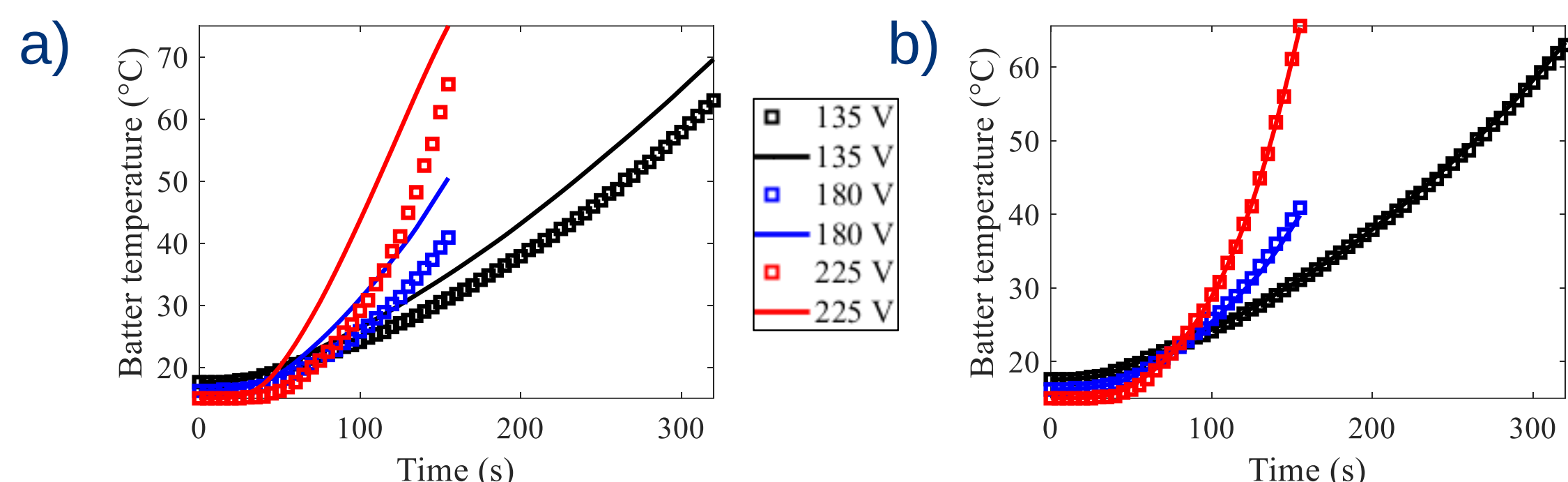


Figure 3. Symbols: experimental batter temperature; lines: Eq. (3). a) Prediction of T using σ from Eq. (1). b) Prediction of T by inverse problem fitting using T profiles.

Using both methods, it is found that σ increases as temperature increases (not show). As expected, the inverse problem lead to much better T predictions, however the variations of other properties as density are included in the estimated values.

CONCLUSION

The inverse method, which involve the use of the temperature data, significantly outperforms the prediction accuracy compared to the traditional method, since the same T is used as objective function. Although it is more complex, provide better estimations.

FUTURE WORK / REFERENCES

For the capacitor equation, the electrode surface area will be estimated at each time, in order to better predict σ values and provides a more fair comparison. Similarly, density variation in the model will be considered.