243rd ACS National Meeting

Copper's Influence on the Formation of Egg White Foams

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Introduction

Egg white foams have long been used in recipes as texturizers due to their near lack of taste and their ability to trap air into baked goods. The additional air lowers the density of baked goods, such as soufflés and angel cakes which would otherwise be very heavy[1]. In addition to texture alteration, the nutritional content of egg whites make it an excellent additive to a balanced diet[2]. However, egg white foams are difficult to use because they have a tendency to break (separation of water content from foam). The whipping of egg whites causes an alteration in the protein structure, due to hydrophobic and hydrophilic portions, and are able to trap air in its new conformation[2]. The delicate nature of the interactions between the air and the proteins can lead foam failure as a consequence of overbeating or sitting for a short amount of time. It has long been suggested that whipping egg whites in copper bowls produces better foams that are smother and longer lasting than foams produced using glass, stainless steel or plastic bowls[3]. It is understood that the egg proteins chelate the copper released from the bowl which results in a stabilization of the whipped product's structure[4]. A similar chelation is seen in the biurett test used to detect the presence of peptide bonds (Figure 1). This stabilization results in fluid retention as well as a more uniform foam.

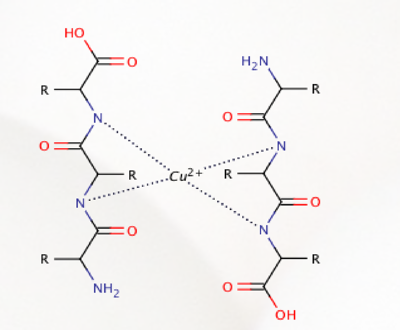

Figure 1. Peptide bonds chelating a copper ion.

By quantifying the amount of copper incorporated into the egg foams, a more substantial connection between the presence of copper and its alteration of the foam characteristics can be achieved.

Experimental

Egg Foam Production

- Samples of egg foam for all experiments were produced using the whites of two large, white eggs.
- Egg whites were separated from the yolk and the foams were whisked immediately after separation.
- A solid copper bowl, a stainless steel bowl, and an electric hand mixer with metal beaters were used to whip the egg whites (Figure 2).

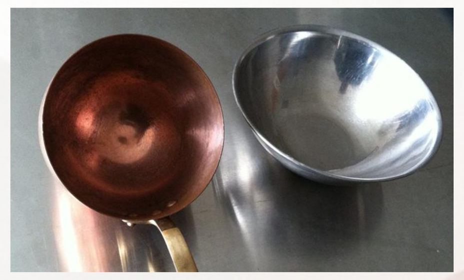

Figure 2. Copper and stainless steel bowls.

- The hand mixer was set to its lowest setting for all foam preparations, and a consistent circular motion was used at a rate of about 1 to 2 revolutions per second.
- Stiff peaks of similar consistencies indicated the whisking endpoints. (To reduce bias, the person whipping the egg whites was not able to see the time lapsed during beating and thus could only judge readiness based on peak consistency.)

Atomic Absorption

- Egg foam samples were prepared by digesting approximately 15 g of egg foam with 25 mL of 70% (v/v) nitric acid under gentle heating and stirring (Figure 3).
- Three types of samples were prepared in triplicate
  - Foam samples produced in a copper bowl
  - Foam samples prepared in a stainless steel bowl
  - Unbeaten egg whites (control samples)

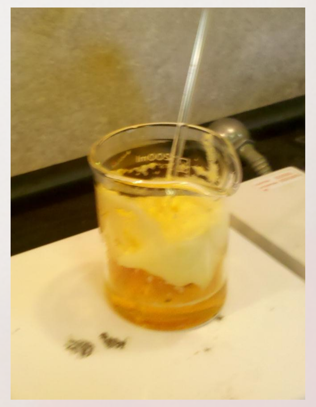

Figure 3. Sample Digestion for AAS.

- A Varian SpectraAA 50, Flame Atomic Absorption Spectrophotometer (Figure 4) was used to perform the analyses with the following settings
  - A copper hollow cathode lamp source
  - 4 mA lamp current
  - Air/Acetylene flame
  - 222.6 nm wavelength
  - 0.2 nm slit width
- A six point calibration curve (0, 2, 4, 6, 8, and 10 ppm) was prepared using a 1000 ppm Copper reference standard from Fisher Scientific dilute with 70% (v/v) nitric acid.

Figure 4. Varian AA.

Draining Analysis

- Two strainers were placed side by side above two identical Mettler Toledo balances, each holding a tarred beaker (Figure 5).
- The apparatus was set up inside a Plexiglas shield to reduce interference due to air movement.
- Balances were alternated between trials to reduce equipment bias.
- Timers were started promptly after the whipping endpoints were reached and the samples were transferred onto the strainers.
- Real time gravimetric data was collected during a total of 30 minutes with readings taken every 5 minutes.

Figure 5. Draining Gravimetric Analysis.

Magnified Foam Image

- Magnified images of the foams were taken using an Olympus SZX10 dissecting microscope with an infinity1 digital camera (Figure 6).
- Images were taken immediately following whipping the egg whites .

Figure 6. Microscope.

Results & Discussion

Atomic Absorption

Analysis of copper content revealed that the samples prepared in the copper bowl had a considerably greater concentration of copper ranging from 7 to 18 ppm (Figure 7). Unbeaten egg whites and foams produced in a stainless steel bowl had copper concentrations below 1 ppm.

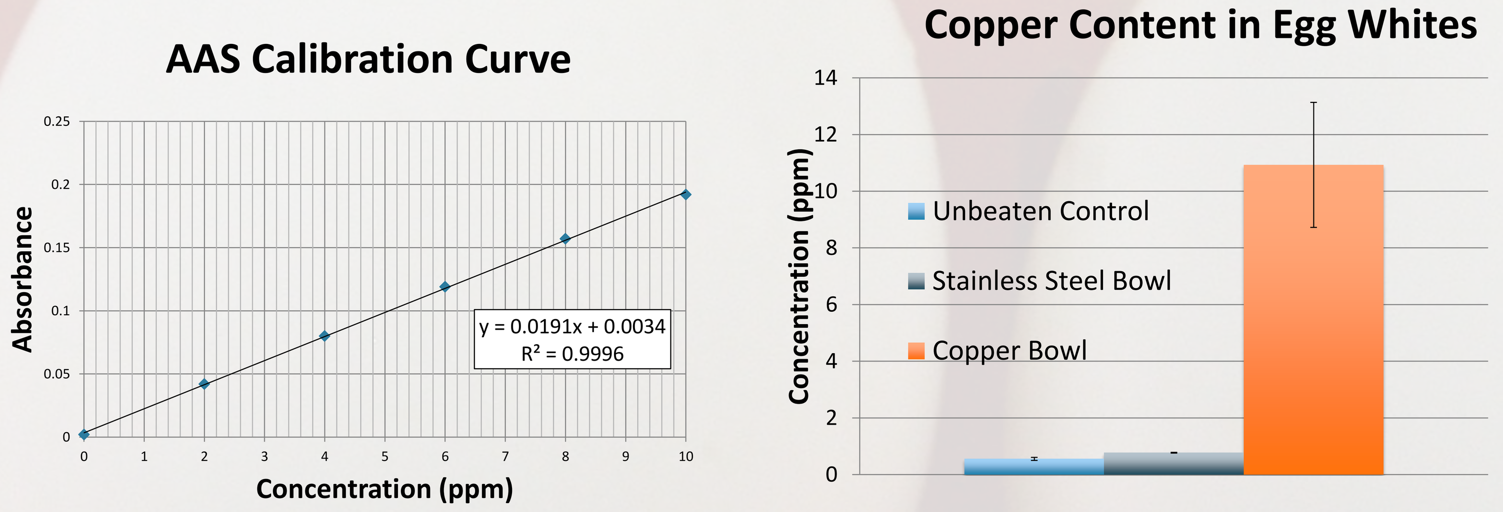

Figure 7. Atomic absorption calibration curve (left) and results (right).

Atomic absorption results show that egg white foams produced in copper bowls contains significantly higher levels of copper than unbeaten egg whites and egg white foams produced in stainless steel bowls.

Draining Analysis

The results of the drainage studies show that egg white foams prepared in copper bowls have better fluid retention properties compared to foams prepared in stainless steel bowls (Figure 8). Over a time period of 30 minutes, the foams prepared in the copper bowl lost an average of 5.51 grams of fluid while the foams prepared in the stainless steel bowl lost and average of 9.18 grams. Also, the total fluid retention was much less variable in foams produced in the copper bowl compared to those prepared in the stainless steel bowl. Error bars on the data points indicate the standard deviation for the measured results.

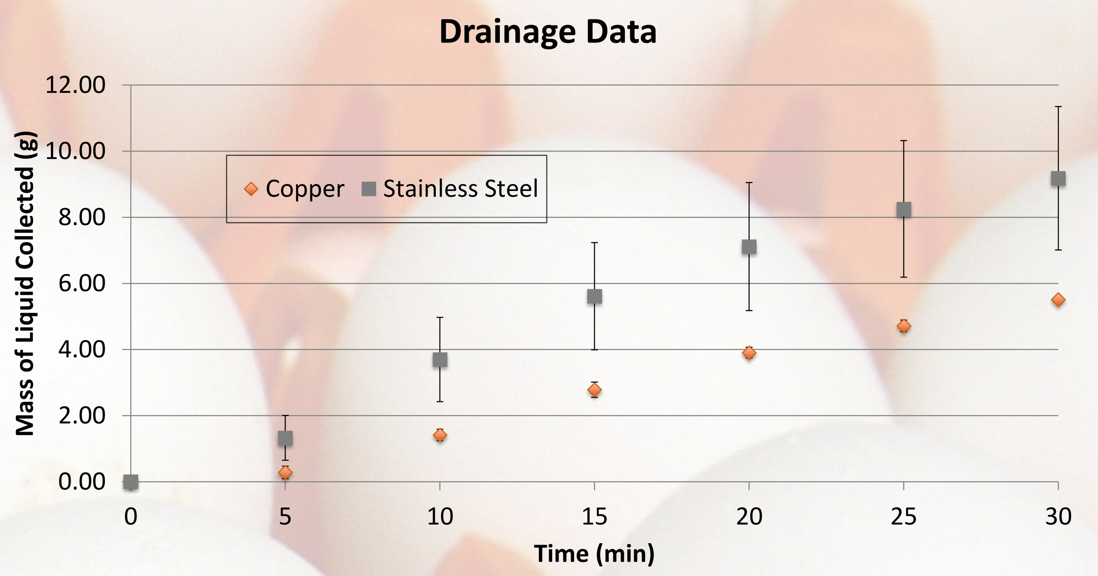

Figure 8. Gravimetric draining result.

The drainage analysis shows that a foam prepared using a copper bowl retains more moisture and is more stable than a foam prepared in a stainless steel bowl.

Magnified Foam Images

The magnified images of the foams show two distinct differences (Figure 9). One is the darker of the foams produced in the copper bowl and the other is the distribution in bubble size. The ranges in bubble size for the copper foam is much smaller than that of the foam produced in the stainless steel bowl. The average bubble size of the foams produced in the stainless steel bowl (260 μm) were significantly different from the average bubble size of the foam produced using the copper bowl (250 μm). The difference in bubble sizes are the result of air diffusion driven by differences in surface tension. Sagis, L et. al. [4] suggests that the addition of copper increases the surface tension of the foam minimizing diffusion and increasing its usable lifetime.

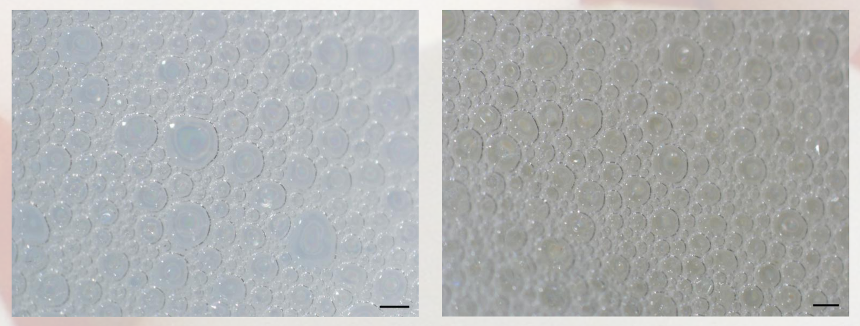

Figure 9. Magnified Foam Images (Stainless steel (left) copper (right)).

The fluid released upon foam collapse was analyzed using a Minolta Chroma Meter CR-200b in d65 mode. The fluid released from the foams produced using the copper bowl had significantly different L*a*b* values (44.7, -0.8, 29.6) compared to those produced using the stainless steel bowl (55.6, -2.2, 12.8).

References

[1] McGee, H. J., Long S. R., & Brigg, W. R. *L Nature* 308 (1984) 667.
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[3] McGee, H. On Food and Cooking, Ch. 2 Scribner, New York. 2004.
[4]Sagis, L. Groot-Mostert, A. Prins A. & Linden, E. *Colloids and Surfaces. 180 (2001) 163.*