Correlation of egg physical quality measurements and functional determinations

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Both physical and functional determinations have served as a means for determining shell egg quality. A study was conducted to determine if correlations exist between these types of egg quality measurements. Shell eggs were collected weekly after processing from a U.S. inline processing facility for three weeks (replicates). Eggs were stored at 4C until testing was conducted. The study was conducted during 10 wks of storage. The physical quality parameters monitored include: egg weight, albumen height, Haugh unit, shell strength, vitelline membrane strength and elasticity, and egg solids. Functional measurements included: angel food and sponge cake volume and mayonnaise depression force (fresh and stored). Angel food cake volume was found to be positively correlated with increased egg weight (P < 0.001), albumen height (P < 0.01), and Haugh unit (P < 0.01), while negatively correlated with increased albumen solids (P < 0.01). Sponge cake volume was positively correlated with increased whole egg solids (P < 0.01) and negatively correlated with egg weight (P < 0.001), albumen height (P < 0.01), Haugh unit (P < 0.01) and vitelline membrane elasticity (P < 0.01). Fresh and stored mayonnaise force measurements were highly correlated (P < 0.0001). Yolk solids were positively correlated with fresh and stored mayonnaise force measurements (P < 0.0001 and P < 0.001, respectively). The results of this study found several strong correlations between objective physical egg quality measurements and more subjective functional quality determinations which could lead to greater use of objective physical assessments to determine functional capabilities of shell eggs.

Key words: shell eggs; physical quality; functionality; extended storage

Introduction

Eggs can serve in many roles in the food system. They can be the source of nutrition for an incubating chick, impart characteristic taste or texture to a food product, provide leavening to bakery products, retard crystallization in foods and candies, and many other functions. The definition of egg quality is dependent upon a given situation. Over the years, physical characteristics and functionality have been utilized to measure egg quality. Initially, the physical characteristics of the egg and its components were assessed to determine if an egg was “good”. Many of the original physical quality determinations were subjective in nature, but subsequent objective methodologies were developed.

The Haugh unit (HU, Haugh, 1937) has been accepted as the “gold standard” for interior egg quality determination in the U.S. It is a ratio calculation involving egg weight and thick albumen height. There has been some concern as to the validity of this measurement since the equation is corrected for a large size egg (Silversides, 1994). Other common physical quality measurements include hand candling,
albumen index, yolk index, specific gravity, shell strength, vitelline membrane strength, egg weight, and shell thickness.

As the understanding of eggs and their role in food products grew, the development of functionality assessment methods grew. It has been accepted that albumen proteins can play an important role in leavening. Furthermore, egg yolk lipoproteins can be vital to the formation of acceptable emulsions. Albumen functionality tests include angel food cake volume, foam height, foam stability and whipping time. Mayonnaise and emulsion stability tests have been commonly used for yolk functionality. Sponge cake volume can be utilized to assess whole egg functionality (Samimi and Ball, 1995). Interpreting the results from functional tests can be highly subjective. Many of these methods require a high degree of input from the tester, whether it be folding in ingredients, visually determining stages of foaming or the consistent addition of oil to an emulsion. All of these factors can dramatically affect the results.

Over the years, advancing technologies have allowed for the development of computer-based instrumentation to aid in measurements and data interpretation. Also, testing instrumentation has been developed that allows for labs throughout the world to utilize the same technology.

This study was conducted to determine if correlations could be found between physical and functional quality measurements. If strong correlations are found, it could reduce the need for both physical and functional testing capabilities in laboratories. Additionally, more precise, objective methods may be able to predict the outcome of less consistent, subjective tests.

**Materials and methods**

Large sized eggs were collected according to the methods outlined by Jones and Musgrove (2005). All eggs were stored at 4C and 80% RH for the duration of the 10 week storage study. Three replicates of eggs were collected on consecutive Mondays from an inline processing facility in the southeastern U.S. An inline facility has hens housed at the processing facility and the eggs move directly to the processing line through a series of belts.

Physical quality measurements were conducted according to the methods described by Jones and Musgrove (2005). Briefly, egg weight, albumen height and HU were recorded with a TSS QCD system (Technical Services and Supplies, Dunnington, York, UK). Shell strength and vitelline membrane strength were detected on a TA-XT2plus texture analyzer (Texture Technologies, Scarsdale, NY, USA) equipped with a 5 kg load cell.

Functionality methods were conducted according to the procedures outlined by Jones (2000). Three Kenwood Major Classic (Delonghi America, Inc., Saddle Brook, NJ, USA) mixers equipped with whisk attachments were utilized to prepare the cake batters and mayonnaise. Cake volume was determined by the rapeseed displacement method. Mayonnaise emulsion strength was determined utilizing a TA-XT2plus texture analyzer (Texture Technologies) equipped with a 5 kg load cell. Emulsion strength was tested immediate after preparation (fresh) and after 7 d storage in a 50C incubator (stored). Total solids were measured utilizing the procedures of Curtis et al. (1986).

All data were pooled before analysis. Correlations were determined according to the PROC CORR procedure of SAS (SAS, 1999). Notable significant correlations are presented in shaded boxes within the tables.

**Results and discussion**

A number of significant correlations were found between the physical and functional egg quality characteristics monitored in the study (Tables 1 and 2). Egg weight was determined to be positively correlated with albumen height (R = 0.91) as well as Haugh unit (R = 0.90). Vitelline membrane elasticity was determined to be positively correlated with egg weight (R = 0.83). Egg weight was also
found to be connected to angel food cake volume (R = 0.84). Egg weight and albumen solids (R = -0.87) as well as sponge cake volume (R = -0.84) were negatively associated.

### Table 1 Correlation of egg physical quality and albumen functionality

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<tr>
<th></th>
<th>Egg weight</th>
<th>Albumen height</th>
<th>Haugh unit</th>
<th>Albumen solids</th>
<th>Shell strength</th>
<th>Vitelline membrane strength</th>
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</table>

1 For each cell, top number is Rho; bottom number is the corresponding P-value.

Albumen height was found to be positively correlated with egg weight (R = 0.91) and Haugh unit (R = 1.00). Vitelline membrane elasticity was found to be associated with albumen height (R = 0.77). Furthermore, albumen height is correlated with yolk solids (R = 0.78). Angel food cake volume (R = 0.81), as well as fresh and stored mayonnaise force (R = 0.82 and R = 0.88, respectively) were found to be correlated with albumen height. Both albumen solids (R = -0.87) and sponge cake volume (R = -0.73) were negatively correlated to albumen height.

Haugh unit values were found to be correlated with vitelline membrane elasticity (R = 0.76) as well as yolk solids (R = 0.79). Additionally, angel food cake volume was associated with Haugh unit scores (R = 0.80). Both fresh and stored mayonnaise force determinations were found to be correlated with Haugh unit values (R = 0.82 and R = 0.87, respectively). As with previously mentioned physical quality measurements, albumen solids and sponge cake volume were found to be negatively correlated with Haugh units (R = -0.70 and R = -0.72, respectively). Albumen solids were also negatively correlated with angel food cake volume (R = -0.75) and vitelline membrane elasticity (R = -0.76).

Whole egg solids and sponge cake volume were found to be positively correlated (R = 0.75). There was a negative correlation determined to exist between vitelline membrane elasticity and whole egg solids (R = -0.82). Additionally, yolk solids are positively associated with fresh and stored mayonnaise force measurements (R = 0.94 and R = 0.87, respectively). No significant correlations were found to exist between shell strength or vitelline membrane strength and any of the other quality factors monitored.

From the correlation analysis of this study, angel food cake volume and mayonnaise force measurements are more closely associated with egg freshness. Both functional characteristics have significant positive correlations to albumen height and Haugh unit values. Sponge cake volume exhibits significant negative correlations with these same factors. This would indicate that sponge cake volume could be enhanced by utilizing aged eggs.

According to the analysis, increases in albumen solids correspond to decreases in angel food cake volume, egg weight, albumen height, Haugh unit and vitelline membrane elasticity. Previously, Fletcher et al. (1983) reported that egg weight did not have a significant effect on albumen solids. The current study does not agree with these findings. Chen et al. (2005) did not measure albumen solids, but found the volume and weight of albumen to decrease during six weeks of storage. It has been suggested that
water migrates from the albumen into the yolk as the egg ages (Romanoff and Romanoff, 1949) and the current correlation analysis supports that supposition. Increased mayonnaise force measurements were found to be positively linked to increased yolk solids. Yolk solids were also found to be positively correlated with albumen height and Haugh unit values. Hidalgo et al. (1996) stated that yolk viscosity decreased during cold storage. The decrease in viscosity could be due to the movement of water into the yolk resulting in lower yolk solids. Whole egg solids were found to be negatively correlated (P < 0.002) with vitelline membrane elasticity. This would indicate that whole egg solids increase as the egg ages, which follows the previous trend of albumen solids increasing as the egg ages.

Table 2 Correlation of egg physical quality and whole egg and yolk functionality

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<th>Yolk solids</th>
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1 For each cell, top number is Rho; bottom number is the corresponding P-value.

Vitelline membrane strength did not have any significant correlations with the factors monitored in the current study, but vitelline membrane elasticity did exhibit several significant correlations with egg quality factors. Membrane elasticity was found to be increased with increased albumen height and Haugh unit values (P < 0.006). This follows the trend reported by Jones and Musgrove (2005) that albumen height, Haugh units and vitelline membrane elasticity all significantly decrease during extended cold storage. Jones et al. (2002) also reported greater vitelline membrane elasticity in eggs with higher Haugh unit scores. Fromm and Matrone (1962) stated that vitelline membrane elasticity increased with egg age. Chen et al. (2005) also reported an increase in vitelline membrane elasticity as the egg aged. Chen and colleagues utilized direct compression tests also, but with a much larger probe. Therefore, the differences in the results indicate that more research should be conducted to determine the effect of probe size on compression measurements of the vitelline membrane.

While some researchers have questioned the validity of the Haugh unit measurement due to the formula being adjusted for a large size egg (Silversides, 1994), the data from the current study can not be utilized to substantiate or disprove this theory since only large size eggs were tested. The results show strong correlations between egg weight, albumen height, and Haugh unit values for large size eggs which supports the basis for the equation (Haugh, 1937). The correlation analysis from this study concurs with the Silversides and Villeneuve (1994) report that changes in albumen quality can be described equally
well by albumen height and Haugh units. Other work (Kidwell et al., 1964) has stated that the egg weight correction factor is not necessary, but does not detract from the Haugh unit value.

Conducting functional tests can be a challenge on many levels. Many functional tests require specialized equipment which often can not be utilized for other laboratory procedures. Many of the methods require the use of a stove or oven. Furthermore, the subjective nature of the results often make it difficult to compare findings between laboratories or even between laboratory personnel conducting the experiments. Functional tests can also be labor intensive. The current results indicate that many physical quality measurements can be correlated to the functionality of the egg and its components. Albumen height and Haugh units were found to have significant correlations with all functional tests conducted in the current study. Therefore, these common egg quality screening techniques could be utilized to predict the functional outcome of a given lot of eggs.

References


