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QUALITY ASSESSMENT OF MICROWAVE PASTEURIZED IN-SHELL EGGS

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ABSTRACT In-shell eggs were pasteurized using a custom built microwave cavity with a slotted waveguide and conventional hot water bath at 60 °C. The quality of albumen and yolk samples from microwave pasteurized, water bath pasteurized and unpasteurized in-shell eggs (not inoculated) were assessed through visual attributes (turbidity-UV-Spectrometer), viscosity (22 °C), thermal analysis (enthalpy of denaturation), and dielectric spectroscopy (200 MHz to 40 GHz). The microwave pasteurized eggs had superior quality in all the parameters analysed and also had a much longer keeping quality compared the unpasteurized eggs.

Keywords: Post-Processing Quality, Egg quality, Microwave, Pasteurization, Shell eggs.

INTRODUCTION Eggs are popular for the exceptional functional properties of its two major components: the egg white and the yolk. Egg white is used as a foaming, leavening, gelling and/or binding agent in numerous food preparations. Also Egg white proteins are the most heat sensitive components of an egg. Egg yolk has good emulsifying and binding properties too (Li-Chan et al, 1995). The physical properties like whipability, foamability, foam stability, viscosity etc., affecting the functional properties, which make the eggs an inevitable ingredient of various food products are severely affected by high temperatures (Van der Planken et al, 2006).

Due to its extraordinary nutritive value, eggs remain a potential host for pathogens like *Salmonella enteritidis*. More than 90 percent of food borne Salmonellosis, caused by *Salmonella enteritidis* is through the shell eggs (Schroeder et al, 2005; Woodward et al, 1997). Most of the *Salmonella enteritidis* outbreaks generally involved Grade A eggs that are washed and disinfected and also met the requirements of the state for shell quality (St Luis et al. 1988). The probability of fresh eggs having Salmonella varies from 0.005 % (Mermelstein, 2001) to 1 % (Griffiths et al. 2005) depending on various factors involved in the egg production.

Thermal processing methods are the most widely used technique for destroying microorganisms and imparting foods with a lasting shelf-life, among which pasteurization has got its own prominent and predestined applications. Pasteurized foods are safety assured for the consumer within the recommended storage period and storage conditions. Today various techniques are applied for the pasteurization and thermal processing of foods. The conventional methods of thermal processing of foods result in peripheral over heating before the food in the centre reaches the required temperature. This is potentially a great problem in pasteurization, especially when it comes to shell eggs.

The Food Safety and Inspection Service (FSIS) of United States Department of Agriculture (USDA) recommends heating the egg white and the egg yolk to 57.5°C and 61.1°C respectively for 2.5 minutes to ensure egg safety against salmonella and other food borne pathogens (FSIS-USDA, 2006). The existing method of pasteurizing the shell eggs uses immersion in hot water at 60 ºC for 20 minutes, results in overheating of the egg white and partially cooked eggs (Mermelstein, 2001; Hou et el., 1996). There are different protein fractions namely conalbumin, ovalbumin, ovotransferin, ovomucoid, ovomucin, globulins, lyzozyme, etc. that are contributing to the functional properties of the egg white as a whole (McDonnell et al, 1955; Cunningham et al, 1995). The denaturation of some of these proteins starts at temperatures as low as 45 ºC.

Studies on the physico-chemical changes due to heat treatment of egg white revealed that at lower temperatures (< 50°C) these changes were only temperature dependent, but at higher temperatures (> 50°C) the time factor, plays an important role, indicating a time-temperature-dependent level of denaturation with an equilibrium (denaturation-saturation) time (Van der Plancken et al. 2006). Therefore the total time of heating is crucial for a better quality pasteurized egg white.

Dev et al. (2008) had demonstrated that microwave heating is an inimitable alternative to overcome the problem of peripheral overheating during shell egg pasteurization. Also the FSIS recommendation of heating up the yolk to a higher temperature (61.1ºC) was absolutely possible without heating the egg white beyond its recommended pasteurization temperature (57.5ºC). The risk of great pressure build-up within the egg shell when heated using microwaves is not inevitable within the pasteurization temperatures (Fleischman, 2004; Rehkopf, 2005). A comprehensive assessment of the functional quality of the microwave heated eggs can be done by examining the changes in the physical properties responsible for that.

Heat induced changes are more pronounced in the egg white than the egg yolk within the pasteurization temperature limits and hence egg white would be a suitable indicator for the comparison of such changes (Li-Chan et al, 1995). Therefore this paper focuses on comparison of physical properties of microwave and water bath in-shell pasteurized egg white with the raw egg white for any heat induced changes. The targeted physical properties were turbidity, viscosity, enthalpy of denaturation, and dielectric spectroscopy.

MATERIALS AND METHODS In-shell eggs were pasteurized using a custom built laboratory microwave oven setup with a specially designed slotted waveguide applicator and using hot water bath maintained at 60 ºC. Effects of heat treatments on the physical properties affecting the functional quality of the egg white recovered from the treated eggs were measured and compared to that of fresh untreated egg white.

Egg samples The fresh whole eggs, within 3 days of grading and packing (identified from the best before date stamped on the eggs, which is usually 35 days from date of packing) (CEMA, 2004), used in this study were procured from the local market and kept in a refrigerator set at 5°C until used. They were all of Canadian Grade A eggs and of large size, each with an average mass of 60±2 g. Prior to pasteurization, the eggs were brought to room temperature of about 24°C by placing the opened carton on the laboratory counter for a period of 3 to 4 hours (tested by breaking and measuring inner temperatures of 3 representative samples) before giving the heat treatments. This is done to replicate the possible use of this technique in the industry, wherein significant amount of energy can be saved by doing so.

Heat treatments for pasteurization Two heat treatments for the pasteurization of in-shell eggs were investigated and compared. Each treatment was done in triplicates (i.e.) three eggs were used for each treatment for the measurement of each parameter within the scope of this study. The first treatment consisted of heating in-shell eggs in a custom built laboratory microwave oven setup with a specially designed slotted waveguide applicator working at 2450 MHz using a power density of 2 W/g. In-shell egg white was heated for 1.25 minutes to raise the temperature to 58 °C and held at 58 ± 0.5 °C for 2.5 minutes, by periodically turning the microwave cycles on and off, as per the FSIS-USDA recommendations (FSIS-USDA, 2006). Temperature measurements were not done during the treatments as an optimised algorithm developed using a microbial validated finite element method for the microwave pasteurization of eggs was used for the on/off cycles (Dev et al, 2008a and 2009) and the microwave operation was controlled by the computer running HPVEE (Agilent) object oriented programming language to maintain the desired process temperature.

The second treatment consisted of immersing the in-shell egg in a temperature controlled water bath maintained at 60 °C for a period of 20 minutes (Schuman et al, 1997). These eggs were left intact without any inserted probes as this was already a commercially practiced technique, approved by FSIS-USDA.

It is clear that the temperatures reached by the egg components using the microwave and water bath heating are not identical. But the objective of this study was to compare the properties of the egg white pasteurized in-shell by the proposed (microwave) technique with that of the commercially practiced (water bath) technique, both meeting the FSIS-USDA pasteurization requirements/recommendations.

Immediately after both the above mentioned heat treatments the shell eggs were immersed in cold water tub containing water at 5 ºC for 10 minutes. This was done to ensure that the extent of heat damage to the proteins did not continue any longer after the pasteurization.

Measurements of the egg white physical properties The physical properties attributed to the functional quality of the egg white of in-shell heat treated and untreated eggs were measured and compared. Eggs were cracked carefully and the egg white was collected in small cylindrical beakers. Shell and yolk was discarded. All measurements were taken in triplicates. Parameters measured to assess the functional properties of egg white were: enthalpy of protein denaturation, viscosity, turbidity and dielectric properties.

Enthalpy of protein denaturation The enthalpy of denaturation is the net value of the combination of endothermic reactions, such as the disruption of hydrogen bonds, and of exothermic processes, such as the breakup of hydrophobic interactions and protein aggregations. The resulting residual enthalpy has been correlated to the remaining content of ordered secondary structure of a protein (Van der Plancken et al, 2006).

The instrument used to measure the enthalpy of denaturation was a TA Instruments Q100 Differential Scanning Calorimeter operated with the TA Instruments Q100 DSC 7.0 Build 244 software. Untreated and heat-treated samples were first placed in aluminium pans (20µl/pan) and then hermetically sealed. The pans were transferred to the instrument pan holder and heated from 20°C to 120°C at a constant rate of 10°C/min. An empty pan was used as a reference. The sample residual enthalpy was the recorded at the denaturation temperature of 83°C.

Viscosity An Oswald viscometer and a temperature controlled water bath were used for measurement and comparison of the egg white viscosity. Measurements were made on all samples at temperature ranging from 0 ºC to 45 ºC for every 5 ºC increment in temperature. Measurements of viscosity could not be made above 45 ºC as any further increase in temperature might lead to further denaturation and clogging of the viscometer capillary. For each sample, measured viscosity values were plotted against temperature and analyzed.

Turbidity Turbidity is a direct measure of the extent of protein coagulation, as coagulated proteins are opaque and reduce the transmittance of light through the egg white. The amount of light absorbed (absorbance) is a function of the turbidity of a liquid. The absorbance of the heat treated and untreated egg white samples was measured at 650 nm (Van der Plancken et al, 2006) using a Biochrom Ultra spec 2100 Pro spectrophotometer at 24 ºC. Plain demineralised water was used for calibration. An absorbance (turbidity) of 0% corresponded to a totally clear solution.

Dielectric properties The change in dielectric properties is considered to be a good indicator of the extent of denaturation of the egg white proteins (Bircan et al, 2002) .The open-ended coaxial probe technique was used to measure and compare the dielectric properties of heat-treated and untreated samples (Figure 1). Measurements of the dielectric properties were made with an Agilent 8722 ES s-parameter Network Analyzer equipped with the high temperature probe model 85070B. This instrument was controlled with the Agilent 85070D Dielectric Probe Kit Software Version E01.02. According to the manufacturer, the equipment has an accuracy of ±5% for the dielectric constant (ε') and ±0.005 for the loss factor (ε") (HP, 1992). The dielectric property measurements (ε' and ε") were taken at 2450 MHz for every 5 ºC rise in temperature from 0°C to 60°C.

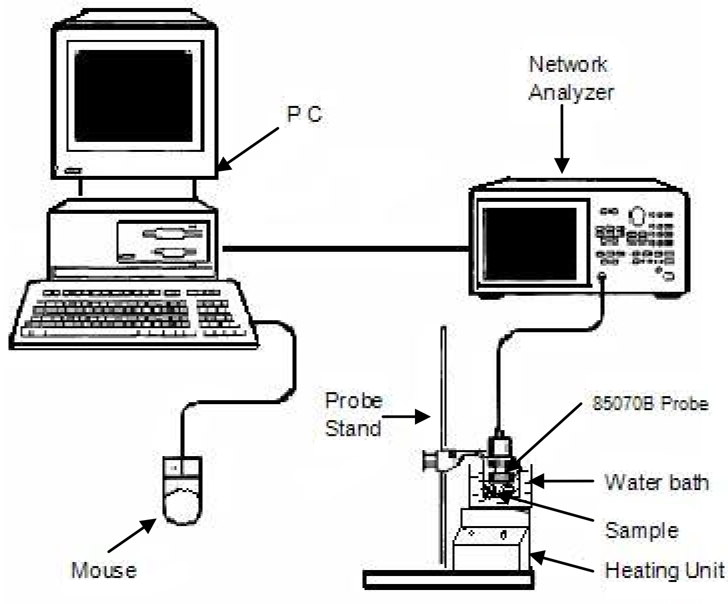


Figure 1. Dielectric properties measurement setup

Data analysis All the data obtained were statistically analyzed using the software MATLAB 7.5 from Mathworks. Analyses of variances followed by Duncan's multiple range tests were conducted to locate significant differences among means.

In all comparisons, significant deviations from mean values obtained from untreated egg white were considered to have an effect on egg white functional properties.

RESULTS AND DISCUSSION

Enthalpy of protein denaturation As shown in the Figure 2, reductions in residual enthalpy indicated that the heat treatments had partially denatured the egg white proteins of all heat treated samples. However, microwave treated samples exhibited less reductions than samples heated in the hot water bath. This implied that denaturation was very less in the microwave heated in-shell egg. These results corroborate the work by Iesel Van der Plancken et al. (2006), for the heat treated egg white.

Statistical analysis performed on the data revealed that the difference in mean enthalpy of the egg white between microwave heated and the untreated (raw) in-shell eggs was not significant ($P<0.01$), whereas the water bath heated in-shell eggs had significant ($P<0.01$) lower enthalpy from the others.

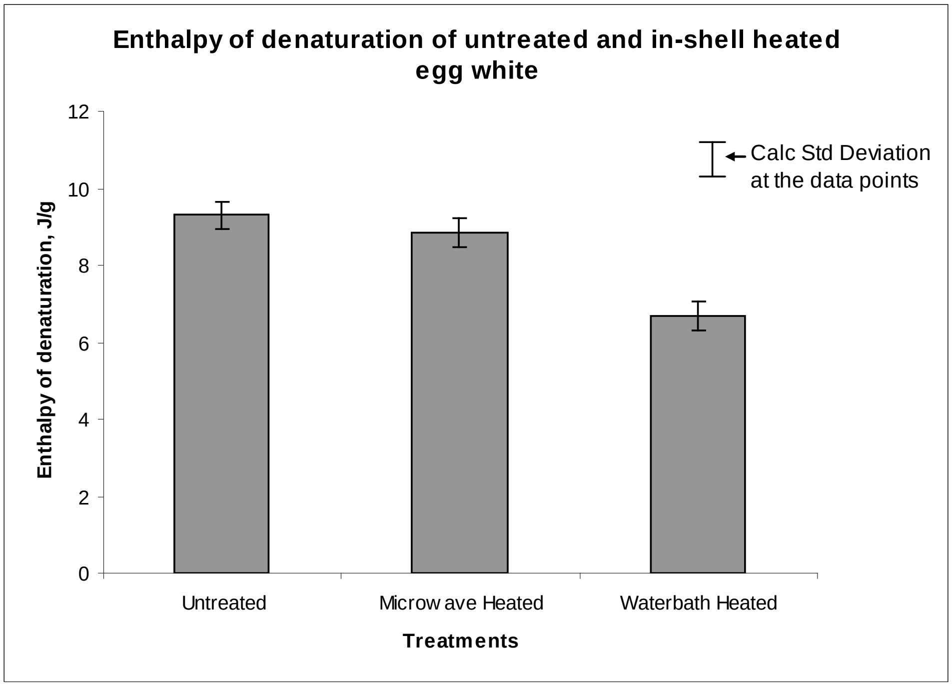


Figure 2. Enthalpy of denaturation of the egg white

Viscosity The egg white viscosity of heat treated eggs were lower than that of untreated eggs (Figure 3), and decreased with temperature (Pitsilis et al, 1975) and the level of protein denaturation. At higher temperatures, differences among the treatments were lower than at lower temperatures. An overview of the data in Figure 4.3 depicts that all the three samples had a considerable difference among them at lower temperatures.

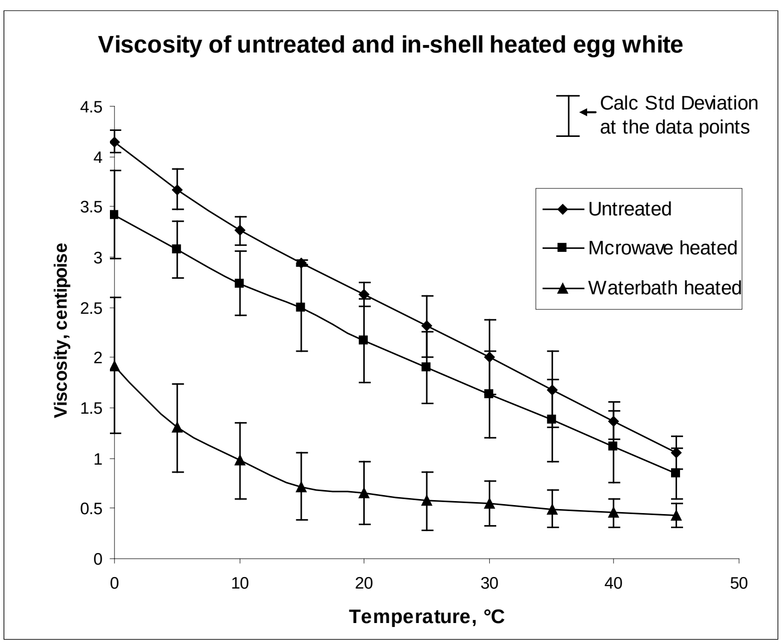


Figure 3. Viscosity of the egg white of untreated and in-shell heated eggs.

The results of the statistical analysis (ANOVA & Duncan's Test) were similar to that of the enthalpy of denaturation. The viscosity of in-shell microwave heated egg white was not significantly different ($P<0.05$) from the viscosity of the untreated ones, whereas the water bath heated samples were significantly different ($P<0.05$) from the other two.

Turbidity The analysis performed on the turbidity of the egg white samples measured as the absorbance at 650 nm indicated that the microwave heated in-shell egg white had better transmittance than the water bath heated ones (Figure 4). This implies that the extent of denaturation is much lesser in the microwave heated samples as coagulation due to denaturation increases turbidity (Van der Plancken et al, 2006).

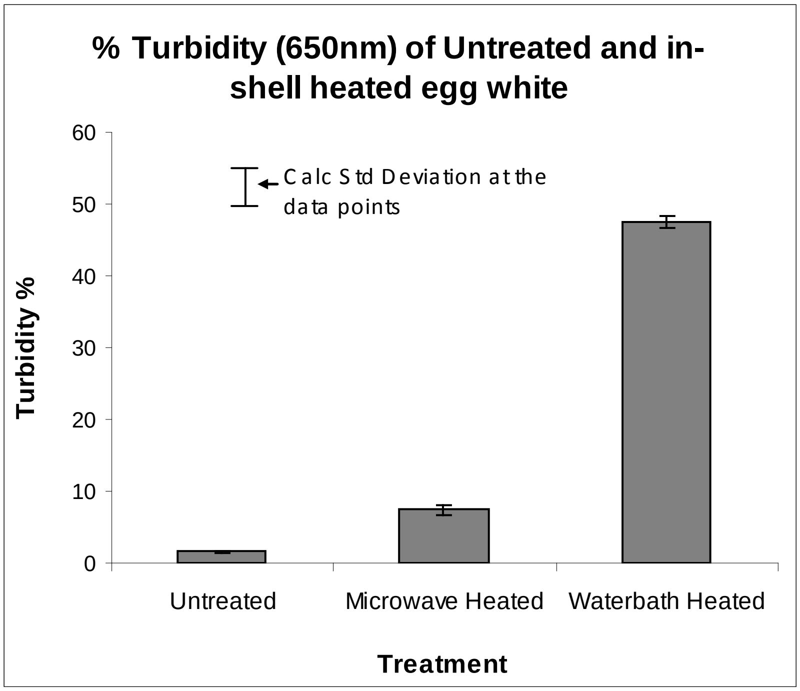
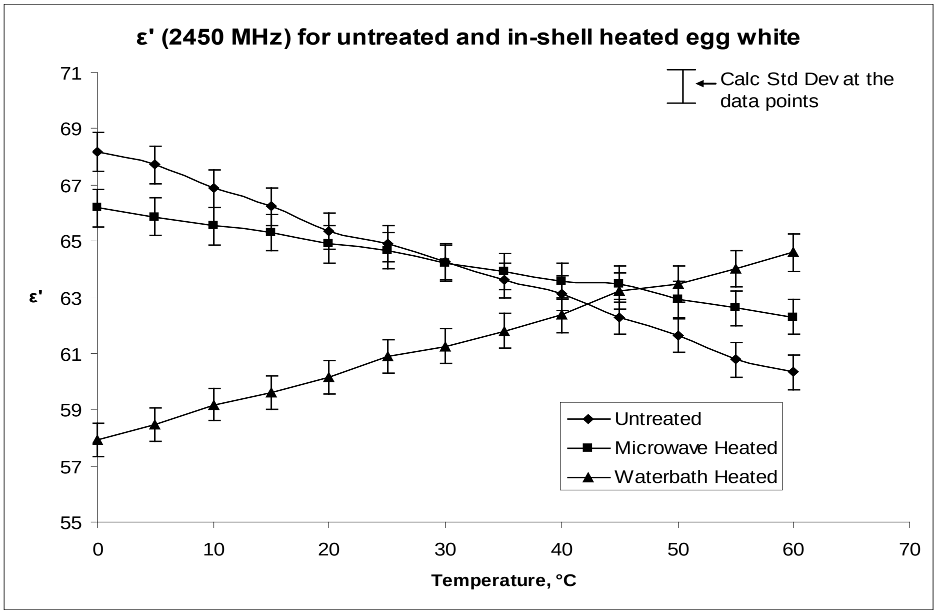


Figure 4. % turbidity (650nm) of untreated and in-shell heated egg white

Differences in mean turbidity values for the egg white taken from untreated, microwave heated or water bath heated eggs were all significant at the 0.01 level. Absorbance values of the microwave heated samples were closer to the untreated ones.

Dielectric properties The dielectric constants and loss factors of the egg white of untreated eggs and of eggs heated in a microwave oven or in a hot water bath as a function of temperature are presented in Figure 7. The trends observed in the dielectric properties measured at 2450 MHz of egg white of microwave heated in-shell eggs were similar to that of the untreated eggs.

The dielectric properties of the egg white of the eggs treated in hot water exhibited a complete change in trend as they became directly proportional to the temperature. This behaviour was associated with a greater denaturation of proteins in these samples. The change in dielectric properties with temperature got reversed with denaturation (i.e.) the dielectric properties were inversely proportional to the temperature when raw (untreated) and became directly proportional to temperature when denatured (Bircan, 2002)).



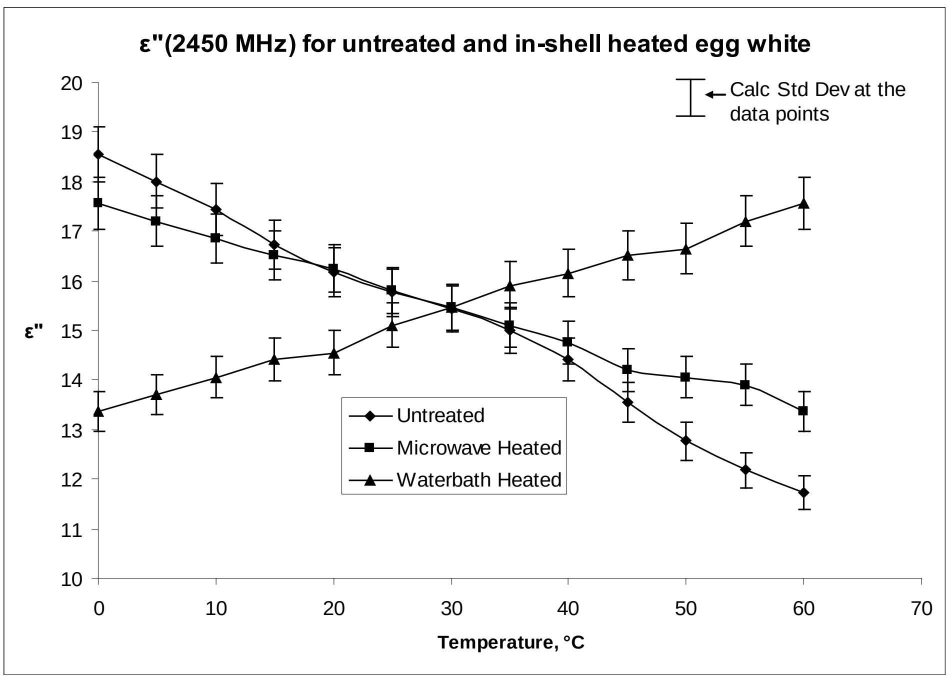


Figure 7. Dielectric properties of the egg white of untreated and in-shell heated eggs.

Statistical analysis (GLM on curves and ANOVA and Duncan's test on the slopes and intercepts) revealed significant differences ($P<0.05$) among all the samples.

CONCLUSION The effects of microwave heating and hot water bath heating of in-shell eggs on the functional properties of the egg white was assessed and compared to that of untreated eggs. It was demonstrated that enthalpy denaturation was much higher for the microwave heated in-shell egg white and also it was clearer and had a higher viscosity. The microwave heated egg white produced more stable foam with low foam density. Also the dielectric properties gave a lucid idea about the extent of denaturation in all the three samples.

From the data obtained from all the tests conducted it had been confirmed that though there was a considerable change in all the above tested parameters in the microwave heated in-shell egg white, the changes were much less when compared to that of the water bath heated ones and the microwave heated ones were more closer to that of the raw (untreated) egg white.

Thus microwave was proven to be a viable and better alternative for the in-shell heating and pasteurization of shell eggs.

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