CHAPTER 6: DISCUSSION

6.1 Baking potential of fresh shell eggs, frozen egg pulp, spray-dried egg powder and the egg powder mixture

The baking potential of fresh shell eggs, frozen egg pulp, spray-dried egg powder and the egg powder mixture were affected by their proximate compositions, pH, foaming capacities and coagulation temperatures.

The proximate composition of the fresh shell eggs used was different to that described by Watkins (1995) and American Egg Board (2001). Fresh shell egg samples had higher protein and carbohydrate contents but less fat and ash contents. This may have been due to differences in diet, age and breed of the laying hens or due to differences in the environment or seasons of the year (Angalet *et al*., 1976; Watkins, 1995; Bennion & Bamford, 1997). These factors could directly affect the proximate compositions and functional properties of final egg products, such as refrigerated, frozen and dehydrated egg products (Pankey & Stadelman, 1969).

The pH of the fresh shell eggs was similar to the study of Toney & Berquist (1983) who reported the pH of liquid whole egg as 7.6. The percentage foaming overrun of fresh shell eggs was the highest due to high protein content and pH of fresh shell egg. The higher the protein content, the higher the percentage foaming overrun and foaming stability (Wilde & Clark, 1996). Chang & Chen (2000) found that the foaming capacity and foaming stability of liquid whole egg changed as pH changed and the trend was nonlinear. The foaming capacity was greatest at the protein "natural" pH (Cheftel *et al*., 1996) of the sample, which was pH 7.6 in liquid whole egg. The foaming stability was also greatly affected by pH. This is due to electrostatic interaction between the molecules in the film (Howell & Taylor, 1991). The thickest, strongest films are formed around the isoelectric point (pI) due to the zero net charges, and electrostatic forces between molecules were minimal. However, egg consists of several proteins with a wide range of pI from 4.1 (ovomucoid) to 10.7

(lysozyme) (Li-Chan *et al.*, 1995; Hammershøj *et al.*, 1999) and Poole *et al.* (1984) use their average as the pI of egg protein which was around 7. Therefore, fresh shell egg had higher percentage foaming overrun than other sample.

The coagulation temperature of fresh shell egg samples were lower than other egg samples. This was due to the high protein content. The higher the protein content, the lower the coagulation temperature of egg protein (Bevridge *et al.*, 1980). However, excessive protein content in sample would not raise coagulation temperature significantly (Seideman *et al.*, 1963).

The water holding capacity of fresh shell egg samples were lower than spray-dried egg powder samples. pH did not only affecting foaming ability, but also influenced the water-holding capacity of egg protein (Arunepanlop, Morr, Karleskind & Laye, 1996) due to the net charge of the proteins in solution (Hermansson, 1982). Generally, it can be said that the water-holding capacity decreased with an increased degree of aggregation (Figure 20) which happened closed to the isoelectric point. If the pI of egg protein was 7, low water-holding capacity resulting from fresh shell egg samples could be explained.

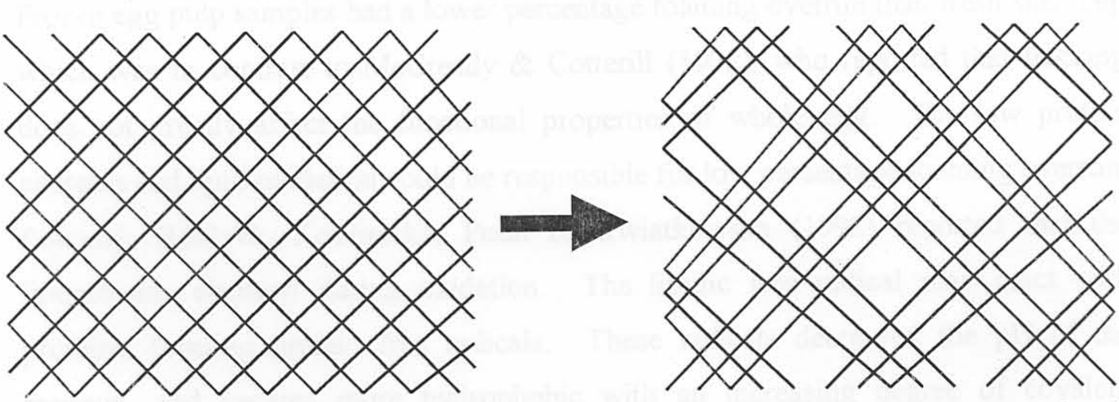

Figure 20 ***Schematic illustration of a change in gel structure due to local aggregation phenomena (Hermansson, 1982)***

Frozen egg pulp samples contained less ash, protein and fat content than the values reported by Watkins (1995) and American Egg Board (2001). However, these sources reported that frozen whole egg should have a similar composition to liquid whole egg. On a dry weight basis, the protein content was lower and carbohydrate content of frozen egg pulp was higher than fresh shell egg. The total solids content of the frozen egg pulp was 27.37%, which imply that it possibly contained higher yolk contents than egg white. Du Preez (2000) stated that the whole egg products should be standardized to an egg solids level of 24.0% to 24.5%. Egg yolk solid is higher than egg white whereas the yolk protein content is lower than egg white (Watkins, 1995).

The frozen egg pulp had a lower pH value than the fresh shell egg samples. It was also lower than the pH of frozen whole egg products of 7.6 reported by Toney & Berquist (1983). Blood spots and off aroma were noticed in thawed frozen egg pulp samples. Ball *et al.* (1987) stated that eggs which were leaking, rotten, with developed embryos, excessive blood spot, off aroma or pH value below 7 should not be used for edible egg products. The off aroma and low pH (6.48) of the frozen egg pulp samples may have been caused by lipid oxidation or growth of microorganisms. The lipid oxidation or microbial action could be due to improper freezing methods and / or the use of low quality eggs such as broken or leaking eggs.

Frozen egg pulp samples had a lower percentage foaming overrun than fresh shell egg which was in contrast to McCready & Cotterill (1972), who reported that freezing does not greatly affect the functional properties of whole egg. The low protein contents and lipid oxidation could be responsible for low percentage foaming overrun. Pokorný, Réblová, Kouřimská, Pudil & Kwiatkowska (1992) reported that the lipoproteins changed during oxidation. The lipidic free radical may react with proteins, forming protein free radicals. These radicals decreased the pH of the medium, and became more hydrophobic with an increasing degree of covalent binding in the lipoprotein fraction, which lead to lower percentage foaming overrun of protein solutions. Therefore, lipid oxidation also influenced the pH of egg products.

The frozen egg pulp had a higher coagulation temperature than the fresh shell egg samples. This could be due to the high carbohydrates content of the frozen egg pulp (Du Preez, 2000). In addition, lower protein content compared to fresh shell egg samples could also be a reason for a higher coagulation temperature. Frozen egg pulp had lower water-holding capacity than spray-dried egg powder but higher than fresh shell egg samples. This was caused by the differences in the net charges (pH) of the samples.

Spray-dried egg powder contained lower protein and higher carbohydrate content than fresh shell egg samples, which is in contrast to results by Watkins (1995) and American Egg Board (2001). The pH value of spray-dried egg powder samples was similar to the value of 8.5 as reported by Toney & Bergquist (1983). From the result of proximate composition of spray-dried egg powder, low percentage foaming overrun resulted due to low protein content. In addition, the egg protein component, globulin, which is responsible for foaming (Cotterill & Winter, 1955) is heat sensitive (Woodward & Cotterill, 1987). Hence, low foaming overrun in heat-treated egg powder were expected. The heat sensitivity of the protein necessitate the use of an emulsifier to obtain foam from egg powder (Bennion & Bamford, 1997).

Spray-dried egg powder had a high coagulation temperature which was due to the low protein contents. It had the highest water-holding capacity which related to the pH of the samples. An increase in acidity or alkalinity away from the isoelectric point of egg protein resulted in high water-holding capacity. The intermolecular disulfide bonds were also important in formation of the network structure and increased WHC in the alkaline region (Handa *et al.*, 1998). It was assumed that the more alkaline the egg sample, the less intermolecular disulfide bonds dominate in network formation. Thus, spray-dried egg powder samples had the highest water-holding capacity due to the high pH.

The egg powder mixture contained more ash and carbohydrates and less protein and fat compared to all the other samples. This could be due to the presence of a substantial percentage of skim milk powder and Nutrifat in the egg powder mixture. Skim milk powder consists of 3% moisture, 0.8% fat, 35.9% protein, 52.3% lactose and 8.0% ash. Nutrifat contained about 5% carbohydrates of the egg mixture. The egg powder mixture samples had a very low percentage foaming overrun which was due to lower protein content and presence of black specks which was believed to be black pepper. This black pepper may have disturbed the stability of the foam by affecting the surface tension of the foam bubbles. In addition, heat sensitive globulins also resulted in low percentage foaming overrun.

The egg powder mixture samples had the highest coagulation temperature compared to all other egg samples. It was due to a low protein content and high carbohydrates content. High carbohydrates content could raise the coagulation temperature of protein solutions (Yang & Baldwin, 1995; Du Preez, 2000). The water-holding capacity of the egg powder mixture was lower than spray-dried egg powder, higher than fresh shell eggs and similar to frozen egg pulp sample. The similarity in water-holding capacity was due to similar pH values.

According to the results of the proximate composition and functional properties of different egg samples, fresh shell egg would have the best baking potential whereas the egg powder mixture samples would have the worst. However, the sponge cake batter mixture contained emulsifier, which promoted the foaming ability of egg powder (Bennion & Bamford, 1997).

6.2 Baking performance

Fresh shell egg sponge cake samples did not result in the highest specific volume and index to volume. However, they gave higher baking volume than frozen egg pulp and egg powder mixture sponge cake samples. Generally, baking volume was affected by the foaming and coagulation properties of the batter.

Frozen egg pulp sponge cake samples obtained lower baking volume than fresh shell egg sponge cake samples whereas a similar baking performance was found compared to egg powder mixture sponge cake samples. McCready & Cotterill (1972) reported that frozen whole egg did not affect the volume of sponge cakes compared to fresh shell egg sponge cake samples. In contrast, Pearce & Lavers (according to Ball *et al.*,

1987) and Jordan, Dawson & Echterling (1952) observed that freezing reduced the baking quality of whole egg. However, Pearce & Lavers found that the baking volume improved after storage of frozen whole egg product for three months and then decreased and Jordan *et al.* (1952) found that treated frozen egg resulted in higher baking volume than fresh shell egg. Frozen egg pulp gave a low baking volume due to their low percentage foaming overrun and high coagulation temperature. Arunepanlop *et al.* (1996) explained that low cake volume was probably due to an inability to prevent the overexpanded air cells from collapsing during baking. In addition, higher coagulation temperature led to an inability to stabilize overexpanded air cells in the cake batter from collapsing during baking. The air cells must have sufficient time to expand and stabilise until the coagulation temperature was reached.

In contrast to what was expected, the spray-dried egg powder sponge cake samples had the highest baking volume with lower foaming capacity and higher coagulation temperature compared to fresh shell egg sponge cake samples. This was due to the addition of emulsifier (Lee, Hoseney & Varriano-Marston, 1982) and higher viscosity of the batter. Although emulsifier was added to all samples, the emulsifier was used in powder form, which can interact better with powdered egg samples (spray-dried egg powder and egg powder mixture) than liquid forms (fresh shell egg and frozen egg pulp). In addition, a comparatively higher batter viscosity was observed after finishing the mixing of all the ingredients in the spray-dried egg powder batch. This may be because the egg powder batches were reconstituted with water at 45°C. According to Bergquist (1995), viscosity in the reconstituted product increased quite rapidly at temperatures above 38°C. Furthermore, Townsend & Nakai (1983) and Gaines & Donelson (1982b) found that viscosity was closely correlated to the foaming capacity. However, Géllinas *et al.* (1999) stated that acceptable cake volume and texture could be obtained from batters with high or low viscosity, even when water was kept constant for all formulations. In addition, the baking volume of sponge cake samples were also influenced by pH. Hill, Cotterill, Funk & Baldwin (1965) stated that the spray-dried egg powder had the highest baking volume at pH 8.5 which was similar to the pH of the spray-dried egg powder sample that was used.

The egg powder mixture sponge cake samples gave lower baking volume than fresh shell egg and spray-dried egg powder sponge cake samples. However similar results to frozen egg pulp sponge cake samples were found. The low baking volume was due to low percentage foaming overrun and high coagulation temperature. However, an emulsifier and water at 45°C were added to the sponge cakes batter mixture. The emulsifier was in powder form which dispersed better in powder egg samples than liquid egg samples.

The baking performance results showed spray-dried egg powder sponge cake samples had the best baking volume. This result was not predicted based on their proximate composition and functional properties. However, the use of an emulsifier benefited the baking performance of the egg powder samples. According to the baking performance results, fresh shell egg and spray-dried egg powder sponge cake samples should have more springy texture than frozen egg pulp and egg powder mixture sponge cake samples due to their baking volume.

6.3 Sensory characteristics and shelf-life as affected by storage temperature and period

Fresh shell egg sponge cake samples had slightly higher water activity than the range of 0.65-0.85 reported by Jones (1994). Water activity was one of the parameters to control the microbial growth (Chirife, 1989). Yeasts and moulds were found on Day 20 at 21°C and Day 16 at 31°C storage for fresh shell egg sponge cake samples sample. This showed that the storage temperature did affect the yeast and mould count of the samples. Therefore, the fresh shell egg sponge cake samples had sixteen days and twelve days of shelf-life stored at 21°C and 31°C, respectively.

Frozen egg pulp sponge cake samples had slightly higher water activity than fresh shell egg sponge cake samples and as reported by Jones (1994). They also had higher yeast and mould counts on Day 20 at 21°C than fresh shell egg sponge cake samples.

Yeasts and moulds were also found on Day 16 at 31°C, which was similar to fresh shell egg sponge cake samples.

Spray-dried egg powder sponge cake samples had lower water activity than fresh shell egg and frozen egg pulp sponge cake samples. However, yeast and mould counts were also found on Day 20 for both 21° and 31°C, although the counts were lower fresh shell egg and frozen egg pulp sponge cake samples. This showed that spray-dried egg powder sponge cake samples had the same shelf-life as fresh shell egg and frozen egg pulp sponge cake samples stored at 21°C.

Egg powder mixture sponge cake samples had the lowest water activities. This was probably due to the higher carbohydrate contents (from skim-milk powder) of the egg fraction in the formula. The low water activity resulted in lower yeast and mould counts. Yeast and mould were only found on Day 24 at 21°C and Day 20 at 31°C.

The egg powder mixture sponge cake samples had a longer microbiological shelf-life than the other sponge cake samples stored at both 21° and 31°C due to the lower water activity.

There were no significant differences in both crumb texture analysis and sensory evaluation between the storage temperatures for all the sponge cake samples. Ellis (1994) found no significant differences in physical changes for sponge cakes which were stored between 21°C and 35°C, unless the sponge cake samples were stored at 45°C.

An interesting phenomenon was observed for texture analysis of the sponge cake samples for the texture analysis. A lower force used meant softer crumb. All sponge cake samples had a harder crumb texture on Day 0 compared to Day 4. This was properly due to the reaction of the emulsifier which act as a softener to bakery products (Brown, 1993). The texture measurements were taken within two hours after baking which probably reflected the firm stage before softening. However, Kamel &

Ponte Jr (1993) found that emulsifiers firmed baked goods in several hours after baking and the softening effect could not be seen until the second or third day or even longer of storage period. Thus, the crumb texture of sponge cake samples were harder on Day 0 than Day 4 samples.

The hardness of sponge cake samples did not show a linear increase over the storage period. Fresh shell egg sponge cake samples had a significant hardening effect on Day 24. Frozen egg pulp sponge cake samples had no significant hardening effect over the storage period. Spray-dried egg powder and egg powder mixture sponge cake samples had noticeable hardening of texture after Day 12. The hardening effect was probably due to the staling of samples. Staling is caused by retrogradation of starch which means that bakery products lose their freshness during storage (Cauvain, 1998). In addition, Jay (1986) stated that the growth of moulds on breads and cakes resulted in hardening of baked products. Hence, water activity of egg samples affected the texture of sponge cake samples over the storage period. In general, the spray-dried egg powder sponge cake samples had the softest crumb texture.

The rubberiness of the sponge cake samples varied over the storage period. Although a softening effect after 4 days of storage was evident from the instrumental texture analysis, this was not reported for all egg samples by the sensory panel, except for spray-dried egg powder and frozen egg pulp sponge cake samples. The reason might be due to the experimental design followed by the sensory panel. At any give time, the panel directly compared samples at a specific storage period. A hardening effect over the storage period was shown for fresh shell egg which were less rubbery compared to the egg powder mixture sponge cake samples that were very rubbery.

Fresh shell egg and spray-dried egg powder sponge cake samples had less brown crusts compared to frozen egg pulp and egg powder mixture sponge cake samples. The crumb colour of fresh shell egg was more yellow followed by spray-dried egg powder sponge cake samples.

The high levels of crust browning could be attributed to the Maillard reaction. In the case of frozen egg pulp sponge cake samples, it contained comparatively more carbohydrates whereas egg powder mixture sponge cake samples contained skim milk powder and Nutrifat. The skim milk powder contained a high concentration of reducing sugars and Nutrifat contained carbohydrates necessary for Maillard reaction to occur.

The yellowness of the crumb was affected by the colour of the egg samples. Darker colours of frozen egg pulp and egg powder mixture samples were noticed. According to Deethardt *et al.* (1965a), the colour of sponge cake were affected by the colour of the yolk which could be influenced by feed. In addition, Campbell *et al.* (1987) stated that excessive acidic or excessive alkaline egg samples affected the crumb colour of bakery products.

Fresh shell egg and spray-dried egg powder sponge cake samples had lower levels of specks whereas the egg powder mixture sponge cake samples had the most specks followed by frozen egg pulp sponge cake samples. The presence of specks in the egg powder mixture sponge cake samples was probably due to black pepper in this sample. The specks from frozen egg pulp sponge cake samples were probably due to the presence of blood spots.

Low intensities of egg smell and baking powder smell were found on egg powder mixture and frozen egg pulp sponge cake samples. This was due to the high level of caramel smell present. The caramel smell was caused by Maillard reaction. However, the caramel smell of frozen egg pulp sponge cake samples were not as strong as that of the egg powder mixture sponge cake samples. Spray-dried egg powder sponge cake samples smelled the most eggy which showed that the egg smell of egg powder was not destructed during spray-drying and storage. On the other hand, fresh shell egg sponge cake samples and spray-dried egg powder sponge cake samples tasted more eggy than the other sponge cake samples. Egg powder mixture sponge cake samples tasted less eggy and baking powder-like. This was due to the high sweetness which was probably masking the egg and baking powder flavours.

The crust of the fresh shell egg and spray-dried egg powder sponge cake samples were less sticky than frozen egg pulp and egg powder mixture sponge cake samples. The sticky feeling on the crust was probably caused by the high concentration of carbohydrates leading to crystallization of sugar on the crust, as well as the movement of moisture from the crumb to the crust during the storage period (Symons, 1994).

Spray-dried egg powder sponge cake samples were the most moist followed by frozen egg pulp sponge cake samples. The high level of moistness in spray-dried egg powder sponge cake was probably due to the higher water-holding capacity of the spray-dried egg powder. On the other hand, high levels of moistness in frozen egg pulp sponge cake samples was probably due to the low foaming overrun of frozen egg pulp samples. It was because the low foaming overrun affected the evaporation of water during baking. It kept the moisture inside the sponge cake.

Spray-dried egg powder sponge cake samples were more spongy than other sponge cake samples. The high sponginess was related to the high baking volume. In contrast, frozen egg pulp and egg powder mixture sponge cake samples were less spongy due to the low baking volume.

The egg powder mixture sponge cake samples were sweeter followed by frozen egg pulp sponge cake samples. The high intensity of sweetness was due to the high contents of carbohydrates. Once again, lactose in skim milk powder was the major factor which contributed the sweetness to egg powder mixture sponge cake samples.