

The effect of fresh, frozen and dehydrated eggs on sponge cake quality

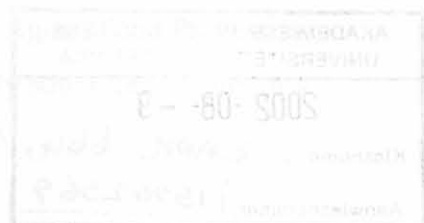
by

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Submitted in partial fulfilment of the requirements for the
degree MInst Agrar (Food Processing)

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January 2002



ACKNOWLEDGEMENTS

I am sincerely grateful for the following persons and organizations for their assistance:

1. My supervisor, Mr. K. K. K. K., for all his help, advice, encouragement and support throughout the entire course of the project.

2. My family, especially my mother, for their love, support and financial assistance.

3. My friends, especially my friends, for their love, support and financial assistance.

4. All the staff members of the Department for their help in many ways.

5. My family, especially my mother, for their love, support and financial assistance throughout the entire course of the project.

6. My friends, especially my friends, for their love, support and financial assistance.



I declare the dissertation herewith submitted for the MInst Agrar (Food Processing) degree at the University of Pretoria, has not been previously submitted by me for a degree at any other University.

ACKNOWLEDGEMENTS

I am sincerely grateful for the following persons and organizations for their contributions:

- Dr HL de Kock, my project leader for all her time, patient, encouragement and dedication throughout the entirety of the project
- Eggbert Eggs (Pty) Ltd for their egg sample supply and financial support
- Croda Chemicals S.A (Pty) Ltd for their emulsifier supply
- All the staff members at the department for their help in many ways
- My family, for their continued encouragement, support and prayers throughout the duration of the project
- My boyfriend, How-Chiun for his support and motivation

ABSTRACT

THE EFFECT OF FRESH, FROZEN AND DEHYDRATED EGGS ON SPONGE CAKE QUALITY

BY

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Eggs are one of the major ingredients for sponge cake baking. The major functional properties of eggs such as coagulating, foaming, emulsifying, colour and flavour may have changed during processing and storage. Once the functional properties change, the baking potential for sponge cake also changes. The major objective of this study was to compare if different forms of egg (fresh shell egg, frozen egg pulp, spray-dried egg powder and a commercial egg powder mixture) would affect the baking volume, sensory characteristics and shelf-life of sponge cakes.

Proximate composition analysis, pH, foaming overrun, coagulation temperature and water-holding capacity of egg samples were determined. Index to volume, specific volume, water activity, yeast and mould counts, texture analysis and sensory properties of sponge cake samples were determined. Spray-dried egg powder sponge cake samples had the best baking volume whereas frozen egg pulp and egg powder mixture sponge cake samples had the lowest baking volume. All sponge cake samples were stored at 21°C and 31°C for shelf-life tests. Egg powder mixture sponge cake samples had the longest microbiological shelf-life. No significant differences were found in physical changes for sponge cakes which were stored at 21°C and 31°C. The sensory properties (browness of the crust, yellowness of the

crumb, presence of black specks, egg smell, caramel smell, baking powder smell, stickiness of the crust, moistness of crumb, sponginess, rubberiness, sweetness, egg flavour, after taste and baking powder flavour) of various samples were different.

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CHAPTER 1: INTRODUCTION

“Eggs or chicken, which came first?” No one knows the real answer. However, eggs have been consumed as human food for over two millennium, that is for sure. They are one of the least expensive sources of animal protein (Stadelman, Olson, Shemwell & Pasch, 1988), and a good source of nutrients. The egg proteins provide all the essential amino acids (Toney & Bergquist, 1983) for the human diet and often act as the standard for measuring the quality of all other food proteins (Watkins, 1995). In addition, vitamins A, B, D, E and K, and especially vitamin B-12 (Pszczola, 1999), as well as phosphorus and iron are supplied. Eggs are also an important source of essential unsaturated fatty acids (linoleic 18:2n6) and oleic acid, a monounsaturated fatty acid (Watkins, 1995). However, eggs are lacking in carbohydrates, calcium and vitamin C (Linden & Lorient, 1999). In South Africa, the consumption of eggs was 290 000 tons in the year 2000, which increased about 23% from the last five years (Department of Agriculture, 2001).

The major functional properties of eggs are coagulating, foaming, emulsifying, and contributing nutrients, colour and flavour. In some instances, they are used to control the growth of sugar crystals (Cotterill, Amick, Kluge & Rinard, 1963). There are no other food or ingredients that can completely replace these egg properties (Yang & Baldwin, 1995).

Eggs are a basic ingredient used by bakers. They contribute unique functional properties for bakery products (Gilbertson & Porter, 2001). However, eggs are one of the most common ingredients which affect the spoilage of bakery products (Jones, 1994), and mishandling can introduce serious food safety risks (Gilbertson & Porter, 2001). Pasteurisation, freezing and drying can act as preservation methods for eggs. Apart from the microbiological deterioration, these preservation methods can also be used to slow down the rate of physical and chemical deterioration to retain the natural appearance and nutritive value of the egg contents (Romanoff & Romanoff, 1944).

Changes to the chemical composition and physicochemical properties of eggs may occur during shell egg storage and during pasteurizing, drying, and freezing (Du Preez, 2000). This alteration in the egg components may be reflected in a loss of functionality of albumen (foaming power) and yolk (emulsifying ability) (Li-Chan, Powrie & Nakai, 1995). Hence, the sensory characteristics of sponge cakes namely: appearance of the colour of crust and crumb, flavour and texture of sponge cakes can be influenced by alteration of functional properties.

The main function of eggs in sponge cakes are foaming and coagulating (Bennion & Bamford, 1997). Sponge cakes are low in fat and belong to the intermediate moisture food products (Singh, 1994). The water activity (a_w) is within the range of 0.65-0.85. With these water activity levels, mould growth is the major microbiological spoilage problem (Seiler, 1976). Besides the microbiological matters, staling should also be considered as a factor in the shelf-life of sponge cakes. Under proper storage conditions (at suitable temperature and package), sponge cakes can have a three-week shelf-life (Jones, 1994).

All the abovementioned forms of eggs have their advantages and disadvantages. There are limited information available regarding the comparison of sensory properties and shelf-life of fresh shell egg, frozen egg pulp, spray-dried egg powder and a commercial egg powder mixture on commercial-type sponge cakes over a storage period. Therefore, this has led to the need for a study into the effects of different egg forms on the sensory properties and shelf-life of sponge cakes.

1.1 Problem statement

Fresh shell eggs are usually used at home for baking purposes, while refrigerated-liquid, frozen and dried eggs are used in the baking industry. This is because fresh shell eggs are more difficult to handle and higher labour or machinery costs are necessary for breaking the fresh shell eggs before baking. In addition, fresh shell eggs often have problems with inconsistency of solids and fat contents which are caused by the varying size of fresh shell eggs (Du Preez, 2000). Egg in the refrigerated- liquid and frozen form is widely used as an ingredient in the baking industry (Bennion & Bamford, 1997), since their functional properties are almost similar to fresh shell eggs and their composition are relatively constant (Du Preez, 20). However, the transportation and storage costs of frozen egg pulp are higher than fresh shell eggs and egg powder. Additionally, one must foresee in advance the product demand to allow time for thawing. The thawed product must be consumed rapidly. Therefore, there is an increased chance of waste if large frozen egg containers are involved (Ball, Hamid-Samimi, Foegeding & Swartzel, 1987). Egg powder would be more convenient to use because it is easier to handle, requires less storage space and lowers the transport costs. But the functional properties, especially the foaming power are degraded by heating during the drying process (Powrie & Nakai, 1985). These changes may affect the baking quality and sensory quality of the final products. Thus, other ingredients such as emulsifiers may have to be added to dried egg powder to overcome this problem.

All the abovementioned forms of eggs have their advantages and disadvantages. There are limited information available regarding the comparison of sensory properties and shelf-life of fresh shell egg, frozen egg pulp, spray-dried egg powder and a commercial egg powder mixture on commercial-type sponge cakes over a storage period. Therefore, this has led to the need for a study into the effects of different egg forms on the sensory properties and shelf-life of sponge cakes.

CHAPTER 2: LITERATURE REVIEW

2.1 Egg composition

A schematic side view of an egg is shown in Figure 1. Eggs mainly consist of shell, albumen (egg white), yolk, chalazae, an air cell and shell membranes.

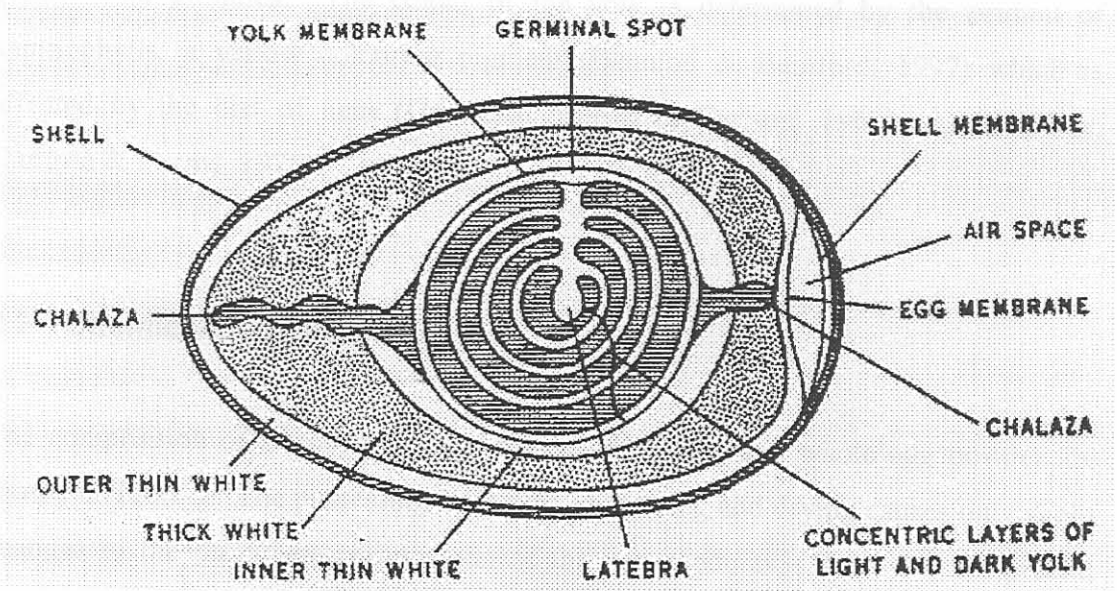


Figure 1 Schematic drawing of the internal structure of a hen's egg (Forsythe, 1957)

Egg albumen is made up of four distinct layers: outer thin white, viscous or thick white, inner thin white, and a chalaziferous layer (Almquist & Lorenz, 1933). It contains about 85% (in dry matter) of the total protein content of an egg (Bennion & Bamford, 1997). The major proteins of albumen are ovalbumin, conalbumin (ovotransferrin), ovomucoid, lysozyme and ovomucin (Parkinson, 1966). The whites are viscous and have a high pH (pH 8.2 - 9) (Toney & Bergquist, 1983) in a fresh egg. The pH changes to a maximum value of about 9.7 (Heath, 1977) during storage due to the loss of carbon dioxide. At this pH, the function of lysozyme, which forms a chemical protection against microorganisms is lost (Cotterill & Winter, 1955;

Bennion & Bamford, 1997). The egg albumen thinning during storage is also affected by pH (Cotterill & Winter, 1955).

2.1 Egg processing

Egg yolk can be regarded as a mixture of particles and plasma. The plasma includes low-density globules which are rich in fat (Parkinson, 1966). The egg yolk protein (livetin) consists of lipoproteins. The pH of egg yolk is pH 6.0 for fresh eggs whereas the pH changes to between pH 6.4 – 6.9 during storage (Li-Chan *et al.*, 1995). Egg yolk contains a high capacity for pigmentation and has a high proportion of yellow yolk globules. The colour of the yolk is determined by the amount of xanthophylls, a yellow colouring pigment (Bennion & Bamford, 1997) which is affected by the diet of hens (Deethardt, Burrill & Carlson, 1965b; Angalet, Fry, Damron & Harms, 1976).

2.2 Chemical composition

The composition of fresh whole egg, frozen whole egg and whole egg powder are shown in Table 1. The processing by means of freezing and drying causes only slight changes to the proximate composition of the egg products. However, the protein structure of egg ingredients change and the liberation of free fat may occur (Powrie & Nakai, 1985).

Table 1 Proximate composition of fresh whole egg, frozen whole egg and whole egg powder on dry base (Adapted from Watkins, 1995)

Composition	Shell egg	Frozen egg pulp	Whole egg powder
Protein (%)	49.00	48.98	48.97
Lipid (%)	44.54	44.49	44.52
Carbohydrate (%)	2.38	2.45	2.38
Ash (%)	4.08	4.08	4.13

2.3.1 Breaking

2.3 Egg processing

Improved technology and the development of mechanical equipment were responsible for small-scale egg processing lines to become large commercial operations (American Egg Board, 2001). Egg products for commercial usage include liquid, frozen and dried whole egg, albumen and yolk. Various blends of whole egg and yolk are also included (Stadelman *et al.*, 1988). The processing steps of whole egg products are shown in Figure 2.

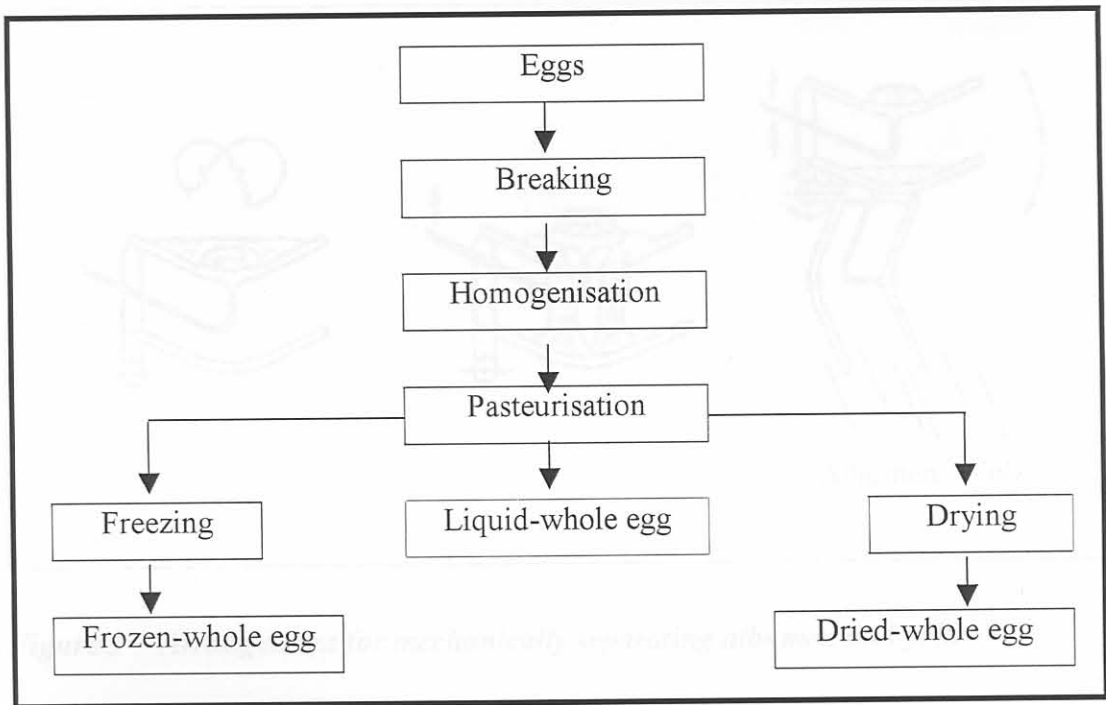


Figure 2 The processing steps of whole egg products (Adapted from Linden & Lorient, 1999)

Ultra-pasteurisation and irradiation have also been used to process whole egg products.

2.3.1 Breaking

This operation (Figure 3) is to break the eggs and separate the yolk, albumin and shells. The egg is placed automatically on a type of egg-cup, is struck by two blades which thus break the egg into two halves. When the egg reaches a receiving spatula, the white will separate from the yolk (Linden & Lorient, 1999). For efficiency and product quality, the breaking plant should be as close to the site of shell-egg production as possible (Watkins, 1995). The broken egg is very easily contaminated by bacteria. Thus, the sanitation system and handling practices in the plant must be very well organized (Galyean, Cotterill & Cunningham, 1972).

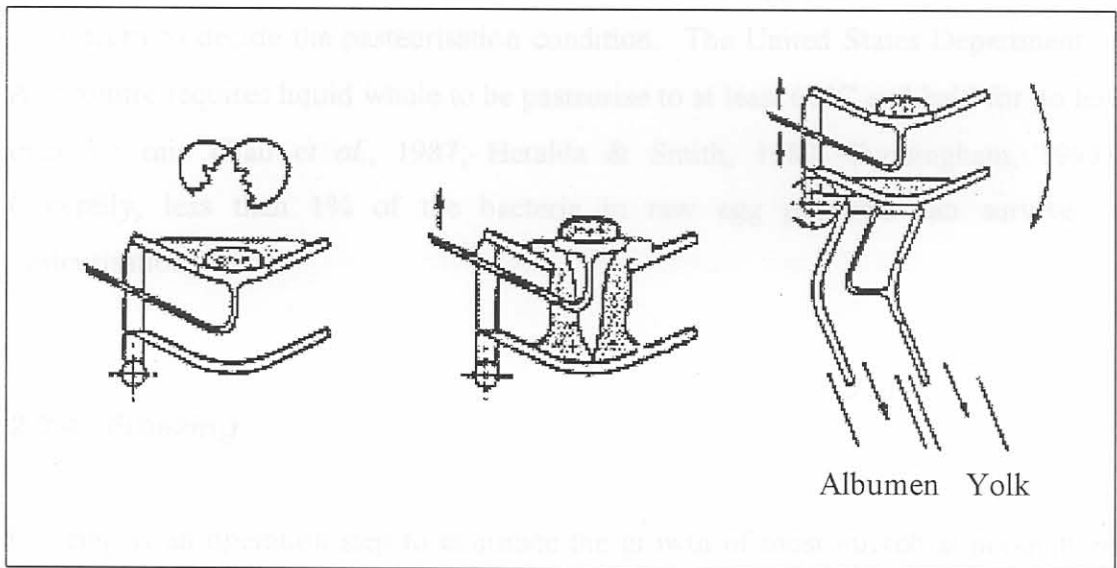


Figure 3 Arrangement for mechanically separating albumen and yolk

2.3.2 Homogenisation

This processing step is to blend the egg white and yolk. The whole egg product's solid level must be standardized to 24.0% -24.5% whereas the solid level of shell egg solids may range between 21% and 25% (Du Preez, 2000). The homogenisation can reduce the severity of heat processing such as pasteurisation and drying (Kincal, 1987).

2.3.3 Pasteurisation

Pasteurisation was first practiced by the egg product industry in the 1930s (Moore, Warren, Davis & Johnson, 1988). The main purpose of pasteurising is to create a wholesome product by eliminating pathogenic bacteria, such as salmonellae. This pathogenic bacteria has been the primary concern for eggs and egg products (Cunningham, 1995). The conditions of pasteurisation depend on the composition of the egg products, and it is closely related to the pH of the egg products. Since *Salmonellae* are most heat resistant at pH 5 to 6, therefore, the pasteurisation conditions are different between the whole egg, egg yolk and egg albumin. In addition, the solid and nature of constituents of the final egg product are also a factor of concern to decide the pasteurisation condition. The United States Department of Agriculture requires liquid whole to be pasteurise to at least 60°C and held for no less than 3.5 min (Ball *et al.*, 1987; Heralda & Smith, 1989; Cunningham, 1995). Generally, less than 1% of the bacteria in raw egg products can survive in pasteurisation.

2.3.4 Freezing

Freezing is an operation step to eliminate the growth of most microbial populations (Heldman & Hertel, 1997). This is carried out in cells or by passing the whole egg products through a tunnel at -45°C (Linden & Lorient, 1999). The freezing and thawing rate, storage temperature and time are very important for the quality of the product. Fast freezing and thawing resulted in less yolk gelation than slow freezing and thawing (Cotterill, 1995). In addition, smaller ice crystals are formed and less dehydration of the proteins occurs (Powrie, Little & Lopez, 1963). The functional properties of whole egg products are only slightly affected. However, the texture is changed by freezing (Cotterill, 1995). Frozen egg has a higher proportion of polyunsaturated fatty acid than egg powder samples (Guardiola, Codony, Manich, Rafecas & Boatella, 1995a). Most frozen-egg products are marketed as ingredients for use in other food products.

2.3.5 Dehydration

2.3.5.1 Storage

Drying or dehydration of foods is an extremely important food processing operation used to preserve foods for extended periods of time by stopping the growth of microorganisms due to water activity of the food (Heldman & Hertel, 1997). For drying, the quality of eggs, handling methods, sanitation practices, pasteurisation procedures, drying, and storage are all may affect the quality of final dehydrated product (Bergquist, 1995).

Spray-drying, freeze-drying, pan-drying, belt-drying as well as foam-drying and foam-spray-drying have been used. Spray-drying (Figure 4) is the most common drying method for commercial egg product in South Africa. The quality of dried egg products changes the least with freeze-drying. However, the cost of freeze-drying is relatively high. Nevertheless, it has been used for producing a dried whole-egg product containing emulsifier primarily for baker use in England (Spicer, 1969) or mostly used as research tool (Guardiola, Codony, Miskin, Rafecas & Boatella, 1995a). Satyanarayana Rao (1993) found that the spray-drying, foam mat drying and freeze drying methods had no significant effect on the palatability and acceptability during one year storage.

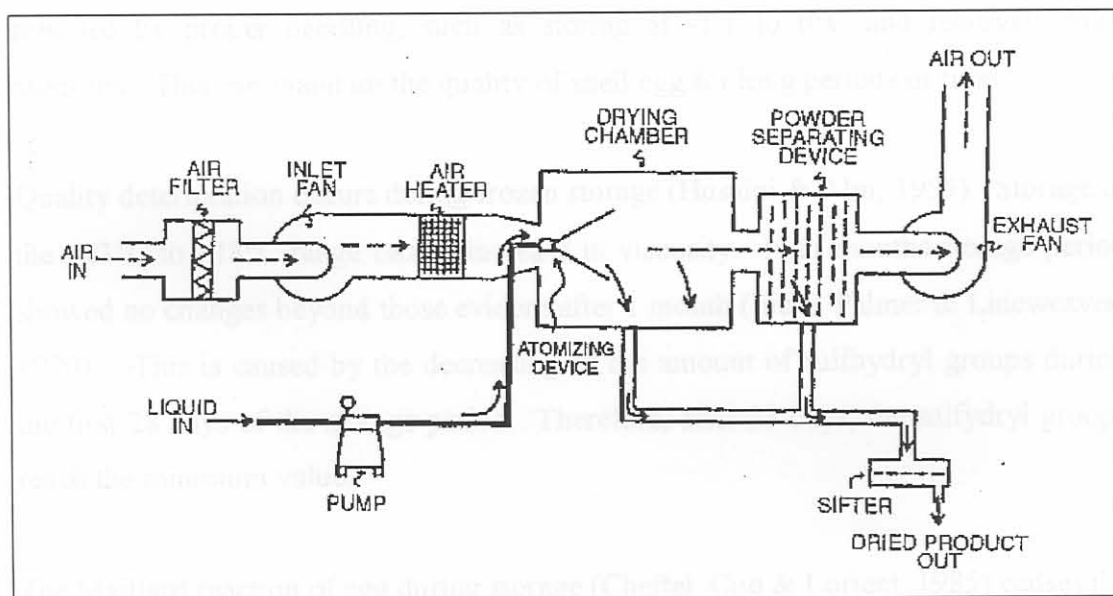


Figure 4 Schematic diagram of spray-drying system (Bergquist, 1995)

2.3.6 Storage

The storage of shell egg, frozen egg and dried egg will all be discussed under this section. Some deterioration in odour and flavour occurs during storage of eggs. Unpleasant flavours are absorbed by eggs if care is not taken to prevent odours in storage areas. In addition, characteristic stale odours and flavours develop in eggs during long storage periods (Campbell, Penfield & Griswold, 1987).

As soon as the egg is laid, changes begin to take place that lower its quality and eventually cause spoilage (Campbell *et al.*, 1987). During the storage, CO₂ losses through the shell cause the pH of albumen to rise, and this changes the structure of the albumen protein (Clinger, Young, Prudent & Winter, 1951). After 3 days the pH may rise to 9.3 or more and render the egg less susceptible to bacterial infection. In addition, evaporation of moisture and movement of water within the egg occur during the storage period. This movement results in enlargement and decreased viscosity of the yolk, weakening of the vitelline membrane, and consequent flattening of the yolk when the egg is broken (Campbell *et al.*, 1987). The thinning of egg white occurs due to changes that take place in the internal molecular structure. These changes can be retarded by proper handling, such as storing at -1.1 to 0°C and relatively high humidity. This can maintain the quality of shell egg for long periods of time.

Quality deterioration occurs during frozen storage (Husaini & Alm, 1955). Storage in the -23°C to -18°C range causes increase in viscosity. Four months storage period showed no changes beyond those evident after 1 month (Ijichi, Palmer & Lineweaver, 1970). This is caused by the decreasing of the amount of sulfhydryl groups during the first 28 days of the storage period. Therefore, after 28 days, the sulfhydryl groups reach the minimum value.

The Maillard reaction of egg during storage (Cheftel, Cuq & Lorient, 1985) causes the off-flavours, discolouration, loss of solubility and loss of nutritive value. This non-enzymatic browning can be retarded by desugarisation of egg product before drying

(Satyanarayana Rao, 1991). However, some workers reported that the Maillard reaction effectively improved functional properties of food proteins (Handa & Kuroda, 1999). Kato, Minaki & Kobayashi (1993) found that the emulsifying properties of dried egg white improved through the Maillard reaction. In addition, the myofibrillar protein of eggs conjugated with glucose through the Maillard reaction resulted in the improvement of the solubility of protein (Saeki, 1997).

2.4 Functional properties

According to Hall (1996), Pour defined functionality as “any property of a food or food ingredient, except its nutritional ones, that influences its utilization”. Most functional properties affect the sensory characteristics of food products which may be influenced by processing, and storage (Ahmedna, Prinyawiwatkul & Rao, 1999). The functional properties of eggs are not only affected by the diet, age, breed of laying hens as well as environment and seasons of the year (Angalet *et al.*, 1976) but also affected by the concentration of protein, pH, time, temperature, ionic strength and presence of other components like salt (Heralda & Smith, 1989; Akintayo, Oshodi & Esuoso, 1999). In addition, the sequence and distribution of amino acids affect the solubility, surface hydrophobicity and ability to stabilize foams and emulsions (Hall, 1996).

Protein solubility has significant influence on the functional properties of egg proteins (Kato, Fujimoto, Matsudomi & Kobayashi, 1986). Generally speaking, a good emulsion, foam, gelation and whipping properties require high protein solubility. In addition, the flexibility of proteins closely related to functional properties. The flexibility means slight protein is structure changes which are too small to detect by observation. However, Kato, Takahashi, Matsudomi & Kobayashi (1983) reported that protein flexibility can be detected by the protease digestion method. Furthermore, protein flexibility is an important structural factor governing the foaming and emulsifying properties, as well as the hydrophobicity of protein. In addition, Townsend & Nakai (1983) found a high correlation between foaming capacity and

molecular flexibility ($R^2 = 0.806$). This relationship indicates that it is important for protein molecules to be flexible enough to spread out at the air/water interface to stabilize fresh air cells, thus preventing the collapsing of foams.

For sponge cakes, the main functions of eggs are foaming, coagulation, water-holding capacity, colour and flavour. Hence, the literature review on functional properties of egg will concentrate on these properties.

2.4.1 Foaming

Eggs play a major role in foaming capacity of cake batter. The typical foam structure is shown in Fig 5. They produce large volume of stable foams which coagulate during heating. This adds particular value to the production of cakes, such as sponge cakes (Du Preez, 2000). Foams can be produced by whipping/ stirring, bubbling/sparging and shaking (Hammershøj, Prins & Qvist, 1999). The rate and motion of beaters can influence the incorporation of air, while pre-treatments like blending, homogenising and temperature, and the addition of ingredients will also influence egg foams (Du Preez, 2000). Protein molecules contain both hydrophilic and hydrophobic sites on their surfaces. During the whipping process the hydrophobic regions facilitate adsorption at the interface, a protein surface tension facilitates the creation of new interfaces and more bubbles (Poole, 1989). As egg is beaten, air is incorporated into the liquid to form foams with bubbles that decrease in size and increase in number (Kim & Setser, 1982). The smaller bubbles will have a higher gas pressure and therefore higher gas concentration, which causes diffusion of gas from small to large bubbles (Hammershøj *et al.*, 1999). The partly unfolded molecules then combine to form stabilizing films around the bubbles (Poole, West & Walters, 1984; Yang & Baldwin, 1995). Whole egg and yolk products will also form foams, but they are not as efficient as egg white (Toney & Bergquist, 1983).

The formation of a stable foam requires high tensile strength or elasticity. Foaming capacity is a very valuable property of the egg white, and involves the ovomucin, the globulins and the ovalbumin (Linden & Lorient, 1999). The globulins facilitate foam formation, the ovomucin-lysozyme complex (Cotterill & Winter, 1955) confers foam stability, and ovalbumin and conalbumin provide heat-setting properties.

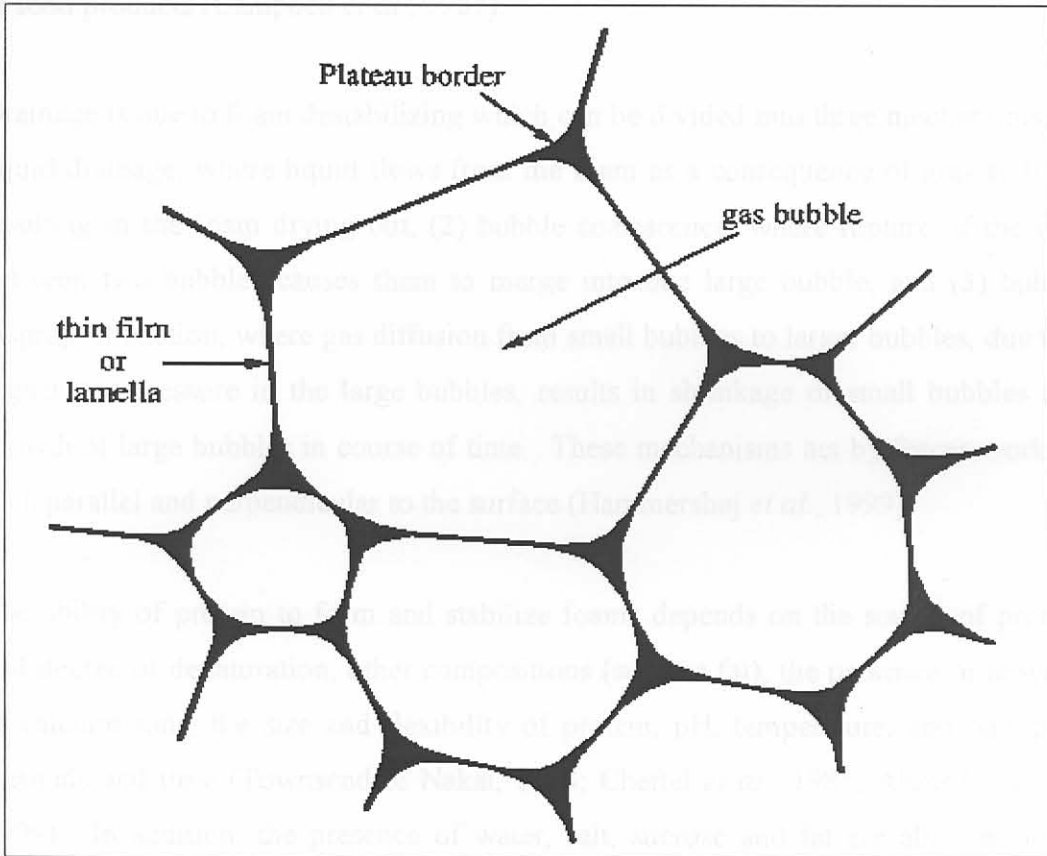


Figure 5 The structure of foam bubbles (Wilde & Clark, 1996)

Globulins contribute to high viscosity and decrease the tendency for liquid to drain away from the air bubbles of foams. It also lowers the surface tension, which is helpful especially in the initial stages of foaming. Low surface tension also enhances small bubble formation and smooth and light texture (MacDonnell, Feeney, Hanson, Campbell & Sugihara, 1955; Ahmedna *et al.*, 1999). Johnson & Zabik (1981) stated that the interaction of lysozyme and globulin, an important function of the foaming process, undergoes destruction during thermal processing (Bharti, Panda & Sahoo, 2001).

The formation of a stable foam requires high tensile strength or elasticity lamella (Yang & Baldwin, 1995). Overwhipping lead to loss of the elasticity of bubbles lost due to insolubilization of too much of the ovomucin (MacDonnell *et al.*, 1955). This is especially important for egg foams when heated. The air in the cells expands, and the albumen surrounding it must either stretch or break. This results in lower volume of food products (Campbell *et al.*, 1987).

Drainage is due to foam destabilizing which can be divided into three mechanisms; (1) liquid drainage, where liquid flows from the foam as a consequence of gravity force resulting in the foam drying out, (2) bubble coalescence, where rupture of the film between two bubbles causes them to merge into one large bubble, and (3) bubble disproportionation, where gas diffusion from small bubbles to larger bubbles, due to a higher gas pressure in the large bubbles, results in shrinkage of small bubbles and growth of large bubbles in course of time. These mechanisms act by forces working both parallel and perpendicular to the surface (Hammershøj *et al.*, 1999).

The ability of protein to form and stabilize foams depends on the source of protein and degree of denaturation, other compositions (such as fat), the presence or absence of calcium ions, the size and flexibility of protein, pH, temperature, and whipping methods and time (Townsend & Nakai, 1983; Cheftel *et al.*, 1985; Ahmedna *et al.*, 1999). In addition, the presence of water, salt, sucrose and fat are also important (Phillips, 1981; Giese, 1994).

Sodium chloride (NaCl): At low concentration, it improves foaming capacity of protein solution (Akintayo *et al.*, 1999). It usually reduces surface viscosity and rigidity of protein films but increase spreading rate, thereby weakening interpeptide attractions and increasing foam volume for certain proteins. However, high levels of NaCl will depress foaming (Oshodi & Ojokan, 1997; Linden & Lorient, 1999). The NaCl reduces foam stability whereas the Ca^{2+} ions can improve stability by forming bridges between the carboxylic groups of the protein. With whole eggs, adding NaCl before beating caused soft foams which were small in volume. Sponge cakes prepared with these foams were small and tough (Briant & Willman, 1956).

Temperature: Hagolle, Relkin, Popineau & Bertrand (2000) and Kato, Ibrahim, Watanabe, Honma & Kobayashi (1989) reported that thermal treatment of solutions drastically increased the foaming quality of lysozyme and improved that of ovalbumin, which both gave very stable foams after being heated to 90°C. Low temperature reduces surface tension. Thus, albumen foams more easily and attains greater volume at room temperature than at refrigerator temperature (St. John & Flor, 1931).

Carbohydrates: Carbohydrates (sucrose, lactose, dextrose, and maltose) depress the foaming capacity but improve foam stability. In this way, the foam-stabilizing role played by the glycoproteins of the egg white (ovomuroid, ovalbumin) is linked to their capacity to retain water in the lamellae (Linden & Lorient, 1999). Sucrose and other sugars often depress foam expansion but improve foam stability, because they increase the bulk viscosity (Cheftel *et al.*, 1985).

Fat: It is well known that low concentrations of contaminating lipids (less than 0.1%) seriously damage the foaming properties of proteins by placing themselves at the air/water interface, thus preventing, through competitive adsorption, the most favourable conformation of protein films (Cheftel *et al.*, 1985; Linden & Lorient, 1999). In addition, the small amounts of fat in flour are detrimental to the stability of egg-white foams (Forsythe, 1957). Commercially available egg substitutes, which contain albumen and added vegetable oils, are not optimal for sponge cakes, because the presence of even small quantities of oil decreases albumen's foaming ability (Kim & Setser, 1982).

Dilution: Henry and Barbour found that the volume of foams could be increased by adding small quantities of water to the albumen before beating. These foams were almost as stable as those made from whites to which no water was added (according to Yang & Baldwin, 1995).

pH: When the pH of egg white was adjusted to 8.75, it resulted in improved volume of cakes and whip-time (Seideman, Cotterill & Funk, 1963). However, Hammershøj *et al.* (1999) found pH 4.8 had the highest foaming overrun, and pH 7.0 had the most stable foam. They explained that at high pH values, the fast exchange of the thiol- and disulphide bonds can influence the surface properties of the protein film, as split-up of disulphide bonds increases the flexibility, opportunity of orientation, and unfolding of the molecule at the interface.

Others factors: Sagis, de Groot-Mostert, Prins & van der Linden (2001) found that the foams prepared with copper ions in eggs took more time to foam, but were also more stable.

2.4.2 Coagulation

Thermal coagulation is extremely important when using egg products with cereal foods. Because of this property, egg binds other food materials together and contributes to thickening. The structural integrity and crumb strength of sponge cake are attributable to coagulation properties of egg protein (Toney & Bergquist, 1983).

Coagulation is the term used to describe the change from the fluid (solution) to the solid or semisolid (gel) state (Linden & Lorient, 1999). Yang & Baldwin (1995) stated that the terms “coagulation” and “gelation” are used interchangeably as a “gel”. It is a formation of a three-dimensional matrix through inter-protein bonding, and the concomitant immobilization of water within this gel structure, determines the textural and other properties of many food products (Gossett, Rizvi & Baker, 1983). A coagulum forms when the structure of egg-protein molecules is changed by heat, acids, alkalies, and other reagents such as urea. Gel viscosity increased with increasing temperature used for heating the protein solutions for all proteins investigated (Ahmedna *et al.*, 1999). The strengthening of the gel formed from egg protein is mainly attributed to hydrogen bonding and hydrophobic interactions and partially to

the formation of intermolecular disulfide bonds (Kato, Ibrahim, Watanabe, Honma & Kobayashi, 1990). Thermal coagulation takes place from 62°C upward in egg white whereas the egg yolk coagulates at 65°C upward.

Parkinson (1966) stated that ovomucoid and ovomucin in egg white and livetins and phosphovitin in egg yolk are noncoagulable by heat. The ovalbumin (Johnson & Zabik, 1981) and conalbumin (Cunningham & Lineweaver, 1965) in egg white are however, responsible for coagulation. The gelling properties of the yolk proteins are associated with the lipoproteins (Linden & Lorient, 1999). The denaturation temperature of conalbumin, globulins, ovalbumin and lysozyme are 57.3°C, 72.0°C, 71.5°C and 81.5°C, respectively (Woodward & Cotterill, 1983; Yang & Baldwin, 1995). The interaction between temperature, dilution, salts, sugar, acid and alkali or alone can influence the coagulation properties (Toney & Bergquist, 1983; Du Preez, 2000).

Dilution: Beveridge, Arntfield, Ko & Chung (1980) found that the firmness of the coagulum decreased with increasing dilution and Hsieh & Resenstein (1989) found that the egg white gel strength increased with the egg white concentration.

NaCl: The gelling ability decreased at higher concentrations of salt (Akintayo *et al.*, 1999). Catsimpoolas & Meyer (1971) stated that hydrogen and ionic bonds are responsible for the stabilization of the gel, and that addition of NaCl will decrease the viscosity of the gel.

Carbohydrates: The coagulation temperature increases with increasing sugar concentration. (Yang & Baldwin, 1995; Du Preez, 2000).

pH: The gel strength generally increased with increasing of pH (Handa, Takahashi, Kuroda & Froning, 1998). The pH alters the gelling ability such as gelling temperature and time and textural properties of protein gel (Chang & Chen, 2000).

Time and Temperature: According to Woodward & Cotterill (1987), there were significant differences in time and temperature interactions for hardness, cohesiveness, and springiness of bakery product. Lowe stated that “the average speed of coagulation of albumen is increased 191 times with a rise in temperature of 1 °C and approximately 635 times with a 10°C increase in temperature” (according to Yang & Baldwin, 1995).

2.4.3 Colour and flavour

The colour of the yolk determines the attraction and acceptability of the egg for the consumer (Linden & Lorient, 1999). The naturally occurring pigments in chicken egg yolk are mainly alcohol-soluble xanthophylls, lutein and zeaxanthin (Du Preez, 2000). These colour pigments are affected by the diet of the laying hens (Deethardt *et al.*, 1965b; Angalet *et al.*, 1976). Deethardt, Burrill & Carlson (1965a) stated that the egg yolk colour influenced the quality of sponge cakes.

Eggs have a very delicate flavour and significantly contribute to desirable sensory properties in finished foods due to its mild flavour and odour (Toney & Bergquist, 1983). However, flavour changes can occur during the storage and handling of eggs both before and after cooking and processing, such as pasteurisation and dehydration (Maillard reaction) (Hard, Spencer, Locke & Georage, 1963).

2.5 Functional property changes due to processing

2.5.1 Freezing

Several processes can be used to extend the shelf-life of eggs. However, these processes could influence the functional properties of the egg products. Pasteurisation, freezing and dehydration may affect the foaming, coagulating, colour and flavour of egg product which may directly affect properties such as baking volume, texture, colour, flavour and shelf-life of sponge cakes.

2.5.1 Heat Treatment

Changes in egg products brought about by heat are of major concern to the processor and user alike. Damage to the whole egg is evaluated, using layer cakes or sponge cakes instead of angel cakes with egg white (albumen) and observing foaming and coagulating properties. In the temperature range of 56°C to 66°C, the denaturation of whole egg takes place and the viscosity of liquid whole egg is reduced. Above this range, fractional precipitation of proteins occurs, while coagulation takes place rapidly above 73°C (Cunningham, 1995).

Certain added substances help to stabilize liquid egg against heat denaturation. Carbohydrates such as sucrose, glucose, fructose, arabinose, mannitol, and xylose have been found to inhibit heat denaturation, as evidenced by preventing the formation of sulfhydryl groups (Woodward & Cotterill, 1983). Carbohydrates also protect whole eggs from coagulation by heat and increase the coagulating temperature of egg products (Cunningham, 1995). In addition, salt also protects against heat denaturation (Woodward & Cotterill, 1983).

Pasteurised frozen whole egg has a different appearance when thawed compared to unpasteurised frozen whole egg. When a temperature of 61°C with a holding time of 3 min was used, the viscosity of the product is reduced. In addition, pasteurisation and freezing increased the beating time required for the preparation of a sponge cake, but improved the foam stability as measured by drainage (Cunningham, 1995).

2.5.2 Freezing

Freezing provide a long shelf-life, but undesirable changes occur in whole egg due to freezing and thawing. Parkinson (1977) reported denaturation of egg during freezing. The slower the freezing rates, the more the denaturation of egg protein. However, Cotterill (1995) reported that the functional properties of whole egg are not drastically affected by freezing.

A lot of workers reported that uniform appearance (such as colour distribution), gelation, thickening and lumpiness were found in frozen whole egg after thawing (Ijichi *et al.*, 1970; Palmer, Ijichi & Roff, 1970; McCready & Cotterill, 1972). In addition, Ijichi *et al.* (1970) found that the thawed whole eggs showed separation and dark colour liquid.

Liquid whole egg undergoes gelation upon freezing and thawing. However, it is less drastic than in yolk alone (Cotterill, 1995). Freezing of liquid whole egg was found to decrease foaming and whipping properties in several studies (Pearce & Lavers and Mori according to Heralda & Smith, 1989). Furthermore, these workers observed that freezing of egg reduced the baking quality of whole egg, but it improved after frozen storage for three months and then decreased again thereafter. In addition, fast thawing may reduce the gelation if a high temperature is used for thawing which “melted” the gel or lumps (Palmer *et al.*, 1970). The freezing rate is very important as it influences viscosity. Fast freezing at -29°C limited viscosity increase to about $\frac{3}{4}$ of the viscosity of whole eggs frozen in a slow airflow, but was not effective in preventing appearance defects (Ijichi *et al.*, 1970; Linden & Lorient, 1999) and functional performance (Palmer *et al.*, 1970).

Besides high temperature, McCready & Cotterill (1972) found that centrifugation of liquid whole egg can also be used to avoid viscosity changes caused by freezing. In addition, homogenisation, colloid milling or stirring with a mixer before freezing limited viscosity changes in liquid whole eggs during frozen storage, but none of these mechanical treatments were effective in preventing liquid separation and caused a curdled appearance in those eggs thawed after storage at -18 to -29°C (Ijichi *et al.*, 1970).

Addition of NaCl, sugar and skimmed milk prior to freezing protected against the gelation of frozen egg products (Ijichi *et al.*, 1970; Dill, Brough, Alford, Gardner, Edwards, Richter & Diehl, 1991). In addition, syrups, glycerin, gum, phosphates, and other sugars can also be used. However, these ingredients may be restricted to specific food products (Cotterill, 1995).

2.5.3 Dehydration

Dehydrated whole eggs have historically been a poorly accepted product (Bergquist, 1995). Egg proteins denature over a wide range of temperature. In addition, the amount of heat that is absorbed by the dried egg product, the method of drying, the dryer design and conditions of its operation, and how rapidly the product is cooled after drying are major factors that affect the functional properties of dried egg products.

Spray-drying is frequently used to obtain powdered eggs (Guardiola *et al.*, 1995a). However, the presence of oxysterols in powdered eggs during drying have been confirmed, and their formation depends on two main factors: (1) the direct or indirect air heating system (Missler, Wasilchuk & Merritt, 1985), and (2) the inlet and outlet temperature (Tsai & Hudson, 1985). When the air is heated indirectly, the formation of oxysterols in the dried egg is lower than when direct heating is applied. According to some authors, this is due to the formation of nitrogen oxides (NO and NO₂) in the air directly heated by passage through a natural gas flame, and these compounds have an oxidative effect on the product (Guardiola *et al.*, 1995b). In addition, Lai, Gray, Buckeley & Kelly (1995) observed that oxysterol formation during the storage of egg powder was greater in samples dried by direct heating than in samples dried by indirect heating (Guardiola, Codony, Rafecas, Grau, Jordán & Boatella, 1997). In addition, Guardiola *et al.* (1997) found that the spray-drying temperature and its interaction with storage time influenced the water activity and moisture of dried egg product. Samples obtained at high spray-drying temperature initially showed lower moisture and water activity. During storage, the low temperature and consequently water activity of dried egg increased more, since it is easier to absorb water. Lipid oxidation lead to a decrease in the nutritive value of egg powder. Addition of antioxidant during preparation and storage (Huber, Pike & Huber, 1995) or packing of the product in nitrogen and carbon dioxide, or a mixture of the two (Bergquist, 1995) might reduce the lipid oxidation during storage.

Maillard reactions take place during the storage of dried egg products. It causes the colour to darken and flavour to change in dried egg products. However, this can be prevented by removing the sugar prior to dehydration. Off-flavours are also produced in dehydrated products during storage (Guardiola *et al.*, 1995b; Yang & Baldwin, 1995). The flavour stability of whole-egg powder can be improved by acidifying the liquid to pH 5.5 before drying (Lieu, Froning & Dam, 1978; Mine, 1997). This inhibits the browning reaction involving the glucose and protein, but does not completely prevent it (Bergquist, 1995).

If stored under proper drying and storage conditions, dried egg products retain their heat-coagulating properties quite well. However, if drying conditions are too severe or if storage conditions are adverse, whole egg and yolk products can lose their heat-coagulation properties as well as their solubility. The conditions under which the dried product is stored will also affect its whipping performance (Bergquist, 1995). Lewis, Marcelli & Watts (1953) found that hexametaphosphate and tripolyphosphate effected the greatest improvement in whipping ability of dried whole eggs. The foaming ability of dehydrated whole egg can also be improved by increasing the temperature at which the reconstituted material is whipped (Bergquist, 1995). Furthermore, Kim & Setser (1982) found that addition of sodium lauryl sulfate and gum stabilizers can improve the foaming ability and stability.

An increase in viscosity in dehydrated whole egg and yolk products can also be observed during storage. Viscosity in the reconstituted product increases quite rapidly at temperatures above 38°C (Bergquist, 1995).

Kato *et al.* (1989) found a significant improvement of functional properties such as the foaming, emulsifying and gelling properties of dried egg white by heating the product in dry state at 80°C for several days. The important structural factors for foaming properties are protein flexibility (Kato *et al.*, 1986), protein-protein interaction and surface hydrophobicity. Since these structures change with heating in the dry state, the foaming properties may be improved.

2.6 Sponge cake

Sponge cakes are low in fat and the moisture can be lost very rapidly when exposed to the atmosphere. Thus, a good moisture vapour barrier packaging is required. High quality cakes should have various attributes including high volume and tenderness, that result from optimized formulas (Géllinas, Roy & Gulliet, 1999). A shelf-life of three weeks can be obtained by optimizing the formulation and choosing the correct wrapping material (Jones, 1994). The main ingredients in sponge goods are egg, sugar and flour with air, which are introduced during the mixing process (Bennion & Bamford, 1997). Emulsifier is important for sponge cake baking when egg powder is used in the formula.

Soft wheat flours are normally used for cake baking. In some cases, baking industries require their own specific milling for their product. The cake flours which are treated with chlorine can improve cake grain texture, volume and it can reduce microorganisms in flour (Posner & Hibbs, 1997). This is because chlorination accelerates the thickening of viscosity of the batter, which allows improved setting of the batter at final stage of baking (Gaines & Donelson, 1982a).

Sugar plays an important role in bakery products. It contributes not only to sweetness, colour and flavour (Maillard reaction) but also serves as tenderizing agent by retarding gluten development during mixing (Bosman, Vorster, Setser & Steyn, 2000). In addition, sugar delay starch gelatinization and raise the coagulation temperature of protein, so that the air cell of batter can be expanded by carbon dioxide and water vapour (Yamazaki & Kissell, 1978). These reactions can maximize the volume of cakes (Bosman *et al.*, 2000).

The function of emulsifier in cakes are to: (1) increase cake volume; (2) provide uniform texture, better crumb structure; (3) softness and tenderness; (4) reduce egg/shortening; (5) increase shelf-life and retard staling; (6) flavour dispersion and release; (7) reduce mixing time; (8) improve performance of dried egg in cake mixes; (9)

stabilize foam and (10) emulsification (Kamel & Ponte Jr, 1993). Glycerol monostearate (GMS) has been used for many years as an improver in bread, rolls and enriched morning goods. It has powerful emulsifying properties and has the ability to complex with starch, slowing down the rate of product staling (crumb firming). GMS can be added as a crumb softener, reducing the fat required for that purpose (Brown, 1993).

2.7 Microbiology

2.7.1 Fresh eggs

Salmonella is the primary concern for eggs and egg products (Cunningham, 1995). *Salmonella* is effectively destroyed by conventional egg pasteurisation, in which the content of broken eggs are heated to 56.6°C for no less than 3.5 min. However, this process results in decreases in the coagulation and foaming properties of albumen (Hank, Kunkel, Dawson, Acton & Wardlaw, 2001).

Fresh egg has three structures, each of which is effective to some degree in retarding the entry of microorganisms: the outer, waxy shell membrane; the shell; and the inner shell membrane. Internally, lysozyme in egg white which is an enzyme has been shown to be quite effective against gram-positive bacteria. Egg white also contains avidin, which forms a complex with biotin, thereby making this vitamin unavailable to microorganisms. In addition, egg white has a high pH (about 9.3) and contains conalbumin, which forms a complex with iron, thus rendering it unavailable to microorganisms. Generally speaking, more microorganisms are found in egg yolk than in egg white, due to the lack of anti-microbial substances in egg yolk. Furthermore, the pH of the yolk is around pH 6.8, making it an excellent environment for most microorganisms (Jay, 1986; Board & Tranter, 1995).

The entry of microorganisms into shell egg is favoured by high humidity. In this case, growth of the microorganisms on the surface of eggs is favoured, followed by penetration through the shell and inner membrane. Moulds generally multiply first in the region of the air sac, where oxygen favours the growth of these forms. Under high humidity conditions, moulds may be seen growing over the outer surface of eggs. In contrast, in low humidity and low temperature environment, surface growth is not favoured, but eggs lose water at a faster rate and thereby become undesirable as products of commerce (Jay, 1986).

Rotten eggs normally contain a mixed infection of gram-negative bacteria and, on occasion, a few gram-positive organisms are present also. The most common contaminants are from the genera *Alcaligenes*, *Acinetobacter*, *Pseudomonas*, *Serratia*, *Cloaca*, *Hafnia*, *Citrobacter*, *Proteus*, and *Aeromonas* (Board & Tranter, 1995). Generally, less than 1% of the bacteria of raw egg products survive pasteurisation. However, *Alcaligenes*, *Flavobacterium*, *Bacillus*, *Proteus*, *Pseudomonas*, *Escherichia*, *Staphylococcus*, coryneform bacteria, and faecal streptococci are found in pasteurised egg and egg products. Furthermore, *Salmonella* has also been reported to survive in unpasteurised spray-dried whole eggs (Moore *et al.*, 1988).

2.7.2 *Sponge Cake*

Sponge cakes belong to the category of intermediate moisture food products due to their high concentrations of sugars, which restrict the availability of water. It has about 20% moisture, and water activities (a_w) within the range 0.65-0.85. With these water activities, sponge cakes can be spoiled by yeast and moulds especially xerophilic organisms. However, bacterial spoilage is rare in this range of water activity (Jay, 1986; Jones, 1994). The sources of spoilage are many such as the cake ingredients, especially sugar, nuts and spices. Fortunately, baking temperatures are sufficient to destroy these organisms. Moulds may enter baked cakes from handling, and air and post-processing contaminations are unavoidable. Usually, bakery products are packaged in plastic films after baking and cooling, and they are consumed within

1 or 2 months. But, a wide range of moulds, such as *Penicillium*, *Aspergillus*, *Cladosporium* and *Eurotium* species gain access to the product surface prior to packaging (Abellana, Magri, Sanchis & Ramos, 1999).

3.3 Objectives

2.8 Sensory evaluation

Descriptive sensory analysis techniques identify, describe and quantify sensory qualities of a given product (Gillette, 1984). They are the most sophisticated tools in the arsenal of the sensory scientist. These techniques help identify underlying ingredient and process variables and/or determine which sensory attributes are important to acceptance (Lawless & Heymann, 1998). These techniques are ideal for shelf-life testing, especially if the judges were well trained and are consistent over time. This technique requires a panel of 5 to 10 trained persons who are thoroughly familiar with the product's sensory characteristics and who can accurately and precisely communicate their perceptions (Gillette, 1984). The descriptive panel provides the food technologist with detailed descriptions on how the colour, aroma, flavour, and/ or texture of the product change over time. While chemical tests are often used, a sensory panel can detect critical changes that the chemical test might miss.

The sensory characteristics will have appreciable differences between the two cake samples. The functional properties of egg products vary with processing and it is therefore expected that the products baked using dried egg powder will be more firm and compact. The colour and flavour of sponge cakes would be more pale and milder, respectively, than the products which are baked with fresh shell egg and frozen egg pulp. This is because the colour and flavour are degraded during spray-drying (Bergquist, 1995).

The shelf life of the sponge cakes will also have differences. This is because the proteins of the egg product will denature during high temperature drying (i.e. spray drying and spray drying). Hence, the water-binding capacity is reduced if the

CHAPTER 3: OBJECTIVES & HYPOTHESES

3.1 Objectives

- To compare the moisture, protein, fat and ash content (%), pH, foaming overrun, coagulation and water-holding capacity of fresh shell egg, frozen egg pulp, spray-dried egg powder and a commercial egg powder mixture.
- To compare the sensory characteristics and the shelf-life of sponge cakes which were baked with fresh shell egg, frozen egg pulp, spray-dried egg powder and a commercial egg powder mixture and stored at two temperatures (21°C and 31°C).

3.2 Hypotheses

- The protein content, pH, foaming properties, coagulation properties and water-holding capacity of egg ingredients will directly affect the sensory characteristics of sponge cakes.
- The sensory characteristics will have noticeable differences among the sponge cake samples. The functional properties of dehydrated egg products are altered by processing and it is therefore expected that the products baked using dried egg powder will be more firm and compact. The colour and flavour of sponge cakes would be more pale and milder respectively, than the products which are baked with fresh shell egg and frozen egg pulp. This is because the colour and flavour are degraded during spray-drying (Bergquist, 1995).
- The shelf life of the sponge cakes will also have differences. This is because the protein of the egg product will denature during high temperature drying (i.e. Pan drying and spray drying). Hence, the water-binding capacity is reduced (Cheftel *et*

al., 1985) which increases the water activity (free water) of the final product. In addition, high water activity will speed up the physical (staling) and microbiological (mould growth) spoilage (Jones, 1994). Therefore, differences in the shelf-life of sponge cake samples are expected.

4.1 Experimental Design

The experiment was divided into Phase 1 (Figure 6) and Phase 2 (Figure 7). The moisture, protein, fat and ash content (%) of each egg ingredient were determined in Phase 1. The moisture content of the individual egg samples was also determined at the end of the fermentation of the sponge cakes (47 °C, 11 pH, 100 rpm, 200 mL, 10 min) to determine water holding capacity were also determined for all egg samples. The water holding capacity samples were analyzed in Phase 2. Specific volume, index of volume and water activity were determined on Day 0. In addition, texture analysis (firmness) were conducted every four days from Day 0 to Day 24, whereas the staling and mould counts were determined every four days from Day 12 onwards. The sensory characteristics of sponge cakes were evaluated every four days from Day 0 to Day 16 only, due to positive yeast and mould counts found on Day 16.



Figure 6 The measurements of Phase 1 to characterize the frozen whole egg, frozen egg pulp, spray-dried egg powder and egg powder mixture samples.

CHAPTER 4: MATERIALS & METHODS

4.1 Experimental Design

The experiment was divided into Phase 1 (Figure 6) and Phase 2 (Figure 7). The moisture, protein, fat and ash content (%) of each egg ingredient were determined in Phase 1. The moisture content of the individual egg samples was applied to calculate the reconstitution formula of the sponge cakes (4.3.2.1). pH, coagulation temperature, foaming overrun and water holding capacity were also determined for all egg samples. The sponge cake samples were analyzed in Phase 2. Specific volume, index to volume and water activity were determined on Day 0. In addition, texture analysis (by instrument) were conducted every four days from Day 0 to Day 24, whereas the yeast and mould counts were determined every four days from Day 12 onwards. The sensory characteristics of sponge cakes were evaluated every four days from Day 0 to Day 16 only, due to positive yeast and mould counts found on Day 16.

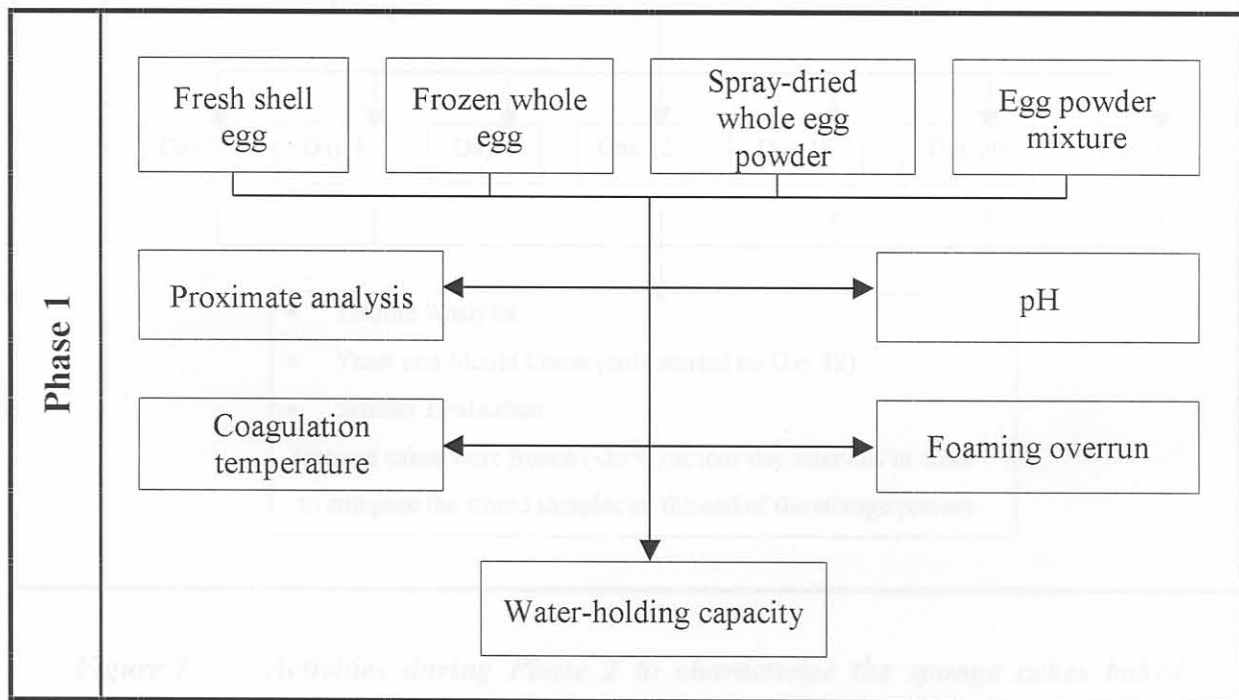


Figure 6 The measurements of Phase 1 to characterize the fresh shell egg, frozen egg pulp, spray-dried egg powder and egg powder mixture samples

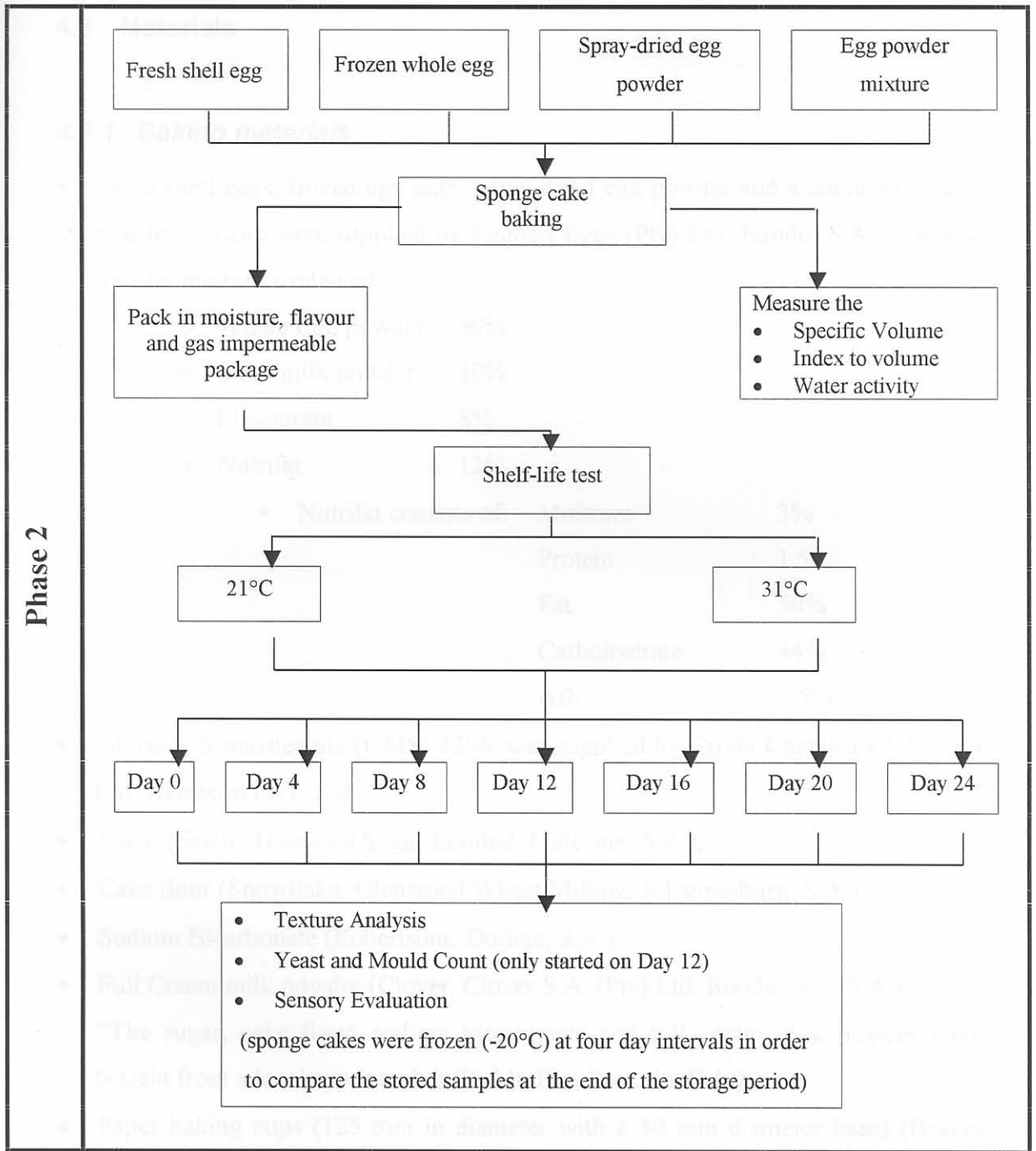


Figure 7 Activities during Phase 2 to characterize the sponge cakes baked from fresh shell egg, frozen egg pulp, spray-dried egg powder or egg powder mixture

4.3 Methods

4.3.1 Phase 1 (Analyses of egg samples)

4.2 Materials

4.2.1 Baking materials

- Fresh shell eggs, frozen egg pulp, spray-dried egg powder and a commercial egg powder mixture were supplied by Eggbert Eggs (Pty) Ltd, Isando, S.A. The egg powder mixture contained:

○ Whole Egg powder	50%
○ Skim milk powder	30%
○ Flavourant	8%
○ Nutrifat	12%
▪ Nutrifat consists of:	
	Moisture 3%
	Protein 1.5%
	Fat 50%
	Carbohydrate 44%
	Ash 1.5%

- Glycerol Monostearate (GMS) 420V was supplied by Croda Chemicals SA (Pty) Ltd, Kempton Park, S.A.
 - Sugar (Selati, Transvaal Sugar Limited, Malelane, S.A.),
 - Cake flour (Snowflake, Glenwood Wheat Milling, Johannesburg, S.A.),
 - Sodium Bicarbonate (Robertsons, Durban, S.A.),
 - Full Cream milk powder (Clover, Clover S.A. (Pty) Ltd, Roodepoort, S.A.)
- *The sugar, cake flour, sodium bicarbonate and full cream milk powder were bought from a local supermarket (Pick'n Pay, Pretoria, S.A.)
- Paper baking cups (125 mm in diameter with a 50 mm diameter base) (Bakers World, Pretoria, S.A.)
 - Moisture, air and flavour impermeable plastic package (130 x 145 mm) (Plastilon, Pretoria, S.A.)

4.3 Methods

4.3.1 Phase 1 (Analyses of egg samples)

Three fresh shell eggs (± 51 g each) were hand-broken and the white and yolk were mixed with a Kenwood Chef Excel mixer at speed 1 for 30 sec at 21°C ($\pm 0.5^{\circ}\text{C}$). The frozen egg samples (2 kg batch size) were thawed by warming up to 40°C using a water bath and cooled to 21°C ($\pm 0.5^{\circ}\text{C}$). The powder samples were reconstituted with 45°C distilled water in ratio 1:3 by stirring with a glass rod, followed by cooling to 21°C ($\pm 0.5^{\circ}\text{C}$) for all the analyses except proximate analysis. All the analyses were done in triplicate.

4.3.1.1 Proximate analysis of egg ingredients

4.3.1.1.1 Moisture content

The AOAC Official Method 925.30 (Lebryk, 1995) vacuum method was used to determine the moisture content of the egg samples. Approximately 5 g of liquid samples (fresh shell egg and frozen egg pulp) and 2 g of dried samples (spray-dried egg powder and egg powder mixture) were weighed in covered tin dishes. These covered dishes were previously dried at $98 - 100^{\circ}\text{C}$ in a force circulated oven (Labcon (Pty) Ltd, Model FSOE), cooled in a desiccator and then weighed after they were cooled to room temperature. The liquid samples were heated in a steam bath without covering the dishes for 1 hr to allow most of the water to evaporate from the sample. Then, all liquid and dried samples were covered and heated in a vacuum oven (VISMARA) for 5 hrs. All the samples were transferred to the desiccator after drying and weighed after they had cooled to room temperature.

% Moisture =

$$\frac{\text{Mass of sample before drying (g)} - \text{Mass of sample after drying (g)}}{\text{Mass of sample before drying (g)}} \times 100$$

4.3.1.1.2 Protein content

A nitrogen analyzer (Leco® FP-528) was used to determine protein content. The instrument was calibrated with five blank samples and EDTA which contained $9.57 \pm 0.04\%$ nitrogen. Approximately 0.25 g of samples was weighed into a tin capsule for liquid samples and tin foil cup for dried samples. Then, the tin capsule or tin foil cup was transferred to the equipment. The results of the samples were indicated on the screen and printed out after a few minutes.

4.3.1.1.3 Fat content

The AOAC Official Method 925.32 (Lebryk, 1995) acid hydrolysis method was used to determine fat content. Approximately 3 g of liquid samples and 1 g of dried samples were weighed into Mojonnier fat-extraction tubes. Ten ml HCl was then added slowly with vigorous shaking. The tube was set in the water bath (BC model BTC-9090), which was heated to 70 °C and brought to boil for 30 min while shaking after every 5 min. Then, the lower bulb of the tube was filled with water, and cooled to room temperature. The sample was extracted by adding 25 ml ether and 25 ml redistilled petroleum ether followed by mixing. The mixture was left to stand until it separated into two separate layers. The upper layer (clear layer) was then drawn off in a beaker (which was dried in a conventional oven, cooled in a desiccator and weighed). The beaker was transferred to a conventional oven at 100°C for 90min for the moisture to evaporate. The beaker was then cooled in the desiccator to room temperature and weighed. The fat content was calculated as follows:

% Fat =

$$\frac{(\text{Mass of sample after drying (g)} - \text{Mass of beaker (g)})}{\text{Mass of sample before drying (g)}} \times 100$$

4.3.1.1.4 Ash content

The AOAC Official Method 945.46 (Lebryk, 1995) was used to determine the ash content of egg samples. Approximately 5 g of liquid sample and 2 g of dried sample were weighed into a silica ashing crucible which had been previously ignited, cooled in a desiccator and weighed. The sample was incinerated in a muffle oven (Gallenkamp) until a light grey ash was obtained, then it was cooled in a desiccator and weighed. The ash content was calculated as follows:

$$\% \text{ Ash} = \frac{\text{Mass of crucible after ashing (g)} - \text{Mass empty crucible (g)}}{\text{Mass of sample before drying (g)}} \times 100$$

4.3.1.2 pH

The pH of egg samples was measured by using the pH electrometer (Mettler DL 25 Titrator). Firstly, the pH meter was calibrated to pH 4 and 7 by dipping the electrode and stirrer in the calibration buffer solutions. Then, the electrode and stirrer was rinsed with distilled water followed by dipping them into the samples. The reading was taken when a stable value appeared.

4.3.1.5 Water-holding capacity (WHC)

4.3.1.3 Foaming overrun

Foams were formed from egg samples at room temperature ($20 \pm 0.5^\circ\text{C}$) by using a Kenwood Chef Excel mixer at speed 3. The whipping period lasted for a total of 15 min with 5 min intervals. The foamed sample was scooped with a spatula and filled into a weighing spoon (60ml). The excess foam was scraped off the weighing

container by using a spatula to level the top of the foam to obtain a constant volume for each measurement (Phillips, German, O'Neill, Foegeding, Harwalkar, Kilara, Lewis, Mangino, Morr, Resentein, Smith & Kinsella, 1990). The foaming overrun (%) was calculated as follows:

$$\% \text{ Overrun} = \frac{(\text{Mass of 60ml egg sample (g)} - \text{Mass of 60ml foam (g)})}{\text{Mass of 60ml foam (g)}} \times 100$$

4.3.1.4 Coagulating temperature

The coagulating temperature of the egg sample was measured using a Rapid Visco Analyzer (RVA) (Newport Scientific (Pty) Ltd, Australia). The temperature was increased by 1°C from 50°C to 85°C at 100rpm in 1 min intervals. Twenty-five grams of egg samples were placed in the RVA aluminum container. Then, a plastic paddle was put into the container and placed on the RVA stage. The paddle was clicked into place to ensure that it turned freely. The RVA stage was pressed down and as the process ran, a graph was plotted.

4.3.1.5 Water-holding capacity (WHC)

The WHC was measured using the high-speed centrifugation method (Barbut, 1996). The egg samples were heated in a water bath (BC model BTC-9090) at 80°C for 40 min in 50 ml polycarbonate centrifuge tubes. The tubes were cooled in ice water immediately after the final temperature was reached followed by centrifuging the tube at 2000 rpm for 30 min with a centrifuge (MSE Super Minor Centrifuge, England,

model 5-80). The coagulated egg samples were measured after careful removal of liquid exudates (Handa *et al.*, 1998). The WHC was calculated as follows:

$$\text{WHC} = \frac{(\text{Mass of raw egg sample (g)} - \text{Mass of coagulated egg sample (g)})}{(\text{Mass of raw egg sample (g)})} \times 100$$

4.3.2 Phase 2 (Baking & analyses of sponge cakes)

4.3.2.1 Reconstitution formula

A reconstitution formula was used to calculate the amount of water (Table 2) that was necessary to be added into the baking formula (Table 3). The moisture content of fresh shell egg was 75.76% (Watkins, 1995). Thus, the reconstitution formula for frozen egg pulp, spray-dried egg powder and egg powder mixture was calculated as follows to obtain the same moisture content as shell egg:

x = the requirement of moisture content equal to fresh egg

$$\frac{x}{\text{Total solid} + x} = 0.76 \text{ (Moisture content of fresh egg)}$$

$$\text{Therefore, } x = \frac{0.76 * \text{Total Solid}}{(1 - 0.76)}$$

However, because there were moisture (y) present in the egg samples already, $x - y$ = water (g) to be added per 100g of egg samples.

The percentages of egg and water were in the sponge cake formula different whereas sugar, emulsifier, cake flour, sodium bicarbonate and milk powder were constant.

Table 2 Calculation of egg % and water % to be added in baking formula

	Fresh shell egg	Frozen egg pulp	Spray-dried egg powder	Egg powder mixture
Moisture (y)	75.76 %	72.63 %	1.86 %	2.89 %
Total Solid	24.24 %	27.37 %	98.14 %	97.11 %
Fresh shell egg moisture * total solid = m		20.74 %	74.35 %	73.57 %
$1 - 0.76 = p$		0.24 %	0.24 %	0.24 %
$m / p = x$		86.41	309.79	306.54
$x - y = \text{water (ml) per 100g of egg sample (z)}$		13.78	307.93	303.65
$z / (z + 100) * 100 = \text{water \% to be added per 100g of egg sample (q)}$		12.11%	75.48%	75.23%
Fresh shell egg ¹ (%) * (100 - q) = egg (%) in baking formula		20.77%	5.79%	5.85%
(Fresh shell egg ¹ (%) * q) + fresh shell egg water ¹ (%) = water (%) in baking formula		14.68%	29.66%	29.60%

¹ Used in baking formula (Table 3)

Table 3 The baking formulas for sponge cakes with fresh shell egg, frozen egg pulp and dried egg powder (Adapted from Bennion & Bamford, 1997)

Ingredients	Fresh shell egg	Frozen egg pulp	Spray-dried egg powder	Egg powder mixture
Egg	23.63%	20.77%	5.79%	5.85%
Water	11.82%	14.68%	29.66%	29.60%
White sugar	32.67%	32.67%	32.67%	32.67%
Emulsifier (GMS)	1.69%	1.69%	1.69%	1.69%
Cake flour	28.20%	28.20%	28.20%	28.20%
Sodium bicarbonate	0.89%	0.89%	0.89%	0.89%
Full cream milk powder	1.09%	1.09%	1.09%	1.09%

4.3.2.2 Baking method

4.3.2.3 Specific volume

The sponge cup cake samples were prepared by the “all-in method” (Figure 8) (Bennion & Bamford, 1997). Water additions were adjusted in the formulations (Table 2) to account for the different moisture contents of the fresh shell egg and other egg samples. During the mixing of ingredients, the frozen egg pulp was warmed up to 40°C (AOAC Official Method, 1995), spray-dried egg powder and egg powder mixture were mixed with sugar and emulsifier, followed by mixing with 45°C distilled water. Two batches of each egg sample were baked which contained seventy-two cup cake size sponge cakes in each batch.

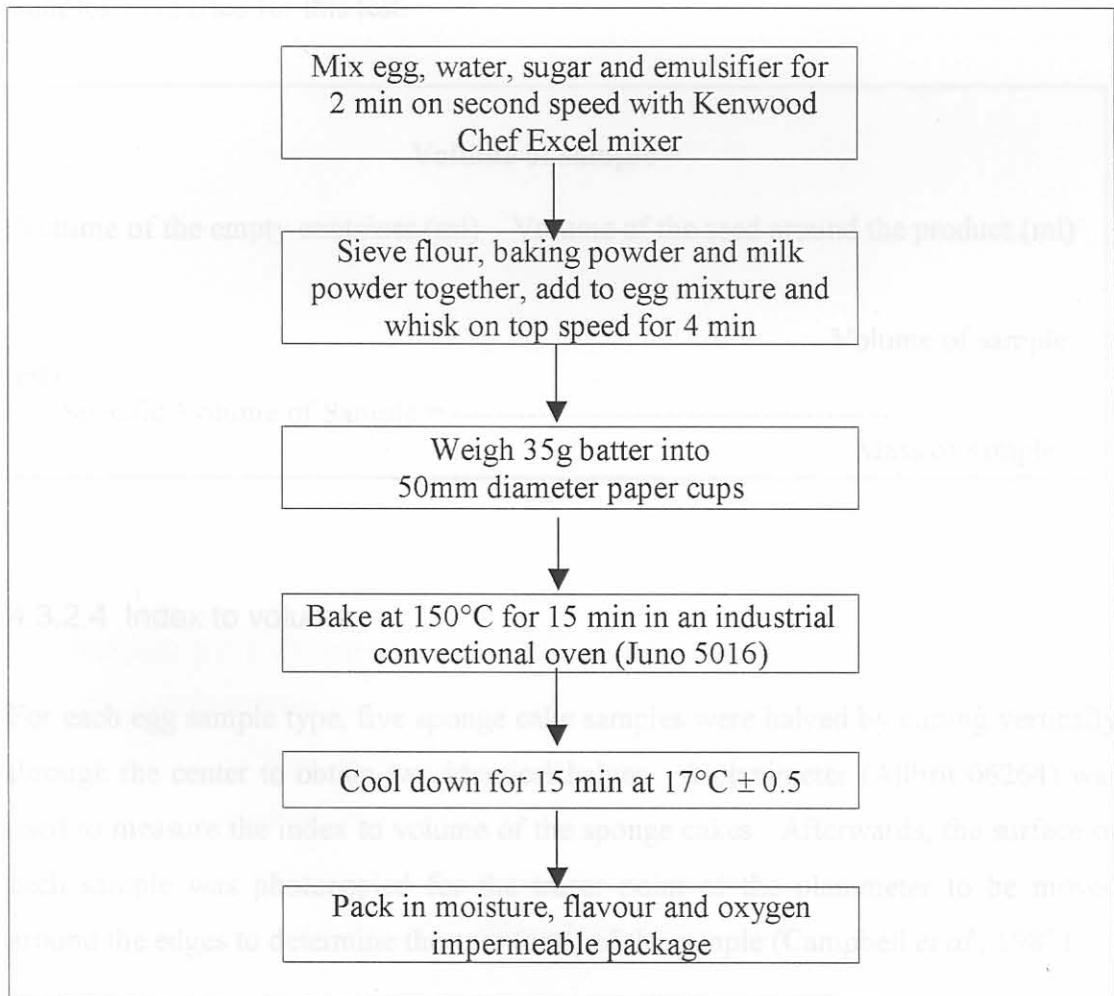


Figure 8 The method used for sponge cake manufacturing (Adapted from Bennion & Bamford, 1997; Abellana et al., 1999)

4.3.2.3 Specific volume

The rapeseed displacement method was used for measuring the specific volume of the sponge cake samples. Rapeseeds were poured into a container until it overflowed. The seed was leveled by passing a ruler across the top of the pot once followed by using a measuring cylinder to measure the volume of seeds. Then, a sample was placed in the empty pot and seeds were poured into the pot until it overflowed. The seeds were leveled by passing a ruler across the top of the pot. The seeds were measured by measuring cylinder once again to obtain the volume of the seed around the product (Campbell, *et al.*, 1987). For each egg sample type, five sponge cake samples were used for this test.

$$\text{Volume of sample} = \frac{(\text{Volume of the empty container (ml)} - \text{Volume of the seed around the product (ml)})}{\text{Volume of sample}}$$

$$\text{Specific Volume of Sample} = \frac{\text{Volume of sample (ml)}}{\text{Mass of sample}}$$

4.3.2.4 Index to volume

For each egg sample type, five sponge cake samples were halved by cutting vertically through the center to obtain two identical halves. A planimeter (Allbrit 06264) was used to measure the index to volume of the sponge cakes. Afterwards, the surface of each sample was photocopied for the tracer point of the planimeter to be moved around the edges to determine the area (cm²) of the sample (Campbell *et al.*, 1987).

4.3.2.5 Water activity

A thermoconstanter (Novasina TH-2) was used to determine the water activity (a_w). The instrument was calibrated at an actual temperature of 25°C with SAL-53, SAL-90 and SAL-11. The setpoint temperature was set in a measuring chamber with a temperature preselector switch. Then, the value for the desired setpoint temperature was adjusted, which can be found in the table “TEMPERATURE/ SET”. A sample bowl was filled with crushed sponge cake and spread evenly. The sample bowl was put into the measuring chamber. After the lid was closed, it was left to equilibrate. The figure was displayed on the machine in terms of % equilibrium relatively humidity.

Equilibrium Relatively Humidity (%)

$$a_w = \frac{\text{-----}}{100}$$

4.3.2.6 Yeast and mould counts

Potato Dextrose Agar was used for yeast & mould counts. The 10⁻¹ dilution was prepared by using 0.1% peptone dilution blank which was autoclaved (A U Tester 437- G) at 121 °C for 15 min before inoculating. Firstly, 10 g of sponge cake sample was weighed and 0.1% peptone water was added to obtain 1:10 dilution. Secondly, the mixture was homogenized in a stomacher (Art Medical Equipment (Pty) Ltd) for 2 min. Then, a sterilized pipette (Gilson) was used to measure 1 ml of diluted sample which was transferred to a sterilized petri dish (Biolab, Diagnostics (Pty) Ltd, Midrand, S.A). Twelve to 15 ml of liquefied agar was poured into each plate. This was followed by mixing the agar and diluted sample together in the petri dish by rotating the plate. The plate was left in place until the agar solidified. Afterwards, the plate was incubated in an incubator (LABex) at 22-25 °C for 5 days (Vanderzant & Splittstoesser, 1992).

4.3.2.7 Texture analysis

The texture of the sponge cake samples was measured by the texture analyzer (TA-XT2®, SMS Stable Micro System). The crust of the sponge cake sample was removed prior to the testing. In addition, the Day 0 samples were analyzed after 1 hour from the packaging time, and Day 4 to Day 24 samples were analyzed within 3min after removing from the storage place. Four replications of each sponge cakes type were determined. The texture area (Figure 9) and settings of the test were as follows:

- Mode: Measure Force in Compression
- Option: Return to start
- Pre-Test Speed: 2.0 mm/s
- Test Speed: 1.0 mm/s
- Post-Test Speed: 10.0 mm/s
- Distance: 10mm
- Accessory: 35 mm cylinder probe
- Sample Preparation: Cut the sponge cake samples into 20mm thickness (Figure 9)

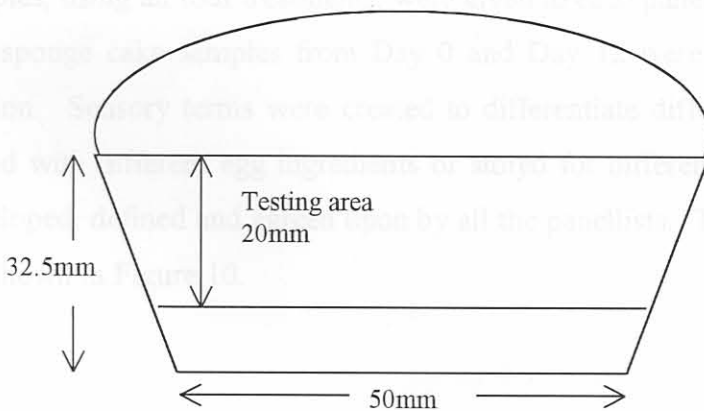


Figure 9 Diagram to show the testing area of samples for texture analysis

Sensory Evaluation of Sponge Cake Definition

APPEARANCE

- *Brownness* - brown colour of crust

4.3.2.8 Sensory Evaluation

4.3.2.8.1 Screening test

Two triangle tests (Lawless & Heymann, 1998) were used for screening 20 panellists to obtain 10 panellists for training. Quarters of a fresh shell egg and egg powder mixture sponge cake samples were used for the first triangle test and 80 ml of 0.025% of 6-n-propyl-2-thiouracil (Sigma, USA) in distilled water solution was used for bitterness sensitivity screening (second triangle test). Randomly selected three-digit numbers were used for labelling all the samples. The panellists who passed both triangle tests were selected for further training.

- *Moistness* - using your finger, press the crumb and feel the moistness

- *Sponginess* - using your thumb and index finger, hold the top and bottom

4.3.2.8.2 Training

Two training sessions of two hours each were held in the Seminar Room (Rm 2-24 of Old Agricultural Building of University of Pretoria). Freshly baked sponge cake samples, using all four treatments, were given to each panellist during the first session and sponge cake samples from Day 0 and Day 12 were served during the second session. Sensory terms were created to differentiate different sponge cake samples baked with different egg ingredients or stored for different days. These terms were developed, defined and agreed upon by all the panellists. The definitions of the terms are shown in Figure 10.

- *Strong after taste* - take a bite of the crust and crumb, chew for 10 sec and determine the intensity of the after taste

Figure 10 The definitions of sponge cake characteristics used for the sensory evaluation

Sensory Evaluation of Sponge Cake Definition

APPEARANCE

- ◆ Brownness – brown colour of crust
- ◆ Yellowness – intensity of bright yellow colour of crumb, low value indicated darker colour but not yellow
- ◆ Have specks - black dots in the crumb

ODOUR (open zip of bag and smell the contents)

- ◆ Egg smell - intensity of egg smell
- ◆ Caramel smell - intensity of caramel smell
- ◆ Baking powder smell - intensity of baking powder smell

TEXTURE

- ◆ Stickiness - using your finger, feel the stickiness of the crust
- ◆ Moistness - using your finger, press the crumb and feel the moistness
- ◆ Sponginess - using your thumb and index finger, hold the top and bottom of the sponge cake and press
- ◆ Rubberiness - chew the crumb for 2-3 seconds to feel the intensity of rubberiness

FLAVOUR

- ◆ Sweetness - take a bite of the crust and crumb, chew and taste the sweetness
- ◆ Egg flavour - take a bite of the crust and crumbs, chew and taste the egg flavour
- ◆ Baking powder flavour - take a bite of the crust and crumbs, chew and taste for any baking powder flavour
- ◆ Strong after taste - take a bite of the crust and crumbs, chew and swallow, wait for 2 sec and determine the intensity of the after taste.

Figure 10 The definitions of sponge cake characteristics used for the sensory evaluation

4.3.2.8.3 Testing period

The generic descriptive test method (Gillette, 1984) was used for evaluating the sensory characteristics of sponge cake samples. All the tests were held in the sensory evaluation laboratory (Rm 2-6 of Old Agricultural Building of University of Pretoria). Ten trained panellists were used. Sponge cakes samples were thawed at room temperature for one hour before tasting. For each panellist, a quarter of sponge cake sample was put into a zip seal plastic bag (80 x 100 mm) which was labeled with a random three-digit number. During each evaluation session, four sponge cake samples (from the same day of storage) which were baked from different egg ingredients, were served on the same tray for each panellist. Drinking water (175ml) was provided for each panellist to rinse his or her mouth before and in between tasting the samples. The evaluation form is shown in Figure 11.

4.4 Statistical analysis of data

One-way analysis of variance (ANOVA) was used to test for the effect of treatment (egg ingredient) on protein content, fat and ash content, pH, coagulating temperature, foaming overrun and water holding capacity. The baking quality (index to volume and specific volume) of sponge cake samples which were baked from various egg ingredients were also compared by ANOVA. Two-way ANOVA was used to test for the effects of treatment and storage time as well as the relevant interaction effects on the sensory properties and texture analysis of the sponge cake samples. When significant differences ($p < 0.05$) were found by ANOVA, the Least Significant Difference test (LSD-test) was used to identify the specific nature of the differences. All analyses were performed using Statistica ® 5.0 and Microsoft Excel 2000 for data capturing.

Figure 11 The sensory evaluation form for sponge cake samples

Name: _____ Date: _____ Set: _____

You have received four samples of sponge cakes. Mark, using a cross, the position of the intensity of the properties, which can either be on the points or between the points on the scale and put the code no. under the cross which you want to indicate

Remember to rinse your mouth with water before and in-between tasting the samples; refresh your breath with coffee bean before and in-between smelling the samples.

Sample no:

Appearance

Brownness _____
not intense very intense

Yellowness _____
not intense very intense

Have speckles _____
not intense very intense

Odour

Eggy smell _____
not intense very intense

Caramel smell _____
not intense very intense

Baking powder smell _____
not intense very intense

Texture

Stickiness (Crust) _____
not intense very intense

Moistness _____
not intense very intense

Rubberiness _____
not intense very intense

Sponginess _____
not intense very intense

Figure 11 The sensory evaluation form for sponge cake samples

CHAPTER 5: RESULTS

5.1 Phase 1

5.1.1 Proximate composition of egg samples

The proximate composition of fresh shell egg, frozen egg pulp, spray-dried egg powder and egg powder mixture samples are shown in Table 4. The ash, protein, fat and carbohydrate contents are expressed on dry matter basis.

The moisture contents of the various egg samples were analyzed to calculate the reconstitution formula (See section 4.3.1) and dry matter basis for all samples. On dry weight basis, the egg powder mixture samples contained more ash than fresh shell egg, frozen egg pulp and spray-dried egg powder samples. There were no significant differences in ash content between fresh shell egg and frozen egg pulp sample on wet basis.

The protein contents differed significantly ($p < 0.05$) among the samples. Fresh shell egg samples contained the most protein and the egg powder mixture contained the least protein on dry basis. Fresh shell egg also contained significantly higher protein content than frozen egg pulp on wet basis.

The fat contents varied significantly ($p < 0.05$) among the samples. The fresh shell egg and spray-dried egg powder contained the most fat whereas the fat content of the egg powder mixture was the least. However, there were no significant differences in fat content between fresh shell egg and frozen egg pulp sample on wet basis.

Fresh shell egg contained the least carbohydrates whereas egg powder mixture contained the most.

Table 4 Proximate compositions ¹ (dry basis) of fresh shell egg, frozen egg pulp, spray-dried egg powder and egg powder mixture samples; Wet basis² of fresh shell egg and frozen egg pulp samples

Sample	Moisture %	Ash %	Protein ³ %	Fat %	Carbohydrate ⁴ %
Fresh Shell Egg	75.76 ^a (±0.66)	3.71 ^a (±0.42) [0.90] ^x (± 0.1)	54.38 ^a (±0.18) [13.80] ^x (± 0.04)	35.67 ^a (±0.19) [8.68] ^x (± 0.04)	6.24 [1.51]
Frozen Egg Pulp	72.63 ^b (±0.01)	3.15 ^a (±0.42) [0.86] ^x (± 0.11)	44.56 ^b (±0.42) [12.20] ^y (± 0.03)	33 ^b (±1.09) [9.03] ^x (± 0.3)	19.29 [5.28]
Spray-dried Egg Powder	1.86 ^c (±0.26)	3.03 ^a (±0.49)	50.68 ^c (±0.03)	35.31 ^a (±1.15)	10.98
Egg Powder Mixture	2.89 ^d (±0.32)	7.21 ^b (±0.49)	36.40 ^d (±0.02)	24.35 ^c (±1.21)	32.04

abcd: Values on dry basis in a column with different letters (abcd) are significantly different (p<0.05)

xy: Values on wet basis in a column with different letters (xy) are significantly different (p<0.05)

¹ Values in brackets () are the standard deviations of the measurements

² Values in brackets [] are on wet basis

³ N x 6.25

⁴ Carbohydrate calculated by difference

5.1.2 pH

Table 5 shows the pH of the various egg samples. The dried egg samples were reconstituted with distilled water (pH 7) before analysis.

Table 5 *pH¹ of fresh shell egg, frozen egg pulp, spray-dried egg powder and egg powder mixture samples*

Sample	pH
Fresh Shell Egg	7.42 ^a (±0.02)
Frozen Egg Pulp	6.48 ^b (±0.02)
Spray-dried Egg Powder	8.11 ^c (±0.01)
Egg Powder Mixture	6.64 ^d (±0.03)

abcd: Values with different letters are significantly different (p<0.05)

¹ Values in brackets are the standard deviations of the measurements

The pH differed significantly for all the samples. Spray-dried egg powder had the highest pH whereas the frozen egg pulp had the lowest pH value.

5.1.3 Foaming Overrun of egg samples

Figure 12 shows the results for foaming overrun of the egg samples which were whipped at room temperature (20 ± 0.5°C). The % foaming overrun of the egg samples differed significantly (p < 0.05). The higher the percentages of foaming overrun, the better the whipping ability. Thus, fresh shell egg samples had the best whipping ability whereas the egg powder mixture samples were the worst.

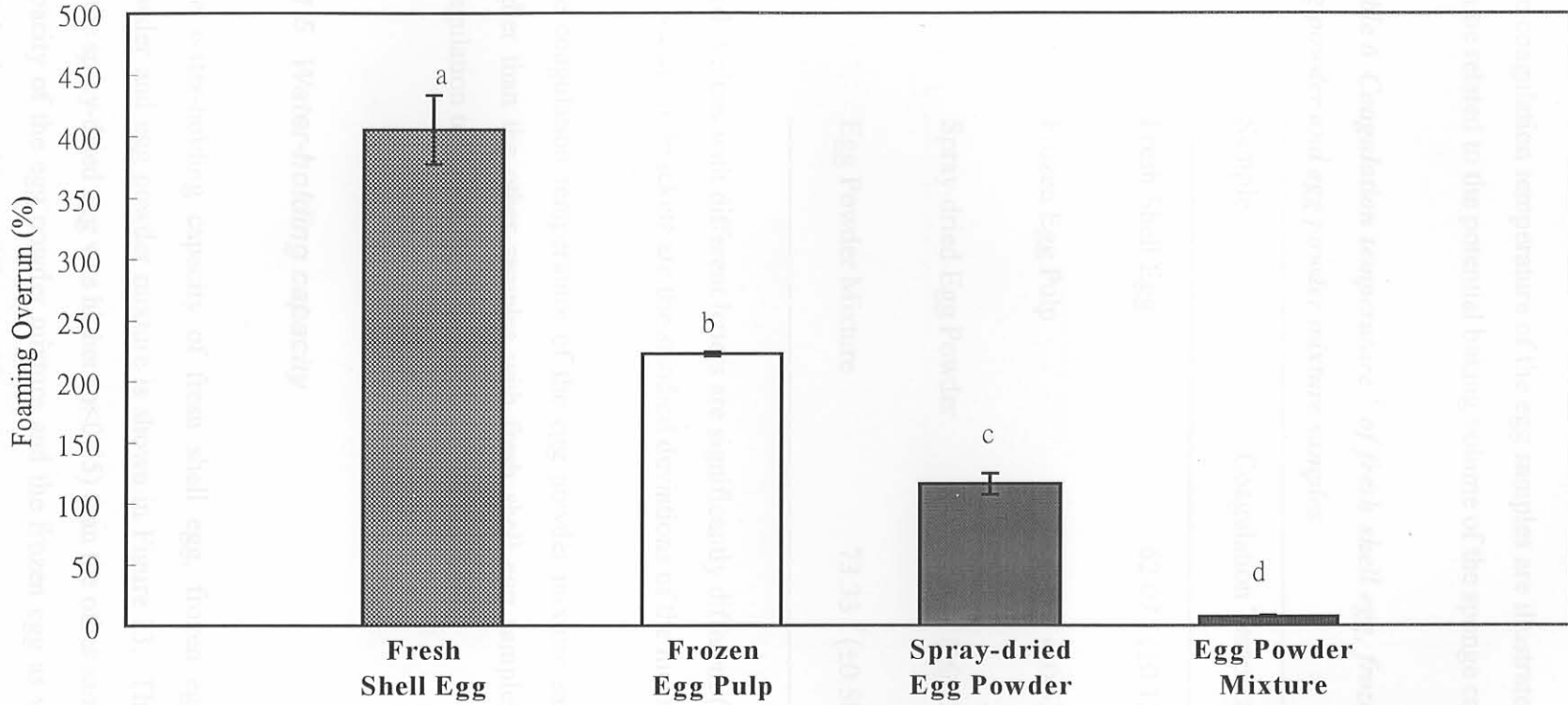


Figure 12 Percentage foaming overrun (\pm standard deviations) of fresh shell egg, frozen egg pulp, spray-dried egg powder and egg powder mixture samples

abcd: Values with different letters are significantly different ($p < 0.05$)

5.1.4 Coagulation temperature

The coagulation temperature of the egg samples are illustrated in Table 6. This result can be related to the potential baking volume of the sponge cakes.

Table 6 Coagulation temperature ¹ of fresh shell egg, frozen egg pulp, spray-dried egg powder and egg powder mixture samples

Sample	Coagulation Temperature (°C)
Fresh Shell Egg	62.07 ^a (±0.12)
Frozen Egg Pulp	68.80 ^b (±0.53)
Spray-dried Egg Powder	67.87 ^c (±0.12)
Egg Powder Mixture	73.33 ^d (±0.58)

abcd: Values with different letters are significantly different (p<0.05)

¹ Values in brackets are the standard deviations of the measurements

The coagulation temperature of the egg powder mixture samples were significantly higher than the other samples with fresh shell egg samples resulting in the lowest coagulation temperature.

5.1.5 Water-holding capacity

The water-holding capacity of fresh shell egg, frozen egg pulp, spray-dried egg powder and egg powder mixture is shown in Figure 13. The water-holding capacity of the spray-dried egg was higher (p<0.05) than the other samples. The water-holding capacity of the egg powder mixture and the frozen egg as well as that of the frozen and fresh egg did not differ significantly.

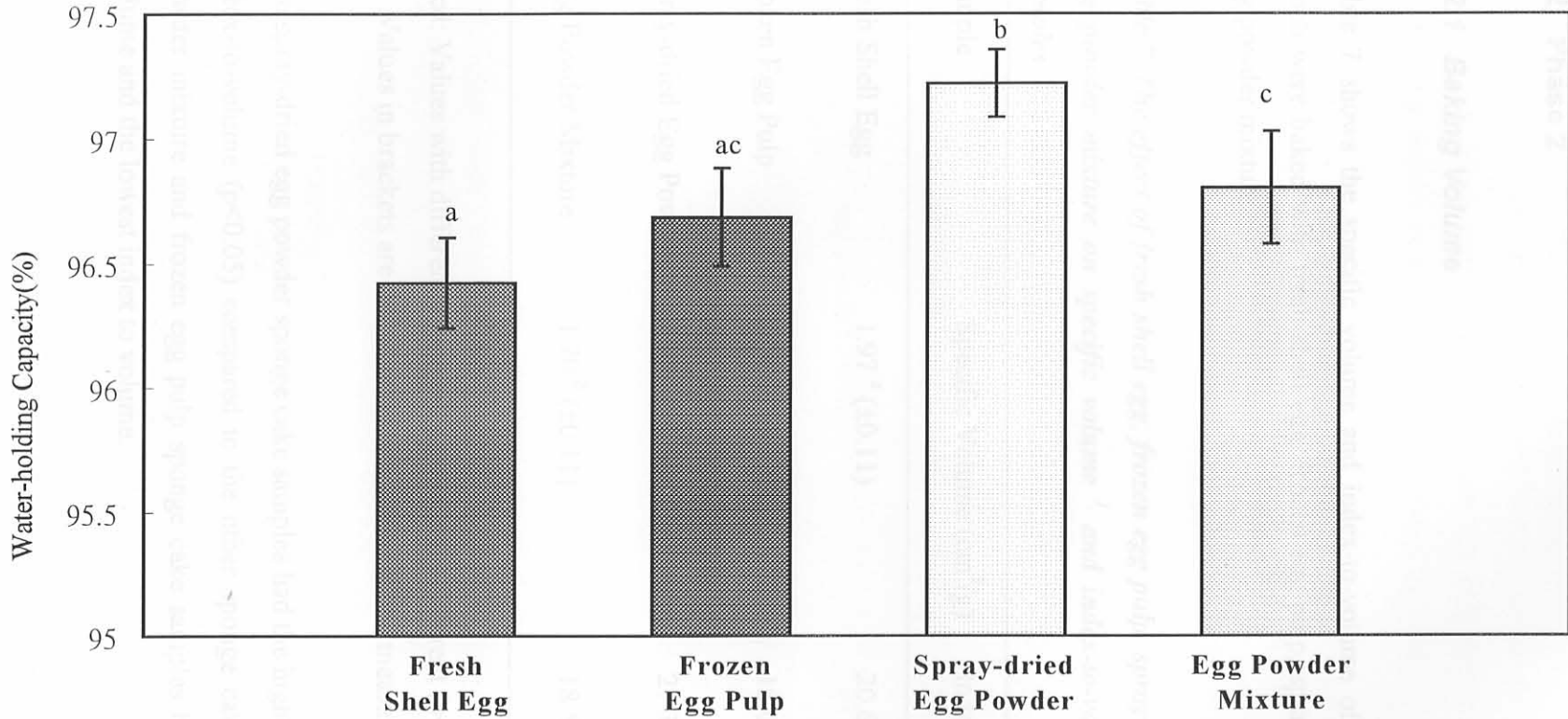


Figure 13 Water-holding capacity (\pm standard deviations) of fresh shell egg, frozen egg pulp, spray-dried egg powder and egg powder mixture samples

abcd: Values with different letters are significantly different ($p < 0.05$)

5.2.2 Water Activity

5.2 Phase 2

5.2.1 Baking Volume

Table 7 shows the specific volume and index-to-volume of sponge cake samples which were baked with fresh shell egg, frozen egg pulp, spray-dried egg powder or egg powder mixture.

Table 7 The effect of fresh shell egg, frozen egg pulp, spray-dried egg powder and egg powder mixture on specific volume ¹ and index-to-volume of sponge cake samples

Sample	Specific Volume (cm ³ /g)	Index to Volume (cm ²)
Fresh Shell Egg	1.97 ^a (±0.11)	20.63 ^a (±0.52)
Frozen Egg Pulp	1.71 ^b (±0.17)	18.00 ^b (±0.53)
Spray-dried Egg Powder	2.12 ^c (±0.11)	21.38 ^c (±0.44)
Egg Powder Mixture	1.70 ^b (±0.11)	18.50 ^b (±0.46)

abcd: Values with different letters are significantly different (p<0.05)

¹ Values in brackets are the standard deviations of the measurements

The spray-dried egg powder sponge cake samples had the highest specific volume and index-to-volume (p<0.05) compared to the other sponge cake samples. The egg powder mixture and frozen egg pulp sponge cake samples had the lowest specific volume and the lowest index to volume.

5.2.2 Water Activity

Water activity of the various sponge cake samples is shown in Table 8. The sponge cake samples which were baked with frozen egg pulp had the highest water activity whereas egg powder mixture had the lowest water activity.

Table 8 The effect of fresh shell egg, frozen egg pulp, spray-dried egg powder and egg powder mixture on water activity of sponge cake samples

Sample	Water Activity
Fresh Shell Egg	0.87
Frozen Egg Pulp	0.88
Spray-dried Egg Powder	0.84
Egg Powder Mixture	0.83

5.2.3 Yeast and mould counts

Table 9 shows the yeast and mould counts of the sponge cake samples which were stored at 21 and 31°C for 12, 16, 21 and 24 days, respectively. Positive yeast and mould counts were found on fresh shell egg and frozen egg pulp sponge cake samples from Day 16 at 31°C in fresh shell egg and frozen egg pulp. Frozen egg pulp sponge cake samples had the highest counts on Day 20 and Day 24 at both storing temperatures. However, the sponge cake samples baked using egg powder mixture had yeast and mould counts only on Day 24 at 21°C. Thus, the egg powder mixture sponge cake samples had the longest shelf-life at 21°C which were between 21 days and 24 days. Yeast and mould counts were found on fresh shell egg and frozen egg pulp sponge cake samples from Day 16 at 31°C. Therefore, the sponge cake samples which were stored for 16 days at 31°C, 20 days at 21°C or 24 days at 31°C were not evaluated by a sensory panel.

Table 9 *Yeast and mould counts (cfu/g) of fresh shell egg, frozen egg pulp, spray-dried egg powder and egg powder mixture sponge cake samples*

Sponge cake sample	°C	Day 12	Day 16	Day 20	Day 24
Fresh Shell Egg	21	ND	ND	10	700
	31	ND	10	>1000	>1000
Frozen Egg Pulp	21	ND	ND	60	>1000
	31	ND	10	>1000	>1000
Spray-dried Egg Powder	21	ND	ND	55	210
	31	ND	ND	130	600
Egg Powder Mixture	21	ND	ND	ND	20
	31	ND	ND	20	440

ND = Not detected at levels <10 cfu/g

5.2.4 Texture analysis

Figure 14 shows the texture measurements of fresh shell egg, frozen egg pulp, spray-dried egg powder and egg powder mixture sponge cake samples from Day 0 to Day 24. Temperature of storage (i.e. 21°C and 31°C) did not have a significant effect on the texture measurements of the sponge cakes. The results of 21°C and 31°C storage temperature are therefore combined.

The crumb softness as evaluated by the texture analyser with compression force differed significantly ($p < 0.05$) among the storage days for all egg samples. In general, the crumb texture of spray-dried egg powder sponge cake samples was the softest, followed by fresh shell egg, frozen egg pulp and egg powder mixture. For fresh shell egg, spray-dried egg powder and egg powder mixture sponge cake samples, a softening of the crumb texture was noticed on Day 4.

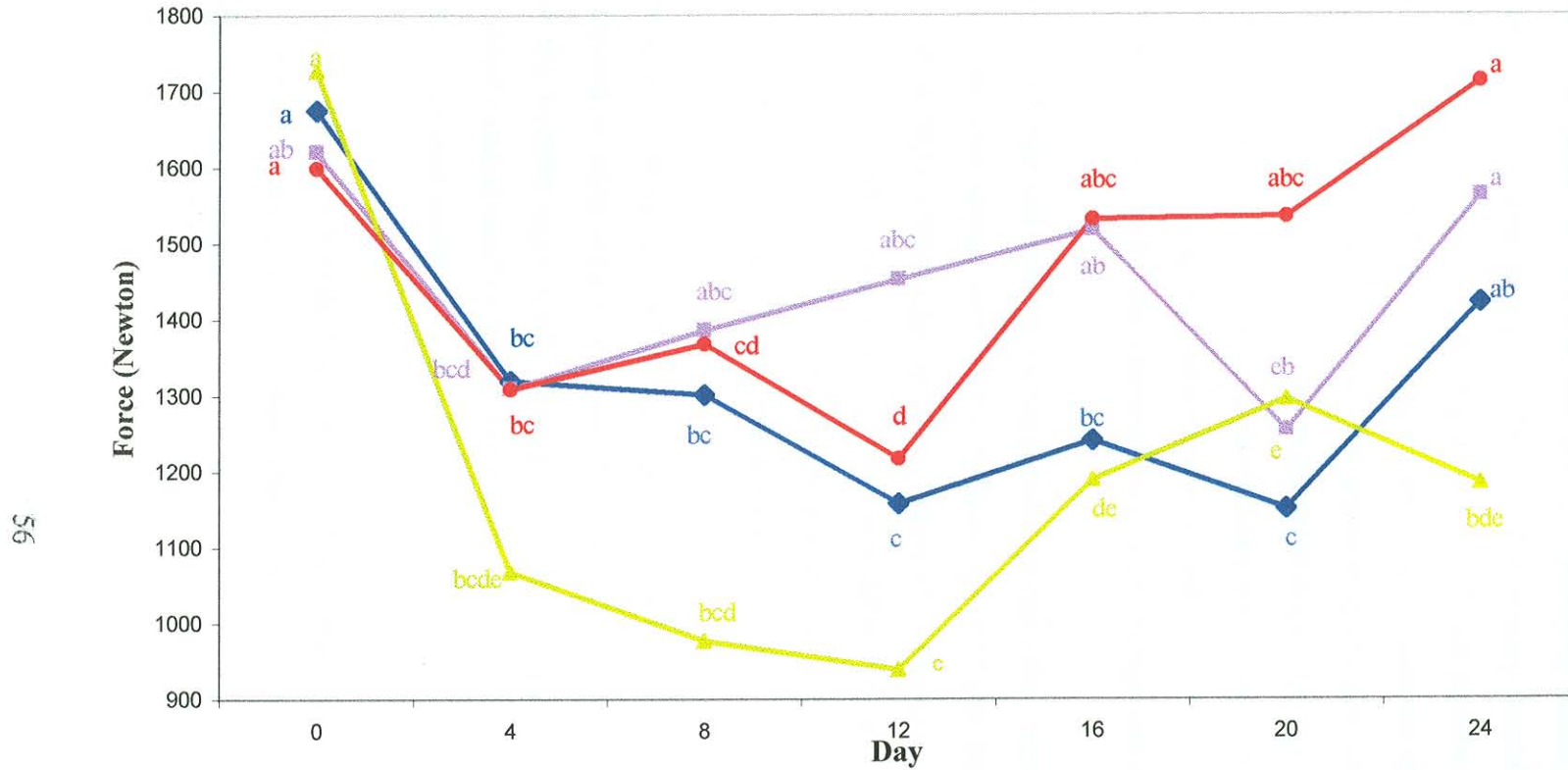


Figure 14 Texture analysis of fresh shell egg (♦), frozen egg pulp (■), spray-dried egg powder (▲) and egg powder mixture (●) sponge cake samples stored from Day 0 to Day 24

abcde: Values for each treatment with different letters are significantly different ($p < 0.05$)

5.2.5 Sensory Analysis

The factors, temperature (i.e. 21°C and 31°C) and period (from Day 0 to Day 16) of storage, respectively, did not differ significantly in sensory characteristics of the sponge cake samples, except “rubbery”. The sensory properties of fresh shell egg, frozen egg pulp, spray-dried egg powder and egg powder mixture sponge cake samples which were assessed by a trained sensory panel are shown in Figures 15, 16, 17, 18 and 19. Figure 15 shows the appearance characteristics of the sponge cake samples. Figure 16 shows the aroma characteristics of the sponge cake samples. The texture characteristics of sponge cake samples are shown in Figure 17. The changes in rubbery texture of sponge cake samples stored over 16 days are shown in Figure 18. Figure 19 shows the flavour characteristics of the sponge cake samples.

Fresh shell egg and spray-dried egg powder sponge cake samples had the least brown crust and least specks which were different ($p < 0.05$) to frozen egg pulp and egg powder mixture sponge cake samples (Figure 15). However, fresh shell egg sponge cake samples had a more yellow crumb which differed significantly ($p < 0.05$) from all the other samples. Egg powder mixture sponge cake samples had the brownest crust, most specks and the least yellow crumb colour ($p < 0.05$).

The spray-dried egg powder sponge cake samples had a stronger eggy smell ($p < 0.05$) compared to other samples (Figure 16). Egg powder mixture sponge cake samples had the weakest eggy smell. Egg powder mixture sponge cake samples had the strongest caramel smell ($p < 0.05$). Fresh shell egg and spray-dried egg powder had the weakest caramel smell.

Fresh shell egg, frozen egg pulp and spray-dried egg powder sponge cake samples had the strongest baking powder smell whereas the egg powder mixture sponge cake samples had the weakest.

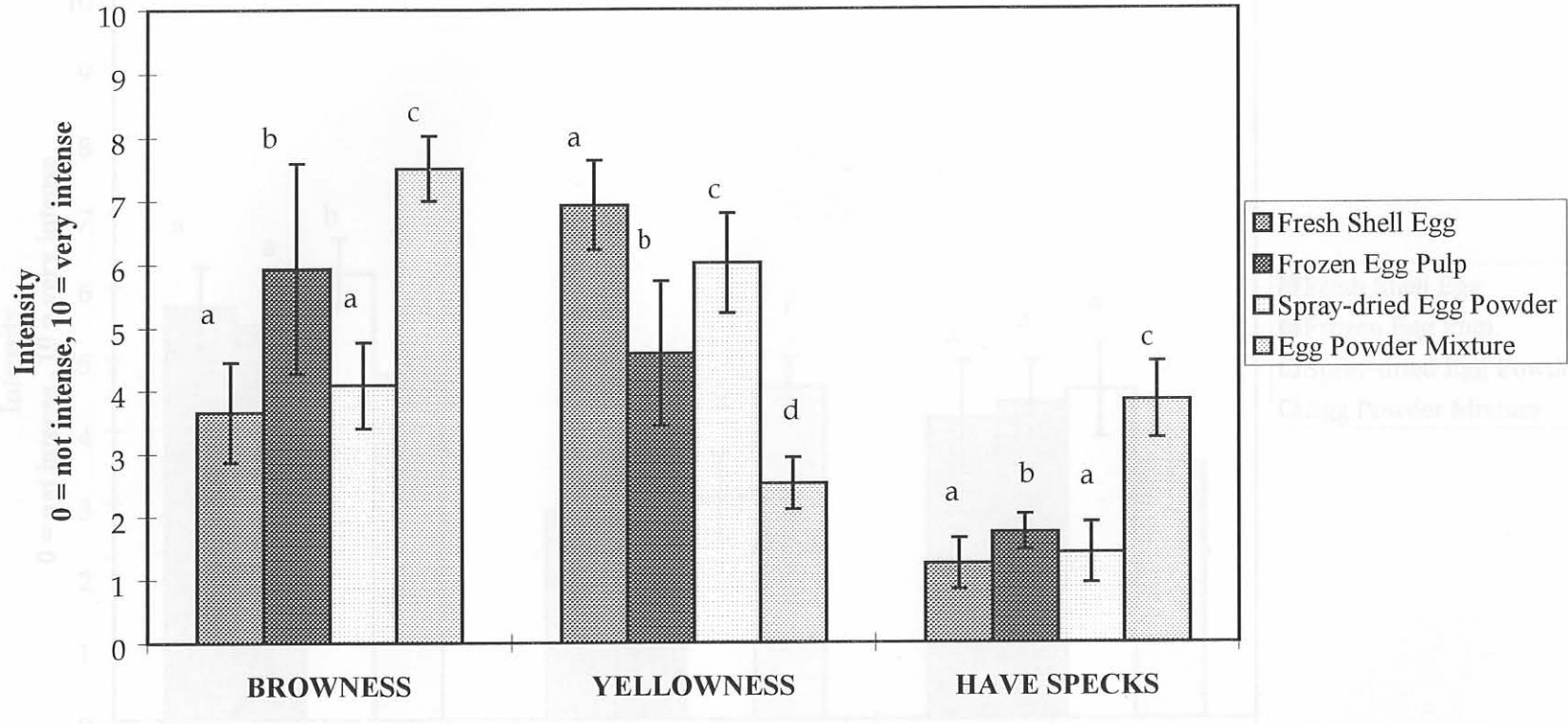


Figure 15 Average ratings (\pm standard deviations) of appearance characteristics of fresh shell egg, frozen egg pulp, spray-dried egg powder and egg powder mixture sponge cake samples as assessed by a trained sensory panel

abcd: Values for a sensory characteristic with different letters are significantly different ($p < 0.05$)

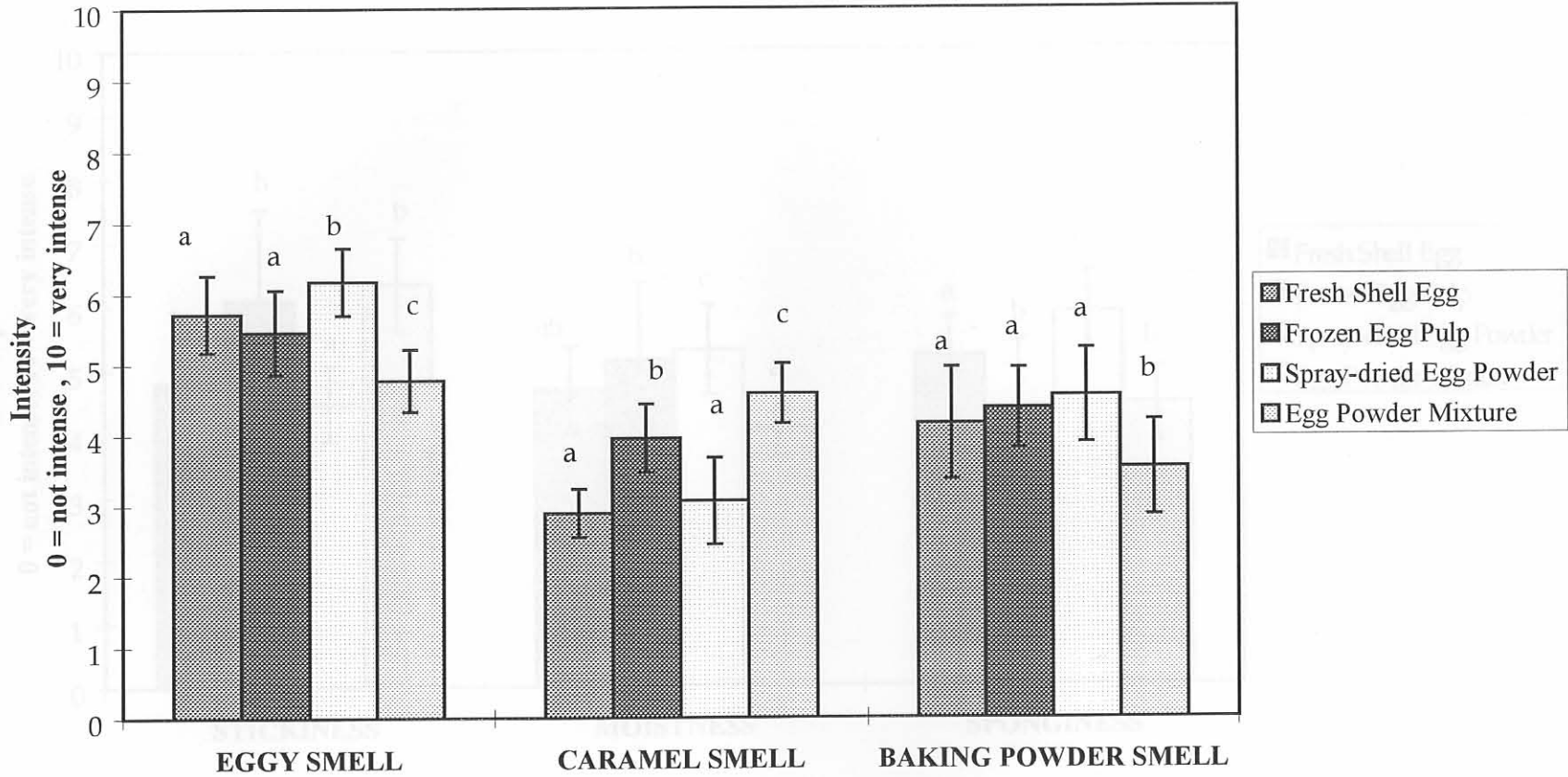


Figure 16 Average ratings (\pm standard deviations) of aroma characteristics of fresh shell egg, frozen egg pulp, spray-dried egg powder and egg powder mixture sponge cake samples as assessed by a trained sensory panel

abcd: Values for a sensory characteristic with different letters are significantly different ($p < 0.05$)

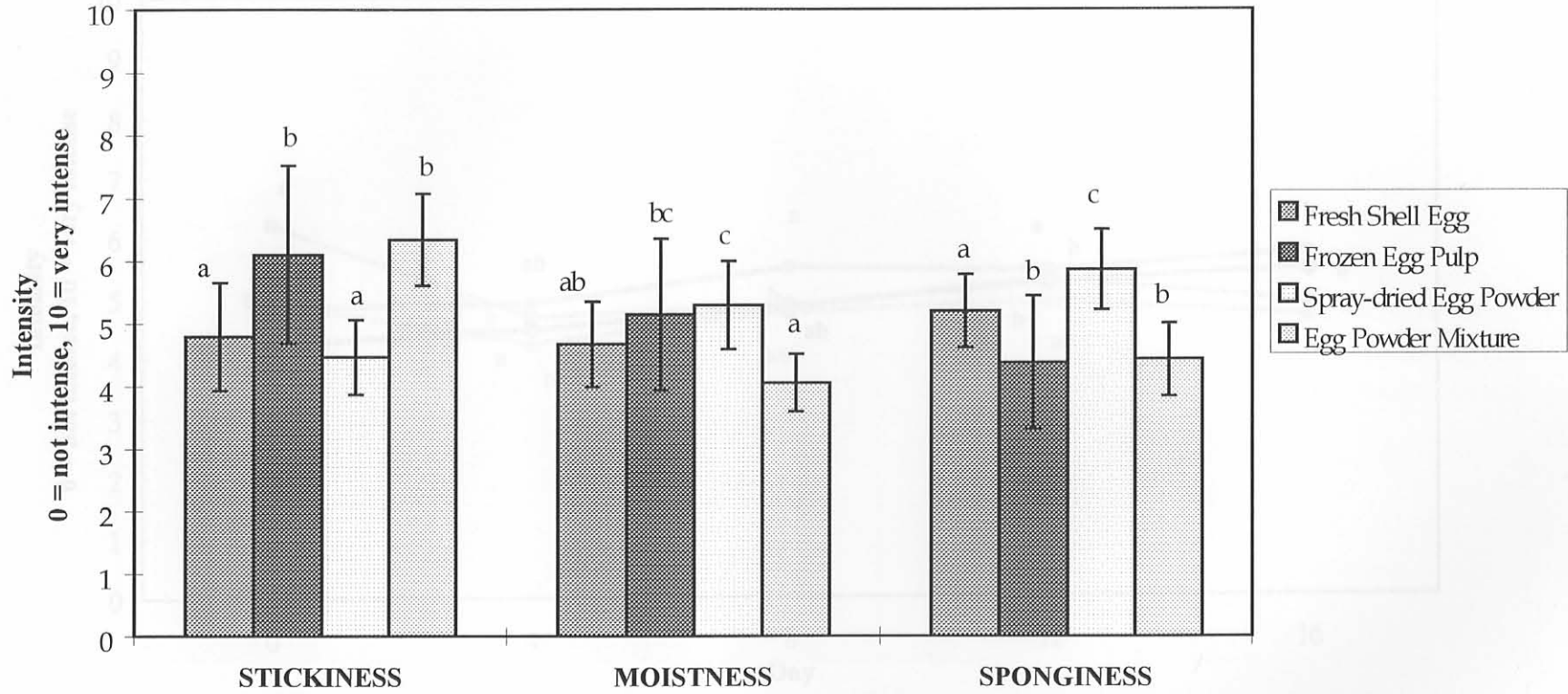


Figure 17 Average ratings (\pm standard deviations) of texture characteristics of fresh shell egg, frozen egg pulp, spray-dried egg powder and egg powder mixture sponge cake samples as assessed by a trained sensory panel

abcd: Values for a sensory characteristic with different letters are significantly different ($p < 0.05$)

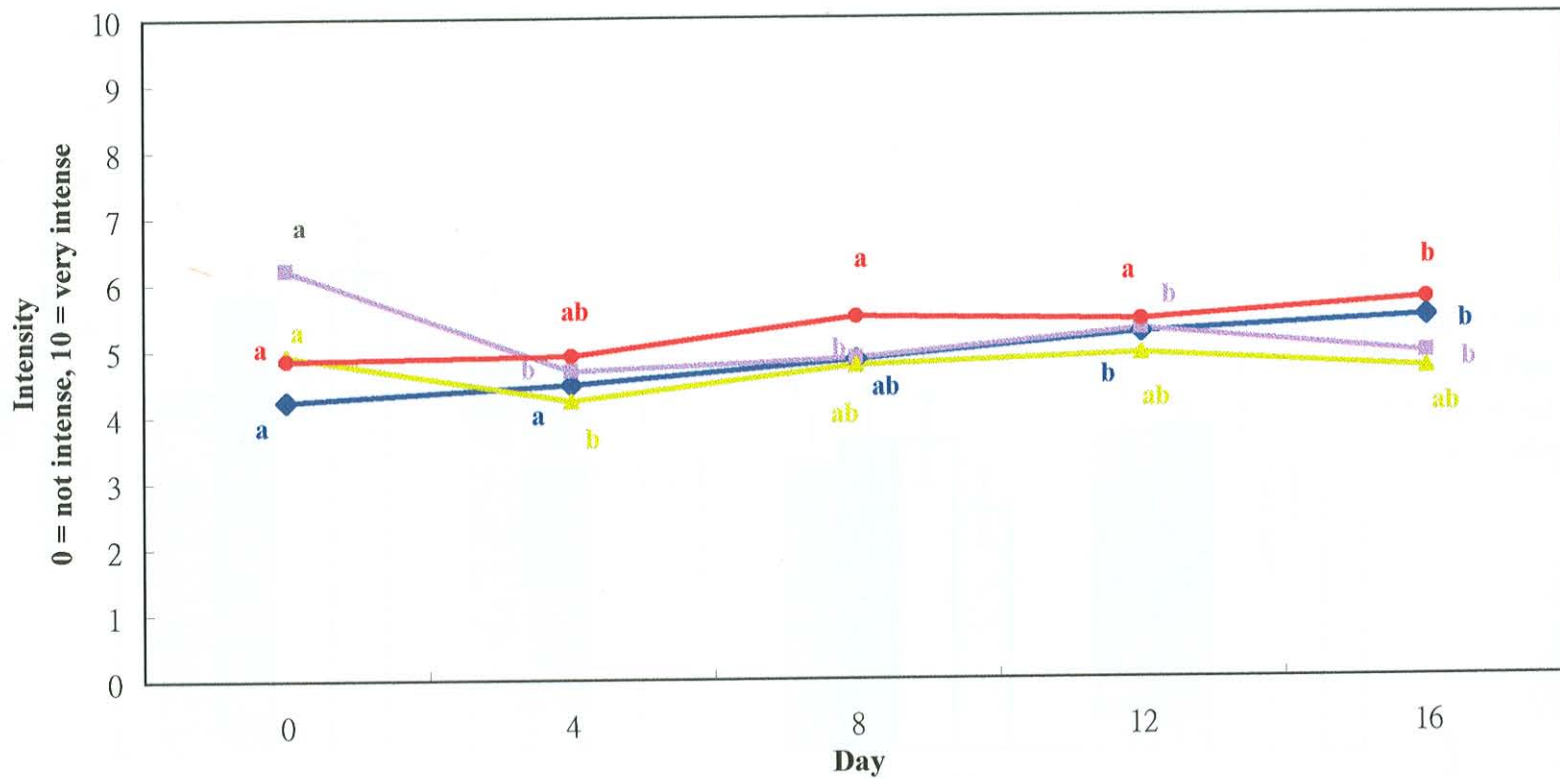


Figure 18 Average ratings of rubberiness for fresh shell egg (♦), frozen egg pulp (■), spray-dried egg powder (▲) and egg powder mixture (●) sponge cake samples as assessed by a trained sensory panel

abcd: Values for a specific treatment with different letters are significantly different ($p < 0.05$)

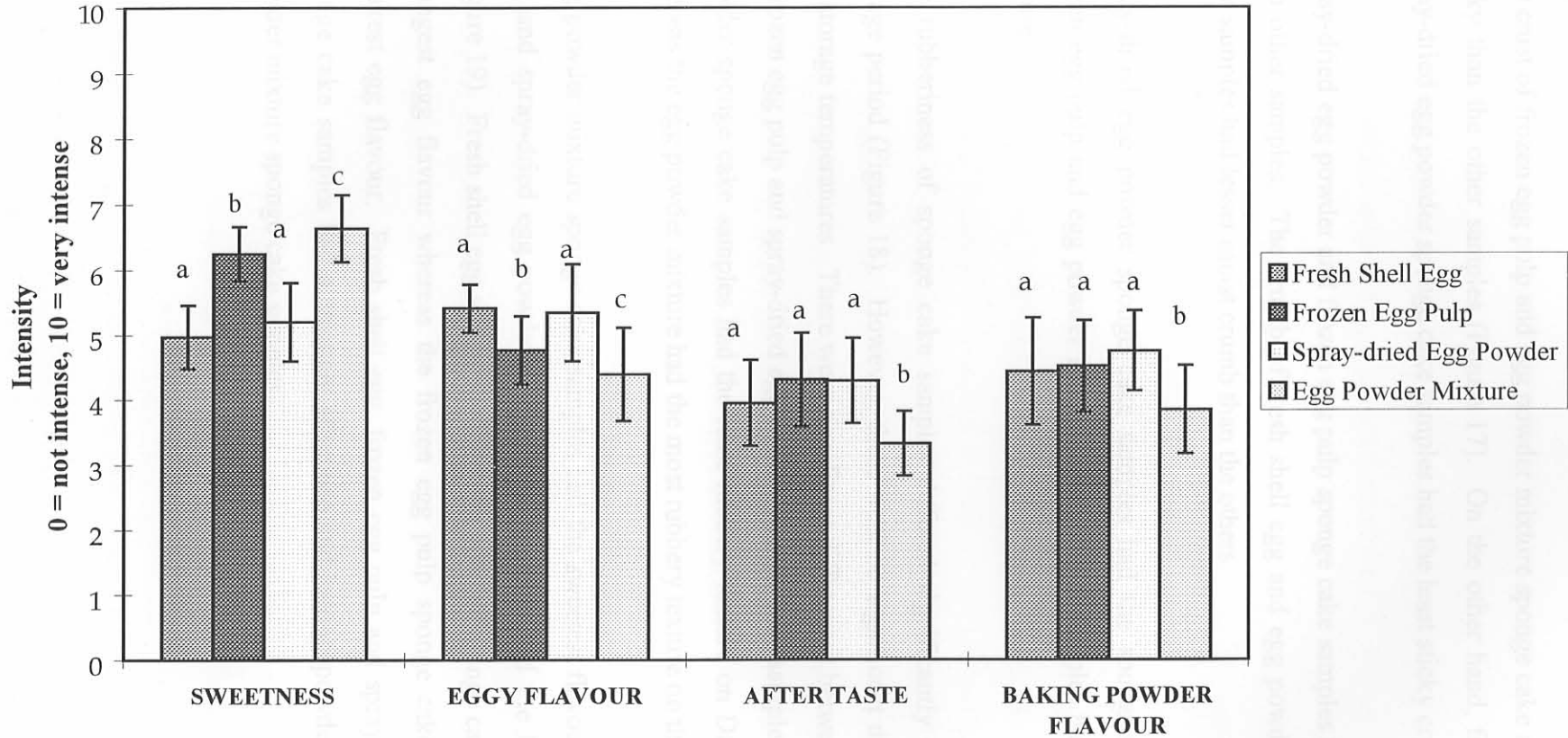


Figure 19 Average ratings (\pm standard deviations) of flavour characteristics of fresh shell egg, frozen egg pulp, spray-dried egg powder and egg powder mixture sponge cake samples as assessed by a trained sensory panel

abcd: Values for a sensory characteristic with different letters are significantly different ($p < 0.05$)

The crust of frozen egg pulp and egg powder mixture sponge cake samples were more sticky than the other samples (Figure 17). On the other hand, fresh shell egg and spray-dried egg powder sponge cake samples had the least sticky crust.

Spray-dried egg powder and frozen egg pulp sponge cake samples had moister crumb than other samples. The crumb of fresh shell egg and egg powder mixture sponge cake samples had lesser moist crumb than the others.

Spray-dried egg powder sponge cake samples had the spongiest texture whereas frozen egg pulp and egg powder mixture sponge cake samples had the least spongy texture.

The rubberiness of sponge cake samples differed significantly ($p < 0.05$) over the storage period (Figure 18). However, there were no significant differences between the storage temperatures. There were significant differences between Day 0 to Day 4 in frozen egg pulp and spray-dried egg powder sponge cake samples. Spray-dried egg powder sponge cake samples had the least rubbery texture on Day 4, 8, 12 and 16 whereas the egg powder mixture had the most rubbery texture on these days.

Egg powder mixture sponge cake samples had the sweetest flavour while fresh shell egg and spray-dried egg powder sponge cake samples had the least sweet flavour (Figure 19). Fresh shell egg and spray-dried egg powder sponge cake samples had the strongest egg flavour whereas the frozen egg pulp sponge cake samples had the weakest egg flavour. Fresh shell egg, frozen egg pulp and spray-dried egg powder sponge cake samples had a stronger aftertaste and baking powder flavour than egg powder mixture sponge cake samples.

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.

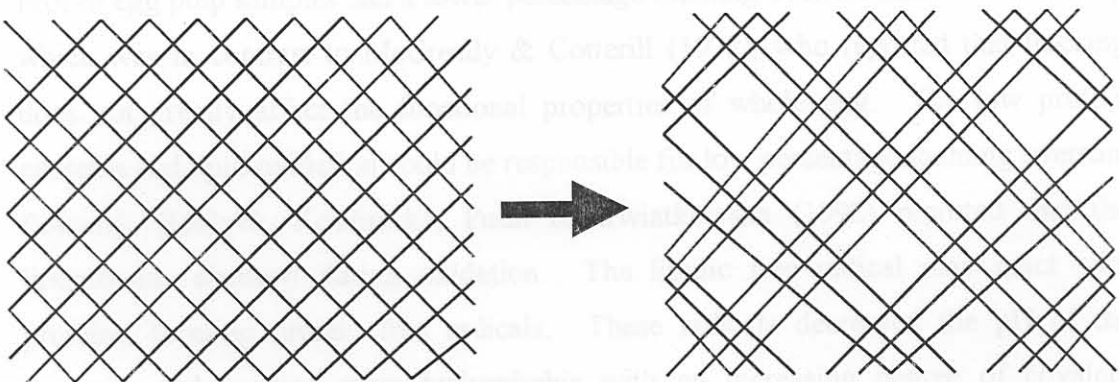


Figure 20 Schematic illustration of a change in gel structure due to local aggregation phenomena (Hermansson, 1982)

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.

The baking performance of the egg powder samples According to the baking

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.

CHAPTER 7: CONCLUSIONS & RECOMMENDATIONS

Sponge cake quality is effected by whether fresh, frozen or dehydrated forms of egg were used. In general, spray-dried egg powder performs better compared to other egg forms.

The proximate composition, pH, foaming overrun and coagulation temperature of egg affect the baking performance of sponge cakes. Frozen egg pulp and the egg powder mixture sponge cake samples have low baking volume due to their low protein content leading to low foaming overrun and higher coagulation temperature. Although it had low foaming overrun, the high baking volume of spray-dried egg powder sponge cake samples is due to an emulsifier added in the sponge cakes batter.

The hypothesis that the shelf-life of sponge cakes baked with different forms of egg will differ, is confirmed by this study. The water activity of the cakes and the temperature of storage play the largest role. The water activity of the cakes is not directly related to the water-holding capacity of the egg samples.

All the samples soften after baking over a period of 4 days due to the action of the emulsifier. The hardening of sponge cake samples is not a linear increase over the storage period. Fresh shell egg sponge cake samples harden after 24 days of storage whereas spray-dried egg powder and egg powder mixture sponge cake samples had noticeable hardening of texture after 12 days of storage.

The sensory attributes of sponge cake were directly influenced by the functional properties of egg samples. In this research, pH played a major role on the functional properties while the protein and fat contents of fresh shell egg, frozen egg pulp and spray-dried egg powder samples do not contribute major differences. Water-holding capacity is also affected by pH; the higher the pH, the more the water binding due to

the gel structure formed and high gel strength. The ingredients of the egg powder mixture samples also affect the functional properties and sensory properties of the batter and sponge cake samples, respectively, especially the inclusion of skim milk powder, Nutrifat and black pepper.

The hypothesis that the sensory properties of sponge cake samples are affected by different forms of egg products is partly accepted. Spray-dried egg powder sponge cakes do not show more compact texture, but paler colour was found on its crumb than fresh shell egg sponge cake samples.

The frozen egg pulp sample that was supplied is not performing similarly to fresh shell egg due to the poor and inconsistent quality. This however, is not a true reflection of the potential of freezing technology. The quality of frozen egg pulp sample varied from different batches. This can be improved by more efficient freezing method and addition of other substances such as sugar or salts. In addition, the total solid contents of frozen egg pulp is also important.

The egg powder mixture that was supplied is not suitable for sponge cake baking. However, spray-dried egg powder with emulsifier added replace beautifully in sponge cake baking. Hence, spray-dried egg powder with emulsifier can replace liquid whole egg in sponge cake baking. Adaptation of the formulation of the egg powder mixture is therefore recommended.

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