
UNIVERSITI PUTRA MALAYSIA

# INTERFACIAL AND RHEOLOGICAL PROPERTIES OF OIL-IN-WATER EMULSIONS AS AFFECTED BY EGG YOLK FROM DIFFERENT SOURCES

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**MASTER OF SCIENCE**
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**WAN ZUNAIRAH WAN IBADULLAH**

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Master of Science**

**July 2008**

**To my husband and family……..**

Abstract of the thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the Degree of Master of Science

**INTERFACIAL AND RHEOLOGICAL PROPERTIES OF OIL-IN-WATER EMULSIONS AS AFFECTED BY EGG YOLK FROM DIFFERENT SOURCES**

By

**WAN ZUNAIRAH BINTI WAN IBADULLAH**

**July 2008**

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Hen egg yolk is an essential ingredient for the preparation of a large variety food emulsions, such as mayonnaises, salad dressings and creams. The preparation and long-term stability of this kind of food are influenced by the solution pH. However, the emulsifying properties of duck and goose egg yolk remain unknown as they have not been clearly documented. In this study, the emulsion properties (droplet size, solubility, and viscosity), interface attributes (interfacial protein concentration, percentage of adsorbed proteins, SDS-Page profiles of adsorbed proteins and interfacial tension) and rheological properties (thixotropic behavior) of oil-in-water emulsions prepared with hen, duck and goose egg yolks were examined. These features were observed at three different pHs (3, 6 and 9). Results showed that pH 6 provided the best conditions for preparing emulsion using the three types of egg yolks. The droplet size of goose egg yolk emulsions at pH 6 was the smallest than

other types of egg yolk at all pH levels. The protein solubility was lower at pH 6 for all types of egg yolk emulsions. The viscosities of hen, duck and goose egg yolk emulsions at pH 6 were higher than those at pH 3 and 9. In the pH range studied, the interface attributes were better at pH 6 for all types of egg yolks. The interfacial protein concentration was higher at pH 6 for the three types of yolks (1.70 mg $m^{-2}$, 1.74 mg $m^{-2}$ and 1.98 mg $m^{-2}$, respectively) than at pH 3 and pH 9. At pH 6, most of the proteins from the three yolks were adsorbed at the interface and the interfacial tension at steady-state was lower (10 mN $m^{-1}$, 13.98 mN $m^{-1}$ and, 8.37 mN $m^{-1}$ respectively) than at pH 3 or pH 9. At pH 3, proteins at the interface were mainly phosvitin, and at pH 9, some apoproteins of HDL and LDL were detected. The pH modulates the composition of yolk proteins at the interface, mainly by modifying the net charge of the proteins causing their repulsion or dimerization.

The micrographic observation showed that the oil droplets were more uniform at pH 6 than those at pH 3 and 9 for all types of egg yolk emulsions. At pH 6, all of the egg yolk emulsions exhibited thixotropic shear thinning behavior under steady shear test. Emulsions produced at pH 3 and 9 exhibited closely the Newtonian behavior. These results suggested that hen, duck and goose egg yolk are able to provide stabilizing effects at pH 6. This study shows a good potential for goose and duck egg yolk to be used as an alternative emulsifying agent in the food industry.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains.

**SIFAT ANTARA MUKA DAN REOLOGIKAL BAGI EMULSI MINYAK DALAM AIR KE ATAS PENGARUH KUNING TELUR DARIPADA PELBAGAI SUMBER**

Oleh

**WAN ZUNAIRAH BINTI WAN IBADULLAH**

**Julai 2008**

**Pengerusi: Prof. Dr. Nazamid Saari**

**Fakulti: Sains dan Teknologi Makanan**

Kuning telur adalah bahan ramuan yang penting dalam penyediaan pelbagai jenis makanan sebagai contohnya mayonis, salad dressing dan krim. Cara penyediaan dan kestabilan untuk kumpulam makanan ini adalah dipengaruhi oleh larutan pH. Walaubagaimanapun, kuning telur itik dan angsa sangat jarang diguna disebabkan kekurangan pencarian data. Di dalam kajian ini, cirri-ciri emulsi (saiz partikel, kelterlarutan dan kepekatan), sifat antara permukaan (kepekatan protein antara permukaan, prfil SDS-PAGE bagi protein yang dijerap dan ketegangan permukaan) dan sifat reologikan (sifat thixotropik) di dalam minyak dalam air telah diselidik dengan menggunakan kuning telur ayam, itik dan angsa pada keadaan pH berbeza iaitu pH 3, 6 dan 9. Keputusan menunjukan pada pH 6 adalah keadaan yang paling baik untuk menyediakan emulsi ketiga-tiga jenis kuning telur ini. Saiz partikel untuk emulsi telur angsa adalah paling kecil berbanding semua emulsi lain. Manakala,

protein terlarut adalah yang paling rendah pada pH 6 untuk semua jenis emulsi. Kepekatan protein antara permukaan adalah paling tinggi pada pH 6 berbanding pH 3 dan 9. Kepekatan protein antara permukaan adalah lebih tinggi pada pH 6 untuk kesemua jenis telur dengan nilai masing-masing 1.70 mg $m^{-2}$, 1.74 mg $m^{-2}$ dan 1.98 mg $m^{-2}$ berbanding dengan pH 3 dan pH 9. Pada pH 6, hampir keseluruhan protein daripada kesemua jenis kuning telur menjerap antara muka dan tegangan antara permukaan pada hubungan kadar ricih adalah rendah pada nilai masing-masing (10 mN $m^{-1}$, 13.98 mN $m^{-1}$, dan 8.37 mN $m^{-1}$) daripada pH 3 dan pH 9. pH 3, protein di antara muka kebanyakannya daripada phosvitin, dan pH 9 sebahagiannya daripada HDL and LDL apoprotein telah dikesan. pH mengubahsuaikan kandungan protein kuning telur pada antara permukaan, terutama dalam mengubah suai caj bersih protein dan menyebabkan penolakan atau dimerization.

Penentuan mikrografik menunjukkan titisan minyak adalah lebih sekata pada pH 6 untuk semua jenis emulsi kuning telur berbanding pH 3dan 9. Emulsi pada pH 6 menunjukkan sifat thixotropik-penipisan ricih apabila diukur ke atas tegasan ricih-kadar ricih. Emulsi pada pH 3 dan 9 bersifat ke arah Newtonian. Kuning telur angsa telah menunjukkan sifat emulsi yang paling baik berbanding kuning telur lain.. Kajian ini juga menunjukkan kuning telur itik dan angsa boleh digunakan sebagai bahan alternatif dalam industri pembuatan makanan.

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## DECLARATION

I hereby declare that the thesis is based on my original work except for quotation and citations, which have been duly acknowledge. I also declare that is has not been previously or concurrently submitted for any other degree at UPM or other institutions.

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**WAN ZUNAIRAH BINTI WAN IBADULLAH**

Date:

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| | |
|---|---|
| **HDL** | High-density lipoprotein |
| **LDL** | Low-density lipoprotein |
| **SDS-PAGE** | Sodium dodecyl sulfate polyacrylamide gel electrophoresis |
| **o/w** | Oil/water |
| **a/w** | Air/water |
| **Apo-LDL** | Apo-low density lipoprotein |
| **PVT** | Phosvitin |
| **Asp** | Aspartic acid |
| **Glu** | Glutamine |
| **Lys** | Lysine |
| **Arg** | Arginine |
| **His** | Histidine |
| **pI** | Isoelectric point |
| **min** | Minute |

# CHAPTER 1

## INTRODUCTION

Egg constitutes a highly complex food system, both in terms of its composition and physicochemical structure. The main constituents of egg are lipids and proteins of exceptionally high biological value which also exhibit remarkable functional properties. As a result of this, whole egg or its fractions, the yolk and the white, are extensively used as functional ingredients in a variety of food such as salad dressings, cakes, omelette, sauces, pie filling, confectionery, meat products, etc., where they play important roles in product preparation as well as in improving its physicochemical stability (Kiosseoglou, 2003a; Kiosseoglou, 2003b; Kiosseoglou, 1989); Mine, 2002; Powrie & Nakai, 1984). Although eggs contain about 74% water, they are a rich source of high-quality protein and an important source of unsaturated fatty acids, iron, phosphorus, trace minerals and vitamins A, E, K and B (Watkins, 1995). Eggs provide a unique, well-balanced source of nutrients for individuals of all ages. Other important properties of eggs are the 'functional properties,' which refer to the attributes of egg constituents, which make them useful ingredients in food such as noodles, mayonnaise, cakes and formulated meat products and confectionary (Mine and Keeturai, 2000). The usefulness of egg materials, as food ingredients, is evident by several food products that contain eggs, either fresh, frozen or as dried powders derived from eggs. In order to improve egg-processing procedures, the properties of egg material must be better understood so that the quality of resulting products can be

improved. Emulsification is a major function of the egg yolk component in the manufacture of mayonnaise and one of several functions in bakery items (Mine and Keeturai, 2000).

Hen egg yolk, which is a complex mixture of different micro particles held in suspension, is an important emulsifying ingredient in the manufacture of mayonnaise, salad dressing and cakes. The solid content of yolk is about 50%. In particular, protein and lipids are the major constituents of yolk, accounting for about 15.7-16.6% and 32-35%, respectively (Powrie and Nakai, 1985). The yolk fraction contains approximately 66% triglycerol, 28% phospholipids, 5% cholesterol and minor amounts of other lipids. Egg yolk is homogeneously emulsified fluid (Juneja, 1996). When diluted with water or saline, it can be separated by centrifugation into plasma (the supernatant) and granule (the precipitate). The granule consists mainly of high-density lipoprotein (HDL) and phosvitin. The major component of plasma is low-density lipoprotein (LDL), accounting for 65% of the total egg yolk protein and livetin, which accounts for 30% of the plasma protein. The livetin fraction consists of α- and β-lipovitellins and exists as a complex mixture with phosvitin (Li-Chan *et al.*, 1995). Phosvitin is a phosphoprotein containing about 10% phosphorus. About 80% of the phosphorus in yolk exists in phosvitin. It has been shown that LDL comprises of 7 major polypeptides, ranging from 19-225 kDa and some minor polypeptides by SDS-PAGE analysis (Mine, 1998a).

Egg yolk is notable for its emulsifying and emulsion-stabilizing ability, which is widely used in salad dressings, such as mayonnaise. However, taking into consideration that whole egg is often used in certain products such as cream, confectionery, cakes, etc., when commercially available yolk is used, it may contain up to 20% egg white due to adherence of albumen to the vitelline membrane (Powrie and Nakai, 1985); hence, constituents from both egg fractions may have to function together in the environment of various food systems. Furthermore, other food ingredients, ranging from low-molecular weight surface-active agents to high-molecular weight biopolymers, may also be encountered in the systems, together with the constituents of eggs, leading to competitive adsorption effects either at o/w or a/w interfaces (Kiosseoglou, 2003). These effects are bound to influence the functionality of the egg constituents to some extent, which can further lead to the modulation of a product's properties, such as its physicochemical stability and rheological behaviour (Tolstoguzox, 1996). The yolk fractions of egg, however, are made up of an extremely diverse mixture of constituents and phenomena such as competitive adsorption at o/w interfaces, or molecular interaction and phase separation may take place even between the egg fraction components themselves (Kiosseoglou, 2003). Due to the high content of protein and the differences in structure and molecular flexibility, competitive adsorption effects are bound to take place when oil droplets are also present in the system when yolk is used on its own in a food system (Kiosseoglou, 2003). In addition to this, low-molecular weight surface-active yolk constituents, such as phospholipids, may also compete for space at the interface with the yolk proteins, or may be involved in hydrophobic interactions with the protein molecules,

resulting in the modification yolk protein emulsifying properties (Kiosseoglou, 2003).

Therefore, it is important to know the way the constituents of egg function in various products in order to control their functionality in the most beneficial way and prepare food products which exhibit a high physicochemical stability and acceptable textural characteristics; this cannot be achieved unless their behaviour in the presence of other food ingredients in emulsion system is well understood (Kiosseoglou, 2003).

There are various reports done on the competitive adsorption of hen egg yolk proteins in oil-in-water emulsions. However, only a few reports on the adsorption behaviour of egg yolk duck and goose egg yolk can be found in the literature. Interestingly, these egg yolks can also contribute to the emulsifying properties used in food products. Studies carried out on the adsorption behaviour of hen egg yolk constituents have been realized with individual constituents such as LDL, phosvitin and livetin (Davey *et al.*, 1969; Kiosseoglou and Sherman, 1983; Mizutani and Nakamura, 1984), or with granules and plasma (Dyer-Houdon and Nnanna, 1993; Anton and Gandemer, 1997). Nevertheless, the concentration of protein and the composition of interfacial film in emulsions, prepared with different poultry sources of egg yolk, remain largely unknown. These parameters are dependent on the competition between the constituents of yolk to form the interfacial film. This phenomenon is strongly related to the

conditions of medium such as pH, ionic strength and concentration of protein. The aim of this work was to understand the behaviour of the emulsions formed with different types of whole yolk derived from hen, duck and goose. Therefore, the objectives of this study were: 1) to determine the effect of pH on the stability of the oil-in-water emulsions made with hen, duck and goose egg yolks and relate them to the emulsifying properties; 2) to determine the influence of pH on the rheological properties of hen, duck and goose egg yolks oil-in-water emulsions and their correspondence to microstructure observation.