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

WAN ZUNAIRAH WAN IBADULLAH

FSMB 2008 17
INTERFACIAL AND RHEOLOGICAL PROPERTIES OF OIL-IN-WATER EMULSIONS AS AFFECTED BY EGG YOLK FROM DIFFERENT SOURCES

WAN ZUNAIRAH WAN IBADULLAH

MASTER OF SCIENCE
UNIVERSITI PUTRA MALAYSIA
2008
INTERFACIAL AND RHEOLOGICAL PROPERTIES OF OIL-IN-WATER EMULSIONS AS AFFECTED BY EGG YOLK FROM DIFFERENT SOURCES

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

Chairman: Prof. Dr. Nazamid Saari

Faculty: Food Science and Technology

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, kelsterlarutan 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 mengubahsuai kandungan protein kuning telur pada antara permukaan, terutama dalam mengubah suai caj bersih protein dan menyebabkan penolakan atau dimerization.

ACKNOWLEDGEMENTS

Alhamdulillah, first of all I would like to express my thanks and gratitude to Almighty Allah S.W.T. who has given me the capability to complete this research and my selawat and salam to his righteous messenger, prophet Mohammad S.A.W. I would like to take this opportunity to express my deepest gratitude to my supervisor Assoc. Prof Dr Nazamid Saari for his valuable suggestions, constructive criticisms, guidance and patience throughout the research. Special appreciation and gratitude is extended to Dr Tan Chin Ping, En Dzulkifly Hashim and Assoc. Prof Dr Siti Noorbaiyah Abdul Malek for the constant guidance, tremendous encouragement and constructive comments. Special thanks to all staff of Faculty of Food Science and Technology and Advanced Oleochemical Technical Division, En Halim and En Shmsual, Institute of Bioscience, En Rafi to have contributed in one way or another towards the success of the research. To Nor Afizah, Azura Liana, Ermina Sari, Taufik Ratule, Azan and Raja Rohaya whose help, suggestions, comments and moral supports have helped in the improvement and completion of this thesis- a million thanks to all of you. Last but least, thanks to everybody that was involved that contributes to the success of this research. My heartful gratitude goes to my husband and family for their encouragement, patience, understanding, support and unwavering love throughout the years of my study.
I certify that an Examination Committee has met on 23 July 2008 to conduct the final examination of Wan Zunairah binti Wan Ibadullah on her Master of Science thesis entitled “Interfacial and Rheological Properties of Oil-In-Water Emulsions as Affected by Egg Yolk from Different Sources” in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the student be awarded the Master of Science.

Members of the Examination Committee were as follows:

Azizah Abdul Hamid, PhD
Associate Professor
Faculty of Food Science and Technology
Universiti Putra Malaysia
(Chairman)

Sharifah Kharidah Syed Muhamad, PhD
Associate Professor
Faculty of Food Science and Technology
Universiti Putra Malaysia
(Internal Examiner)

Jamilah Bakar, PhD
Professor
Faculty of Food Science and Technology
Universiti Putra Malaysia
(Internal Examiner)

Azhar Mat Easa
Associate Professor
Food Technology Division
Universiti Sains Malaysia
(External Examiner)

HASANAH MOHD. GHAZALI, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 30 December 2008
This thesis submitted to the Senate Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Master of Science. The members of the Supervisory Committee are as follows:

Nazamid Saari, PhD  
Professor  
Faculty of Food Science and Technology  
Universiti Putra Malaysia  
(Chairman)

Tan Chin Ping, PhD  
Associate Professor  
Faculty of Food Science and Technology  
Universiti Putra Malaysia  
(Member)

Dzulkifly Mat Hashim  
Faculty of Food Science and Technology  
Universiti Putra Malaysia  
(Member)

HASANAH MOHD GHAZALI, PhD  
Professor and Dean  
School of Graduate Studies  
Universiti Putra Malaysia

Date: 15 January 2009
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.

WAN ZUNAIRAH BINTI WAN IBADULLAH

Date:
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT</td>
<td>iv</td>
</tr>
<tr>
<td>ABSTRAK</td>
<td>vi</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>viii</td>
</tr>
<tr>
<td>APPROVAL</td>
<td>ix</td>
</tr>
<tr>
<td>DECLARATION</td>
<td>xi</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>xv</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>xvi</td>
</tr>
<tr>
<td>LIST OF ABBREVIATIONS</td>
<td>xviii</td>
</tr>
</tbody>
</table>

## CHAPTER

### 1 INTRODUCTION

### 2 LITERATURE REVIEW

2.1 Egg yolk  
2.1.1 Egg yolk  
2.2 Composition of yolk  
2.3 Physicochemical properties of yolk  
2.4 Proteins and lipoproteins in granules and plasma  
2.4.1 Granules  
2.4.2 Plasma  
2.4.3 Phosvitin  
2.4.4 Lipovitellins  
2.4.5 Protein and lipoproteins in plasma  
2.4.6 Livetin  
2.4.7 Low density lipoproteins  
2.5 Functional properties of protein  
2.6 Solubility  
2.7 pH and solubility  
2.8 Definition of emulsion  
2.9 Emulsions in food  
2.10 The oil-water interface and emulsion stability  
2.10.1 The oil-water interface  
2.10.2 Types of interfacial film  
2.10.3 Droplet interactions and flocculation  
2.11 Molecular factors affecting emulsifying properties  
2.11.1 Solubility  
2.11.2 Conformation of adsorbed protein  
2.12 Influence on stability of emulsion  
2.13 Competitive adsorption  

xii
2.14 Egg yolk and its functionality properties 26
2.15 Yolk proteins at oil/water interfaces 28
2.16 Advances in food industry 31
2.17 Rheology in food emulsion 33
2.18 Stability and rheology of egg yolk emulsion 34

3 THE EFFECTS OF pHs ON EMULSIFYING PROPERTIES OF EGG YOLK FROM DIFFERENT SOURCES

3.1 Introduction 35
3.2 Materials and Method 38
  3.2.1 Materials 38
  3.2.2 Determination of protein, fat and ash content 38
  3.2.3 Yolk solution 39
  3.2.4 Determination of Protein solubility 39
  3.2.5 The preparation of emulsion 40
  3.2.6 Adsorbed proteins and interfacial concentration 40
  3.2.7 Measurement of the average droplet diameter 41
  3.2.8 Electrophoresis 41
  3.2.9 Interfacial tension 41
  3.2.10 Statistical analyses 43
3.3 Results and Discussion 43
  3.3.1 Emulsion properties related to the stability 43
  3.3.2 Interface attributes which are affected by solution pH and related to emulsion stability 49
3.4 Conclusions 76

4 EFFECT OF RHEOLOGICAL PROPERTIES OF HEN, DUCK AND GOOSE EGG YOLK OIL-IN-WATER EMULSIONS AT DIFFERENT pHs

4.1 Introduction 77
4.2 Materials and Methods 80
  4.2.1 Materials 80
  4.2.2 Yolk solution 81
  4.2.3 Emulsion preparation 81
  4.2.4 Microstructure analysis 81
  4.2.5 Viscosity measurement 82
  4.2.6 Statistical analysis 82
4.3 Results and Discussion 84
  4.3.1 Flow curves 83
  4.3.2 Droplet microstructure 94
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.4 Conclusions</td>
<td>96</td>
</tr>
<tr>
<td>5 CONCLUSIONS AND RECOMMENDATIONS</td>
<td>97</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>99</td>
</tr>
<tr>
<td>APPENDICES</td>
<td>115</td>
</tr>
<tr>
<td>BIODATA OF AUTHOR</td>
<td>119</td>
</tr>
</tbody>
</table>
LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Functional role of food proteins in food systems</td>
</tr>
<tr>
<td>3.1</td>
<td>Proximate analyses of hen, duck and goose egg yolk</td>
</tr>
<tr>
<td>3.2</td>
<td>Protein solubility of hen, duck and goose egg yolk oil-in-water emulsions as a function of pH</td>
</tr>
<tr>
<td>3.3</td>
<td>Average droplet diameter of hen, duck and goose egg yolk oil-in-water emulsions as a function of pH</td>
</tr>
<tr>
<td>3.4</td>
<td>Interfacial protein concentration of hen, duck and goose egg yolk oil-in-water emulsions as a function of pH</td>
</tr>
<tr>
<td>3.5</td>
<td>Percentage of adsorbed proteins of hen, duck and goose egg yolk oil-in-water emulsions as function of pH</td>
</tr>
<tr>
<td>4.1</td>
<td>Thixotropy of hen, duck and goose egg yolk oil-in-water emulsions as function of pH</td>
</tr>
<tr>
<td>4.2</td>
<td>Modeling of the flow curve between 0 and $100 \text{ s}^{-1}$ of shear stress of the hen, duck and goose egg yolk oil-in-water emulsions using Power Law: $\eta = k\gamma^n$</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>The part of an egg (Powrie, 1977)</td>
<td>7</td>
</tr>
<tr>
<td>3.1(a)</td>
<td>SDS-PAGE electrophoresis of adsorbed and unadsorbed proteins in hen egg yolk oil-in-water emulsions at pH 3, pH 6 and pH 9</td>
<td>63</td>
</tr>
<tr>
<td>3.1(b)</td>
<td>SDS-PAGE electrophoresis of adsorbed and unadsorbed proteins in duck egg yolk oil-in-water emulsions at pH 3, pH 6 and pH 9</td>
<td>64</td>
</tr>
<tr>
<td>3.1(c)</td>
<td>SDS-PAGE electrophoresis of adsorbed and unadsorbed proteins in goose egg yolk oil-in-water emulsions at pH 3, pH 6 and pH 9</td>
<td>65</td>
</tr>
<tr>
<td>3.2(a)</td>
<td>Interfacial tension reduction as a function of time for hen egg yolk solutions (0.0025% w/v)-n-hexadecane system at pH 3, 6 and 9</td>
<td>72</td>
</tr>
<tr>
<td>3.2(b)</td>
<td>Interfacial tension reduction as a function of time for duck egg yolk solutions (0.0025% w/v)-n-hexadecane system at pH 3, 6 and 9</td>
<td>72</td>
</tr>
<tr>
<td>3.2(c)</td>
<td>Interfacial tension reduction as a function of time for goose egg yolk solutions (0.0025% w/v)-n-hexadecane system at pH 3, 6 and 9</td>
<td>73</td>
</tr>
<tr>
<td>3.3(a)</td>
<td>Interfacial pressure changes as a function of time for hen egg yolk solutions (0.0025% w/v)-n-hexadecane system at pH 3, 6 and 9.</td>
<td>73</td>
</tr>
<tr>
<td>3.3(b)</td>
<td>Interfacial pressure changes as a function of time for duck egg yolk solutions (0.0025% w/v)-n-hexadecane system at pH 3, 6 and 9.</td>
<td>74</td>
</tr>
<tr>
<td>3.3(c)</td>
<td>Interfacial pressure changes as a function of time for hen egg yolk solutions (0.0025% w/v)-n-hexadecane system at pH 3, 6 and 9.</td>
<td>74</td>
</tr>
<tr>
<td>4.1(a)</td>
<td>Flow curves of oil-in-water emulsions made with goose egg yolk as a function of pH: thixotropic loop</td>
<td>88</td>
</tr>
</tbody>
</table>
4.1 (b) Flow curves of oil-in-water emulsions made with hen egg yolk as a function of pH: thixotropic loop

4.1 (c) Flow curves of oil-in-water emulsions made with duck egg yolk as a function of pH: thixotropic loop

4.2 (a) Viscosity curves of oil-in-water emulsions made with goose egg yolk as a function of pH

4.2 (b) Viscosity curves of oil-in-water emulsions made with duck egg yolk as a function of pH

4.2 (c) Viscosity curves of oil-in-water emulsions made with hen egg yolk as a function of pH

4.3 (a) Confocal laser scanning micrographs of three oil-in-water emulsions (0.5% w/v duck yolk, 37.5%vol oil, pH 3(a), 6(b) and 9(c), 20°C)

4.3 (b) Confocal laser scanning micrographs of three oil-in-water emulsions (0.5% w/v hen yolk, 37.5%vol oil, pH 3(a), 6(b) and 9(c), 20°C)

4.3 (c) Confocal laser scanning micrographs of three oil-in-water emulsions (0.5% w/v goose yolk, 37.5%vol oil, pH 3(a), 6(b) and 9(c), 20°C)
# LIST OF ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>HDL</td>
<td>High-density lipoprotein</td>
</tr>
<tr>
<td>LDL</td>
<td>Low-density lipoprotein</td>
</tr>
<tr>
<td>SDS-PAGE</td>
<td>Sodium dodecyl sulfate polyacrylamide gel electrophoresis</td>
</tr>
<tr>
<td>o/w</td>
<td>Oil/water</td>
</tr>
<tr>
<td>a/w</td>
<td>Air/water</td>
</tr>
<tr>
<td>Apo-LDL</td>
<td>Apo-low density lipoprotein</td>
</tr>
<tr>
<td>PVT</td>
<td>Phosvitin</td>
</tr>
<tr>
<td>Asp</td>
<td>Aspartic acid</td>
</tr>
<tr>
<td>Glu</td>
<td>Glutamine</td>
</tr>
<tr>
<td>Lys</td>
<td>Lysine</td>
</tr>
<tr>
<td>Arg</td>
<td>Arginine</td>
</tr>
<tr>
<td>His</td>
<td>Histidine</td>
</tr>
<tr>
<td>pI</td>
<td>Isoelectric point</td>
</tr>
<tr>
<td>min</td>
<td>Minute</td>
</tr>
</tbody>
</table>
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.
2.1 Egg Yolk

Eggs have been known as an important food from the time ancient men first snatched them from the nests of wild birds. Today, eggs remain a popular food in all countries of the world. Egg yolk contributes to human dietary requirements by supplying high-quality protein, mineral, vitamins, and essential fatty acids (Dyer-Hurdon and Nnanna, 1993). In addition to its nutritive value, egg yolk is used in the food industry for emulsifying properties. Egg yolk is often used as a food ingredient because of its excellent emulsifying properties. However, emulsifying properties of different sources of poultry are not well known (Baldwin, 1986). This is further deterred by the fact that the egg industry in the world is almost exclusively related to chicken eggs (Stadelman, 1977). The ability of some strains of ducks and geese to produce large numbers of eggs has led to suggestions that such eggs should be included among eggs for human consumption (Stadelman, 1977).