UNIVERSITI PUTRA MALAYSIA

EXTRACTION AND PHYSIOCHEMICAL CHARACTERIZATION OF BAOBAB (Adansonia digitata L.) SEED OIL AND ITS APPLICATION IN THE PRODUCTION OF MAYONNAISE STABILIZED BY BAOBAB PROTEIN

ZAHRAU BAMALLI NOURUDDEEN

FSTM 2019 10

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By

ZAHRAU BAMALLI NOURUDDEEN

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

December 2018

DEDICATION

I dedicate this thesis to my beloved husband in person of Dr. Nouruddeen Bashir Umar, and my children Abdulhaleem Nour Bashir and Abdul Hakeem Nour Bashir for their unwavering love, sacrifice, patience, encouragement and best wishes.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

EXTRACTION AND PHYSIOCHEMICAL CHARACTERIZATION OF BAOBAB (*Adansonia digitata* L.) SEED OIL AND ITS APPLICATION IN THE PRODUCTION OF MAYONNAISE STABILIZED BY BAOBAB PROTEIN

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Chairman : Professor Hasanah Mohd Ghazali, PhD
Faculty : Food Science and Technology

Baobab (*Adansonia digitata* L.) is a wild plant, with various uses. The leaves and the pulp from the fruit and plant are staple food for many populations in Africa, most especially in the central region of the continent. The seeds are rich in oil and protein content. In addition, the seeds have been reported to have many nutritional and medicinal benefits. However, the seeds are not widely/fully utilized for their application in the food industries. Attention on the baobab plant has always been on the fruit pulp and leaves, while the seeds have always been over looked despite the high mono and polyunsaturated fatty acid and antioxidant present in the oil and high lysine content in the protein from the seed. Studying the physical and chemical, as well as the functional properties of the oil and protein extracted from the seed will be a step forward in cooperating the oil and protein into our food system. In view of the foregoing, this study presents the characterization of the oil and protein isolate and fractions (albumin, globulin, glutelin and prolamin) extracted from the seed; modification of the oil by blending with other vegetable oils to improve its application in the food industry. The effect of egg yolk substitution with protein isolate extracted from the defatted seed of baobab on the properties of mayonnaise is also investigated.

The oil was extracted from baobab seed using two different methods: Soxhlet extraction (SE) and ultrasound-assisted extraction (UAE). Results showed that, despite extraction for only 2 h, UAE yielded 18.7% crude oil, representing nearly 81% of the yield obtained with SE. Quality indices such as free fatty acid content 7.92% (SE) and 6.87% (UAE), peroxide value 3.13 meq O_2/kg (SE) and 3.20 meq O_2/kg (UAE) and oxidative stability 6.85 h (SE) and 6.96 h (UAE), and other physico-chemical properties such as fatty acid composition, triacylglycerol profile, thermal behaviour and solid fat content of both oils were comparable. Oleic, linoleic, palmitic and stearic acids were the dominant fatty acids in the baobab oil. However, the UAE oil was slightly more viscous (54.12 cP) and yellow in color (29.33 Y) than the SE oil, indicating co-extraction of compounds not extracted with SE. γ-Tocopherol was the predominant and abundant Vitamin E isomer in the oil and was found to be higher in UAE (626.01mg/g) compared to SE (536mg/g). Phenolic content 509.47 mg GAE/mg, flavonoid content 44.17 μg QE/g and IC_{50} of 133.43 μg/ml where predominant in UAE sample compared to SE.

Baobab proteins were extracted as isolate and fractions; the isolate yield was 50.40% while the yield for the fractions were albumin 38.73%, globulin 39.63%, glutelin 18.87% and prolamin 6.00%. Extract from the defatted seeds were evaluated for their physicochemical properties (isoelectric point, bulk density, color, and amino acid profile) and functional properties (Emulsion and foaming capacity, water and oil absorption, solubility and gelation). Results show that the protein isolate was significantly higher in the emulsion (69.3%) and emulsion stability (48.5%), foaming (68.10%) and foaming stability after 60 min (23%), water and oil absorption capacity (142% and 62.51%) compared to the fractions (albumin, globulin, glutelin and prolamin). Turbidity measurement shows the following isoelectric points: baobab protein isolate (pH 3.5) and fractions; albumin (pH 4.5), globulin (pH 6), and glutelin (pH 6.5), respectively. Prolamin was not precipitated upon pH adjustment but was precipitated using cold acetone. Solubility of the protein isolate and fractions (albumin, globulin and glutelin) showed an increase in solubility as the pH increased until both samples reached their isoelectric point. Baobab protein isolate (116.23 °C) shows a higher denaturation followed by prolamin fraction (106 °C), with lowest in albumin fraction (74.48 °C). Lysine was the dominant essential amino acid in both the protein isolate and the fractions (albumin, globulin, glutelin and prolamin).

Baobab oil was blended with four different oil: palm olein (PLO), coconut (CO), soybean (SBO) and sunflower oil (SFO) using 4 different ratios (90:10, 80:20, 70:30 and 50:50%). Blending baobab oil with 30% and 50% PLO increased the levels of monosaturated and saturated fat from 38.2% and 34.3% to 39.7 and 38.4%, respectively. This was found to increase the oxidative stability of baobab oil from 6.8 h to 10.27 h. Blending baobab oil with CO oil increased lauric acid content from 0.1% to 25.4% at 50:50% ratio. Blending baobab oil with soybean and sunflower oil increase the polyunsaturated level of the baobab oil. Baobab seed oil blends with 30% sunflower oil and 20% soybean oil reduce the oxidative stability index of baobab oil from 6.8 h to 5.56 h and 4.68 h. Blends of baobab oil with PLO and CO filled the cold test, while blends with SFO and SBO passed the cold test. Emulsion stability after 30 min was significantly higher in the SFO (81%) and SBO (83.9%) in 50% blends with the least stability at 50% blend with PLO (21.8%) and CO (49%). After one week of emulsion storage blends with PLO were separated. Oils with an oxidative stability of 5-6 h are used in the production of mayonnaise. Therefore, 70% baobab oil blended with 30% soybean was the perfect oil to be used in the mayonnaise production.

Protein isolate from the defatted seed of baobab was used as the egg yolk substitute in the production of mayonnaise. Blend of 30:70 % soybean and baobab oil was the oil used for the mayonnaise production. Results shows that moisture content (15.81%), protein content (8.79%), and total carbohydrate content (26.30%) of the mayonnaise produced using baobab protein isolate was comparable with the mayonnaise produced from egg yolk, while the ash (3.12%) and total lipid content (44.8%) were significantly lower than the mayonnaise produced from egg yolk. Mayonnaise produced from baobab protein isolate had a higher b* (26.75) color compared to mayonnaise produced from egg yolk (20.81). Mayonnaise produced from egg yolk were lighter compared to the one produced from baobab protein isolate. Rheological properties (firmness, stickiness and adhesion and viscosity), acid and peroxide value were studied. The results show a significant difference at P<0.05 in the rheological properties between the fresh and stored sample after 4 months, while peroxide and acid value showed no significant difference at P<0.05. A 9-point hedonic scale sensory analysis was carried out with 30 panelists. Results of sensory analysis conducted on the mayonnaise produced from egg yolk and protein isolate were generally accepted with good scores, for creaminess (7.07 and 6.3), pastiness (8.3 and 7.4), stability (6.20 and 5.98) and aroma (7.6 and 5.7). The overall acceptability of the mayonnaise from egg yolk (7.27) were not significantly different at P<0.05 with protein isolate (6.71), but value wise the egg yolk mayonnaise where more acceptable.

Abstrakt tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

EKSTRAKSI DAN KARAKTERISASI FIZIKOKIMIA MINYAK BIJI BAOBAB (*Adansonia digitata* L.) DAN APLIKASINYA DALAM PRODUKSI MAYONNAIS YANG DITABABOL DENGAN PROTEIN BAOBAB

Oleh

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Baobab (Adansonia digitata L.) adalah tumbuhan liar dengan pelbagai kegunaan. Daun dan pulpa dari buah dan tumbuhan adalah makanan ruji bagi kebanyakan populasi di Afrika, terutamanya di rantau tengah benua. Bijinya kaya dengan kandungan minyak dan protein. Sebagai tambahan, biji benihnya telah dilaporkan mempunyai manfaat nutrisi dan perubatan. Walau bagaimanapun, bijinya tidak digunakan secara meluas untuk kegunaan dalam industri makanan. Tumpuan kepada tumbuhan baobab lazimnya ke atas pulpa buah dan daun, sementara bijinya diabaikan walaupun tinggi asid lemak mono- dan politaktepu dan antioksidan hadir dalam kandungan minyak dan tinggi lisin dalam protein dari bijinya. Mengkaji fizikal dan kimia, serta ciri-ciri fungsian minyak dan protein yang diekstrak dari biji akan menjadi satu langkah ke hadapan dalam menjayakan minyak dan protein ke dalam sistem makanan kita. Memandangkan yang terdahulu, kajian ini membentangkan pencirian minyak dan pencilan protein dan pecahannya (albumin, globulin, glutelin dan prolamin) yang diekstrak daripada biji; pengubahsuaian minyak dengan pengadunan dengan minyak sayuran lain untuk meningkatkan penggunaannya dalam industri makanan. Kesan penggantian kuning telur dengan pencilan protein yang diekstrak dari biji baobab dinyahlemak kepada sifat-sifat mayones turut dikaji.

Minyak tersebut diekstrak dari biji baobab menggunakan dua kaedah yang berbeza: Pengekstrakan Soxhlet (SE) dan pengekstrakan dibantu oleh ultrabunyi (UAE). Keputusan menunjukkan bahawa, walaupun pengekstrakan hanya 2 jam, UAE menghasilkan 18.7% minyak mentah, mewakili hampir 81% daripada hasil yang diperolehi dengan SE. Indeks kualiti seperti kandungan asid lemak bebas 7.92% (SE) dan 6.87% (UAE), nilai peroksida 3.13 meq O_2 / kg (SE) dan 3.20 meq O_2 / kg (UAE) dan kestabilan oksidatif 6.85 jam (SE) dan 6.96 jam (UAE), dan sifat fiziko-kimia lain seperti komposisi asid lemak, profil triasilgliserol, sifat haba dan kandungan lemak

pepejal kedua-dua minyak adalah setanding. Asid oleik, linoleik, palmitik dan stearik adalah asid lemak dominan dalam minyak baobab. Walau bagaimanapun, minyak UAE sedikit lebih likat (54,12 cP) dan berwarna kuning (29.33 Y) daripada minyak SE, menunjukkan pengekstrakan bersama bahan yang tidak diekstrak dengan SE. γ-Tocoferol adalah isomer vitamin E yang dominan dan banyak dalam minyak dan didapati lebih tinggi dalam UAE (626.01mg / g) berbanding SE (536mg /g). Kandungan fenolik 509.47 mg GAE / mg, kandungan flavonoid 44.17 μg QE / g dan IC50 133.43 μg / ml adalah lebih banyak dalam sampel UAE berbanding dengan SE.

Protein baobab diekstraksi sebagai pencilan dan pecahan; hasil pencilan adalah 50.40% manakala hasil untuk pecahan adalah albumin 38.73%, globulin 39.63%, glutelin 18.87% dan prolamin 6.00%. Ekstrak dari benih yang telah dinyahlemak telah dinilai bagi sifat fizikokimia (titik isoelektrik, kepadatan pukal, warna, dan profil asid amino) dan ciri-ciri fungsian (Emulsi dan kapasiti pembusaan, penyerapan air dan minyak, kelarutan dan penggelan). Keputusan menunjukkan bahawa pencilan protein jauh lebih tinggi dalam emulsi (69.3%) dan kestabilan emulsi (48.5%), pembusaan (68.10%) dan kestabilan pembusaan selepas 60 minit (23%), kapasiti penyerapan air dan minyak (142% dan 62.51 %) berbanding dengan pecahan (albumin, globulin, glutelin dan prolamin). Pengukuran kekeruhan menunjukkan titik isoelektrik berikut: pencilan protein baobab (pH 3.5) dan pecahan; albumin (pH 4.5), globulin (pH 6), dan glutelin (pH 6.5), masing-masing. Prolamin tidak dimendakkan sewaktu penyesuaian pH tetapi dimendakkan menggunakan aseton sejuk. Keterlarutan dalam pencilan dan pecahan protein (albumin, globulin dan glutelin) menunjukkan peningkatan keterlarutan kerana pH meningkat sehingga kedua-dua sampel mencapai titik isoelektrik mereka. Pencilan protein Baobab (116.23 °C) menunjukkan denaturasi yang lebih tinggi diikuti oleh pecahan prolamin (106 °C), dengan yang terendah dalam pecahan albumin (74.48 °C). Lisina adalah asid amino penting yang dominan dalam kedua-dua protein pecilan dan pecahan (albumin, globulin, glutelin dan prolamin).

Minyak baobab dicampur dengan empat minyak yang berbeza: olein sawit (PLO), kelapa (CO), kacang soya (SBO) dan minyak bunga matahari (SFO) menggunakan 4 nisbah yang berbeza (90:10, 80:20, 70:30 dan 50:50 %). Pengadunan minyak baobab dengan 30% dan 50% PLO meningkatkan tahap lemak monotepu dan lemak tepu dari 38.2% dan 34.3% kepada 39.7 dan 38.4%. Ini didapati meningkatkan kestabilan oksidatif minyak baobab dari 6.8 jam kepada 10.27 jam. Campuran minyak baobab dengan minyak CO meningkat kandungan asid laurik dari 0.1% kepada 25.4% pada nisbah 50: 50%. Pengadunan minyak baobab dengan minyak kacang soya dan bunga matahari meningkatkan kadar politaktepu minyak baobab. Campuran minyak biji Baobab dengan minyak bunga matahari sebanyak 30% dan 20% minyak kacang soya mengurangkan indeks kestabilan oksidatif minyak baobab dari 6.8 jam kepada 5.56 jam dan 4.68 jam. Campuran minyak baobab dengan PLO dan CO memenuhi ujian sejuk, manakala campuran dengan SFO dan SBO melepasi ujian sejuk. Kestabilan emulsi selepas 30 minit adalah lebih tinggi bagi SFO (81%) dan SBO (83.9%) dalam campuran 50% dengan kestabilan paling kurang pada 50% campuran dengan PLO (21.8%) dan CO (49%). Selepas satu minggu penyimpanan campuran emulsi dengan PLO terpisah. Minyak dengan kestabilan oksidatif 5-6 jam telah digunakan dalam pengeluaran mayones. Oleh itu, 70% minyak baobab yang dicampur dengan 30% kacang soya adalah minyak yang sempurna untuk digunakan dalam pengeluaran mayones.

Pencilan protein dari biji baobab yang telah dinyahlemak digunakan sebagai pengganti kuning telur dalam pengeluaran mayones. Campuran 30:70% minyak kacang soya dan baobab adalah minyak yang digunakan untuk pengeluaran mayones. Keputusan menunjukkan bahawa kandungan lembapan (15.81%), kandungan protein (8.79%), dan kandungan karbohidrat (26.30%) daripada mayones yang dihasilkan menggunakan pencilan protein baobab adalah setanding dengan mayones yang dihasilkan daripada kuning telur, manakala abu (3.12% dan kandungan jumlah lipid (44.8%) adalah jauh lebih rendah daripada mayones yang dihasilkan daripada kuning telur. Mayones yang dihasilkan daripada pencilan protein baobab mempunyai warna b * (26.75) yang lebih tinggi berbanding dengan mayones yang dihasilkan daripada kuning telur (20.81). Mayones yang dihasilkan daripada kuning telur adalah lebih ringan berbanding dengan yang dihasilkan dari pencilan protein baobab. Sifat reologi (kepejalan, kelekitan dan lekatan dan kelikatan), nilai asid dan peroksida dikaji. Hasilnya menunjukkan perbezaan yang ketara pada $P < 0.05$ dalam sifat reologi antara sampel yang segar dan yang disimpan selepas 4 bulan, manakala nilai peroksida dan asid menunjukkan tiada perbezaan yang ketara pada $P < 0.05$. Analisis sensori 9 titik skala hedonik dilakukan dengan 30 panelis. Keputusan analisis sensori yang dilakukan pada mayones yang dihasilkan daripada kuning telur dan pencilan protein umumnya diterima dengan skor yang baik, untuk kekriman (7.07 dan 6.3), ketempelan (8.3 dan 7.4), kestabilan (6.20 dan 5.98) dan aroma (7.6 dan 5.7). Kebolehterimaan keseluruhan mayones dari kuning telur (7.27) adalah tidak jauh berbeza dengan pencilan protein (6.71) pada $P < 0.05$, tetapi dari segi nilai mayones kuning telur adalah lebih diterima.

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This thesis was submitted to the Senate of the Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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LIST OF ABBREVIATIONS

µg	Microgram
µL	Microliter
µm	Micrometre
ANOVA	Analysis of variance
AOAC	Association of Official Analytical Chemists
AOCS	American Oil Chemists' Society
atm	Standard atmosphere
BFCS	Baobab Fruit Company Senegal
cP	Centipoise
DPPH	Radical scavenging activity
DSC	Differential Scanning Calorimetry
EC	European commission
ES	Emulsion stability
EU	European union
FAO	Food and Agriculture Organization
FDA	Food and Drugs Administration
FFA	Free fatty acids
FTIR	Fourier Transform Infrared Spectroscopy
GHz	Gigahertz
HPLC	High Performance Liquid Chromatograph
IR	Infrared
IUPAC	International Union of Pure and Applied Chemistry
IV	Iodine Value
K	Kelvin
kHz	Kilohertz
kWh	Kilowatt hour

LPL	Lipoprotein lipase
M	Mean
MGC	Minimum gelation capacity
mL	Millilitre
MPa	Mega pascal
MPOB	Malaysia Palm Oil Board
NMR	Nuclear Magnetic Resonance
O/W	Oil-in-water
OAC	Oil absorption capacity
OSI	Oxidative stability index
p-AV	P-anisidine Value
PV	Peroxide Value
RI	Refractive Index
SD	Standard deviation
SE	Soxhlet extraction
SEE	Super critical extraction method
SFC	Solid Fat Content
SFI	Solid Fat Index
TAG	Triacylglycerol
UAE	Ultrasound-assisted extraction
UHPLC	Ultra-High Performance Liquid Chromatograph
USDA	United State Department of Agriculture
W	Watt
W/O	Water-in-oil
WAC	Water absorption capacity

CHAPTER 1

INTRODUCTION

1.1 About the Plant

Baobab (*Adansonia digitata* L.) is known by a very large number of local names: English (baobab, monkey bread tree, Ethiopian sour gourd, Cream of Tartar tree, Senegal calabash fruit, upside-down tree), French (pain de singe, arbre aux calebasses), Portuguese (Cabaçevre), Arabic (būħibāb, hamao-hamaraya, habhab, hamar, tebeldi) and Hausa (kuka) (Burkill, 1985). Baobab belongs to the family *Bombacaceae* which is a sub family of *Malvaceae.* The genus is known as *Adansonia* and belongs to the species of *Adansonieae* (Bremer *et al*., 2003). There are eight species but *A. digitata* L. is the most commonly known and widespread in Africa (Baum, 1995a). Another specie is *A. gibbosa* which only grows in North-Western Australia, while the other 6 remaining species can be found in the island of Madagascar (Baum *et al*. 1998). *A. digitata* L. grows in the drier parts of Africa in countries such as Botswana, Nigeria, Sudan, Mozambique, Namibia, South Africa and Zimbabwe (Coates and Palgrave, 2000). Over the years, baobab has been exported around the world, so much so that the tree is now grown in countries like Hawaii, Puerto Rico, Virgin Islands and Florida, India, Sri Lanka, China, Jamaica and Holland (Sidibe and Williams, 2002).

Baobab is a tree that has a long life as it can live for hundreds of years (Gebauer *et al.*, 2002). Each and every part of the tree has been reported to be useful (Igboeli *et al.*, 1997 and Gebauer *et al.*, 2002). The tree has a high water holding capacity and extensive root system. The tree grows in tropical regions and can withstand hot temperatures as high as 42 °C, It can also withstand low temperatures, however, not frost condition (Diop *et al.*, 2006). Low rainfall causes the baobab tree to become stunted. It grows well in regions that have annual rainfall of 10 to 100 cm (FAO 1988). Almost all parts (root, fruits, tubers, seeds, flowers and leaves) of the tree are edible and have been used as ingredients in African local dishes. The leaves and seeds have been used for different purposes such as food, shelter, medicine and even fishing and hunting materials (Venter and Venter, 1996).

The dried fruit pulp is very high in vitamin C (almost ten times much higher than oranges) (De Caluwé *et al.*, 2010). Proximate analysis of the ripe fruit shows moisture content of 8.7% with 2.7% protein, 0.2% fat, 73.7% carbohydrate, 8.9% fibers and 5.8% ash (Arnold *et al.*, 1985). The total sugar content in the fruit pulp was reported to be 23.2% and the reducing sugar was 18.9 % (Nour *et al.*, 1980). The fruit pulp also contains organic acids such as tartaric, citric, succinic, tartaric, and malic, thus making it acidic (Airan and Desai, 1954). Milky drinks serving as substitute for milk have also been reported to be produced from the pulp by dissolving it in water (Becker, 1983). The liquid of the pulp has also been used in local bakeries and breweries as cream of tartar and fermenting agent, respectively (Becker, 1983). Furthermore, baobab pulp has been used in local dishes as an appetizer or seasoning component (Burkill, 1985). Salt rich in potash for soap-making have been reported to be obtained from the pods of the fruits when burned (Ajayi *et al.*, 2003). Figures 1.1 shows images of baobab tree, leaves, fruit, fruit pulp, seed and seed oil.

The leaves are staple food for a number of populace in central Africa (Yazzie *et al.*, 1994; Gebauer *et al.*, 2002). The leaves are mostly cooked fresh as spinach or dried and they are often used as powder which can be used in soups over boiled rice or gruels. The dried leaves contain 13-15% protein, 60-70% carbohydrate, 4-10% fat, 16% ash and around 11% fiber (De Caluwé *et al*., 2010). The leaves are also reach in vitamin A and minerals such as iron, calcium, manganese, zinc, potassium, phosphorus, magnesium and molybdenum (Yazzie *et al.* 1994). The leaves also contain up to 5 of the 8 essential amino acids and, thus, can be said to be also high in protein (Becker, 1983; Yazzie *et al.*, 1994; Nordeide *et al.*, 1996). The seeds have been reported to have protein source (15-28%), energy and mineral (Osman, 2004). The high protein content and protein solubility at both acidic and alkaline pH suggests the potential usefulness of baobab seed protein as food protein.

Figures 1.1: The Baobab Tree (a) Baobab tree (Chitty, 2018) (b) leaves (Wikipedia, 2018) (c) powdered leave (Pandavita, 2017) (d) fruit (Biznakenya, 2017a) (e) fruit pulp (Biznakenya, 2017b) (f) seed (Savannah & Sahel, 2017) and (g) seed oil (Nature's tattva, 2017)

The dried baobab seed contains 12-30% oil which has been reported to contain high levels of palmitic (24.02%), stearic acids (4%) as well as oleic (39.42%) and linoleic acids (26.07%) (Glew *et al.*, 1997; Ezeagu *et al.*, 1998; Magdi, 2004). Unsaturated and saturated fatty acids are made up 73.11 % and 26.89 % of the total fatty acids, respectively (Ajayi *et al.*, 2003). Essien and Fetuga (1989) provided basic information on the physical and chemical characteristics of the seed oil and they observed that the mean iodine value showed a similar degree of unsaturation when compared with corn oil. This implies that the baobab seed oil can be of potential benefit in the food industry as it contains high unsaturated fatty acids which have been reported in vegetable oils to reduce cholesterol levels in the human body. Nkafamiya *et al.* (2007) has suggested that the baobab seed oil could be used in the cosmetics industry for soap-making due to the high saponification value observed (196 mg/KOH). A study in Nigeria also showed that β-carotene content was 43.36 μg/100g, twice that of palm kernel oil and 7 times that of corn oil (Yazzie *et al.,* 1994). With the unique ability of the seed and increase demand in the oil industries, the seed of baobab could be an alternative source in the oil market.

1.2 Problem Statement

The seed of baobab (*A. digitata* L.) has been reported to have 12-30% oil content (Nkafamiya *et al.,* 2007; Arnold *et al.,* 1985; Magdi, 2004; Addy and Eteshola, 1984) and a protein content of 15-28% (Magdi, 2004; Addy and Eteshola, 1984). The attention on this plant has always been on the leaves and the pulp from the fruits. After the removal of the pulp from the seeds, the seeds are not widely used/utilized. Oil extracted from the seed is rich in monounsaturated and polyunsaturated fatty acids (Ajayi *et al.*, 2003), while the protein extracted from the seed is high in essential and non-essential amino acid (Magdi, 2004). Compared to other plant seed protein, baobab seed protein is rich in lysine which is mostly found in cereal plants. Despite the nutritional composition of the seed, the seeds are not fully utilized and widely used. Studies on the oil and protein extracted from the seed were limited to basic information on the fatty acid composition of the oil, few physicochemical analysis of the oil (such as the refractive index, free fatty acid, peroxide value and saponification), protein solubility of the protein concentrate and the amino acid of the seed. Detailed information on the oil characterization (thermal behavior, solid fat content and antioxidant activity) and physicochemical, functional and thermal denaturation of the protein isolate and fractions (albumin, globulin, glutelin and prolamin) of baobab seed has not been reported. To integrate the baobab oil and protein isolate into the human food system, a detailed and comprehensive analysis on the properties of the oil and protein isolate has to be studied and this led to the objectives of the present study.

1.3 Objectives of study

The overall aim of this study was to investigate and provide an insight into the use of baobab seed oil in terms of food application and as a functional food. In view of the above, the following objectives were driven:

1. To extract oil from *A. digitata* L. seed using solvent and ultrasound extraction methods and characterize the oil
2. To extract and characterize protein isolate and fractions (albumin, globulin, glutelin and prolamin) from the press cake after oil extraction and to determine their functional and physicochemical properties.
3. To determine the effect of baobab protein isolate in oil-in-water emulsion using baobab seed oil blended with palm olein, coconut oil, sunflower oil and soybean oil
4. To determine the effect of egg yolk substitution with baobab protein isolate the properties of mayonnaise

1.4 Thesis Outline

The thesis is organized as follows:

Chapter 2 presents a review on baobab fruit pulp, leaves, seed and oil. In addition, the theory and application of emulsion is also discussed as well as previous studies on lipids and proteins extraction. The effect of oil quality and the method of modification to improve the quality of the oil and mayonnaise production and review on the mayonnaise are also highlighted.

In chapter 3, the oil extraction process, experimental methods and analysis of baobab seed oil is described. The results on physicochemical and antioxidant activities are discussed.

Chapter 4 presents the methodology on protein extracted from the press cake of baobab after oil extraction. The chapter also presents and discusses the results on protein isolation and characterization.

Chapter 5 presents the methodology and analysis on oil modification by blending as well as the results and discussion of the blended oils. Furthermore, the chapter describes the methodology the effect of baobab protein isolate and blended oil in oil-in-water.

Chapter 6 presents the methodology, results and discussion of mayonnaise made from egg yolk and mayonnaise made from protein extract of defatted baobab seed

Chapter 7 finally summarizes and concludes the research that has been carried out in this study. Future works are also suggested at the end of this chapter.

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