EFFECTS OF DOMESTIC PROCESSING ON QUALITY OF JERING [*Pithecellobium jiringa* (L.)]

ASHUWINI SRIDARAN

UNIVERSITI SAINS MALAYSIA

2013

EFFECTS OF DOMESTIC PROCESSING ON QUALITY OF JERING [*Pithecellobium jiringa* (L.)]

by

ASHUWINI SRIDARAN

Thesis submitted in fulfillment of the requirements for the degree of Master of Science (MSc) in the field of Food Technology

School of Industrial Technology

Universiti Sains Malaysia

February 2013

ACKNOWLEDGEMENT

I would like to express my gratitude to all those who have assisted me and made the completion of this thesis possible. I am especially obliged to Universiti Sains Malaysia (USM) for the postgraduate fellowships awarded which was of great help in supporting my life as a student. I am deeply indebted to my supervisor, Professor Abd Karim Alias and co-supervisor Associate Professor Dr. Rajeev Bhat, from the School of Industrial Technology, USM whose help, stimulating suggestions and encouragement helped me at all time of research and writing of this thesis. They have also offered continuous support in acquiring permission for the usage of equipments and laboratory premises that were vital for my work. I would also like to thank the examiners of my thesis Dr. Rabeta Mohd Salleh from the School of Industrial Technology, USM and Associate Professor Dr. Wan Aida Wan Mustapha from Universiti Kebangsaan Malaysia (UKM) for their critical comments and suggestions to improve my thesis.

I am also grateful to academic and non-academic staffs in the School of Industrial Technology for critical suggestions during my seminars and assistance throughout my laboratory research work. Not forgetting the laboratory staffs in the School of Biological Sciences, USM for their guidance in performing analyses critical for my research. My friends and laboratory mates have supported me in my work by offering suggestions to improve my project. I want to thank them for all their help, support, interest and valuable hints.

I would like to especially thank my parents and family whose love and blessings enabled me to complete this work.

TABLE OF CONTENTS

CHAPTER 1: INTRODUCTION

CHAPTER 2: LITERATURE REVIEW

CHAPTER 3: MATERIALS AND METHODS

CHAPTER 4: RESULTS AND DISCUSSION

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF UNITS

° C	degree Celcius
µg	microgram
µl	microlitre
cm	centimeter
g	gram
h	hour
kg	kilogram
l	liter
m	meter
M	molar
mg	miligram
ml	mililitre
mm	milimeter
mM	milimolar
MPa	mega Pascal
N	normality
nm	nanometer
rpm	rotation per minute
s	second

LIST OF ABBREVIATIONS AND SYMBOLS

α	alpha
β	beta
<	less then
>	more than
AABA	alpha amino buteric acid
AAE	ascorbic acid equivalent
AAS	amino acid score
ABTS	2,2-azinobis (3-ethyl-benzothiazoline-6-sulfonic acid)
AI	α-amylase inhibitors
AIA	α-amylase inihibition activity
BAPNA	N-α-benzoyl-DL-arginin-p-nitroanilid
BHA	butylated hydroxyanisole
BHT	butylated hydroxytoluene
CAE	catechin equivalent
DPPH	2,2-diphenyl-1-picrylhydrazyl
EA	emulsion activity
EAA	essential amino acid
ES	emulsion stability
FA	foaming activity
FAME	fatty acid methyl esters
FC	Folin-Ciocalteau

$FeCl_3.6H_2O$	iron (III) chloride hexahydrate
Fermentation (R)	Rhizopus spp. fermentation
Fermentation (Y)	yeast fermentation
FRAP	ferric reducing potential
FS	foaming stability
FSE	ferrous sulphate equivalent
GAE	gallic acid equivalent
HCl	hydrochloric acid
HPLC	high-pressure liquid chromatography
L.	Leguminosae
LGC	least gelation capacity
n	number of samples
NaOH	sodium hydroxide
NFE	nitrogen free extract
OAC	oils absorption capacity
P. jiringa	*Pihecellobium jiringa*
P/S	polyunsaturated/saturated fatty acid
PS	protein solubility
ROS	reactive oxygen species
SAA	sulphur containing amino acid
SD	standard deviation
spp.	species
TBHQ	tert-butyhydro-quinone

TCA	trichloroacetic acid
TFC	total flavonoids content
TI	trypsin inhibitors
TIA	trypsin inhibition activity
TIU	trypsin inhibitory unit
TPC	total phenolic content
TPTZ	2,4,6-tri(2-pyridyl)-1,3,5-triazine
WAC	water absorption capacity

PENGARUH PEMPROSESAN DOMESTIK TERHADAP KUALITI JERING [*Pithecellobium jiringa* (L.)]

ABSTRAK

Pithecellobium jiringa L. (jering) adalah sejenis kekacang bukan-konvensional yang biasa dimakan oleh penduduk di rantau Asia Tenggara. Kajian ini mengkhusus pada sifat-sifat fiziko-kimia, antioksidan, antinutrisi dan berfungsi jering dan kesan pemprosesan domestik (hidroterma dan fermentasi) terhadap kualiti parameter-parameter tersebut. Jering terlebih dahulu disubjekkan pada pendidihan (21.0 ± 1.0 minit), masakan tekanan (121 °C, 0.2 MPa, 20 minit) dan fermentasi yis (*Saccharomyces cerevisiae*) dan *Rhizopus spp.* sebelum dianalisis. Jering mengandungi kandungan lembapan (58.55%), protein kasar (14.19%) ekstrak bebas nitrogen (EBN) (82.1%) dan nilai tenaga kasar (1662.49 kJ 100 g^{-1}) yang tinggi serta kandungan lipid kasar (1.45%) yang rendah. Fermentasi menggunakan *Rhizopus spp*. meningkatkan kandungan protein dan serat kasar. Pemprosesan hidroterma dan fermentasi yis meningkatkan kandungan EBN dan nilai tenaga kasar. Jering mencatatkan skor asid amino (SAA) (92-250%) yang tinggi dan aras amino asid sulfur (AAS) yang signifikan. Fermentasi yis dan *Rhizopus spp*. meningkatkan profil asid amino dan SAA. Asid lemak yang dikesan kebanyakannya (54.73%) ialah asid lemak tak tepu. Pemprosesan hidroterma dan fermentasi mengurangkan nisbah asid lemak politaktepu/tepu (P/T). Jering menunjukkan jumlah kandungan fenolik (JKF) dan jumlah kandungan flavonoids (JKV) yang sangat tinggi. Fermentasi *Rhizopus spp.* meningkatkan JKF dan JKV dengan ketara. Pengolahan hidroterma mengurangkan JKF (35-98%) dan JKV (61-90%) secara signifikan ($p<0.05$). Fermentasi yis turut mengurangkan JKF (74-94%) dan JKV (83-94%). Kandungan tanin jering mentah adalah yang tertinggi diikuti jering yang dididih, yang dimasak menggunakan tekanan dan yang difermentasi. Jering mempunyai aktiviti antioksidan yang tinggi apabila dikaji menggunakan asai-asai potensi antioksidan penurunan ferik (FRAP), 2,2-azinobis (asid 3-etil-benzotiazolin-6-sulfonik) (ABTS), 2,2-difenil-1-pikrilhidrazil (DPPH) dan fosfomolibdat. Fermentasi *Rhizopus spp.* meningkatkan kapasiti antioksidan manakala pemprosesan hidroterma dan fermentasi yis menyebabkan pengurangan ataupun peningkatan yang tidak signifikan ($p>0.05$). Ekstraksi air dan metanol menghasilkan kapasiti antioksidan yang lebih tinggi. Kandungan asid fitik serta aktiviti-aktiviti perencatan enzim (tripsin dan α-amilase) yang tinggi telah dikurangkan atau disingkirkan sepenuhnya oleh semua kaedah pemprosesan. Pemprosesan hidroterma dan fermentasi *Rhizopus spp.* mengurangkan profil keterlarutan protein, kapasiti penyerapan air (KPA) dan kapasiti penyerapan minyak (KPM) manakala fermentasi yis meningkatkan sifat-sifat tersebut. Semua kaedah pemprosesan meningkatkan aktiviti emulsi (AE) dan kestabilan emulsi (KE) dan mengurangkan aktiviti pembuihan (AP) dan kestabilan pembuihan (KP). Kapasiti penggelan terendah (KPT) dikurangkan oleh semua kaedah pemprosesan. Sifat-sifat fungsian bergantung kepada kepekatan, pH dan kekuatan ionik. Secara keseluruhannya, jering mengandungi sifat-sifat fiziko-kimia, antioksidan, antinutrisi dan fungsian yang sangat baik. Parameter-parameter kualiti ini mengalami perubahan yang signifikan apabila diproses menggunakan kaedah pemprosesan domestik yang boleh diubahsuai untuk pembangunan produk makanan baru dan/atau bahan ramuan. Jenis pemprosesan yang dipilih untuk memproses jering bergantung kepada keperluan pengguna kerana setiap jenis pemprosesan membawa kesan-kesan yang berbeza terhadap kualiti jering.

EFFECTS OF DOMESTIC PROCESSING ON QUALITY OF JERING [*Pithecellobium jiringa* (L.)]

ABSTRACT

Pithecellobium jiringa L. (jering) is a non-conventional legume commonly consumed by people of the South-East Asia region. This study is specifically concerned with physicochemical, antioxidant, antinutritional and functional properties of jering and effects of domestic processing (hydrothermal and fermentation) on these quality parameters. Jering was subjected to boiling (21.0 ± 1.0 minutes), pressure cooking (121 °C, 0.2 MPa, 20 minutes), yeast (*Saccharomyces cerevisiae*) and *Rhizopus spp*. fermentation. Jering had high moisture content (58.55%), crude protein (14.19%), nitrogen free extract (NFE) (82.1%) and gross energy values (1662.49 kJ 100 g^{-1}) and low crude lipid level (1.45%). *Rhizopus spp*. fermentation improved crude protein and fiber contents. Hydrothermal processing and yeast fermentation increased the NFE and gross energy values. Jering exhibited high amino acid score (AAS) (92-250%) and significant levels ($p<0.05$) of sulphur containing amino acids (SAA). *Rhizopus spp.* and yeast fermentation improved amino acid profile and AAS. Fatty acids detected were primarily unsaturated fatty acids (54.73%). Hydrothermal processing and fermentation reduced the polyunsaturated/saturated fatty acids (P/S) ratio. Jering exhibited superior total phenolic content (TPC) and total flavonoids content (TFC). *Rhizopus spp.* fermentation significantly improved ($p<0.05$) TPC and TFC. Hydrothermal processing considerably reduced TPC (35-98%) and TFC (61-90%). Yeast fermentation also reduced TPC (74-94%) and TFC (83-94%). Tannin content was the highest in raw jering followed by boiled, pressure cooked and fermented jering.

Jering possessed high antioxidant activity when investigated via ferric reducing antioxidant potential (FRAP), 2,2-azinobis (3-ethyl-benzothiazoline-6-sulfonic acid) (ABTS), 2,2-diphenyl-1-picrylhydrazyl (DPPH) and phosphomolybdate assays. *Rhizopus spp.* fermentation increased the antioxidant activity while hydrothermal processing and yeast fermentation exhibited decrease or insignificant increase ($p>0.05$). Water and methanol extraction conferred higher antioxidant capacity. Phytic acid and enzyme (trypsin and α-amylase) inhibition activities were reduced or eliminated by all processing methods. Hydrothermal processing and *Rhizopus spp.* fermentation reduced while yeast fermentation improved the protein solubility profile, water absorption capacity (WAC) and oil absorption capacity (OAC). All treatments improved emulsion activity (EA) and emulsion stability (ES) and reduced foaming activity (FA) and foaming stability (FS). Least gelation capacity (LGC) was decreased by all treatments. Functional properties were dependent on concentration, pH and ionic strengths. Overall, jering confers good nutritional, antioxidant and functional properties. These quality parameters were significantly affected by domestic processing methods which can be suitably modified for development of new food products and/or ingredients. The choice of processing method for jering depends on the needs of the consumers as all processing methods brings about varying effects to the quality of jering.

CHAPTER 1

INTRODUCTION

1.1 Background

Legumes, edible fruits or seeds of pod-bearing plants of the family Leguminosae is a “boon” to human nutrition, not only due to their much highlighted nutritional benefits, implausible anti-oxidant properties and overall health improvement claims, but also for the fact that they are cheap and readily available in the diet patterns of people from the low-income groups in developing countries (Maninder et al., 2007; Tharanathan & Mahadevamma, 2003). Although a large number of legumes exists world over (approximately 20,000 species), the utilization of many of these legumes is mainly centered around kidney beans (*Phaseolus vulgaris*), soy beans (*Glycine max*), and cowpea (*Vigna unguiculata*) mainly due to commercialization and their adapted usage as food ingredients, novel food products and even for industrial purposes (Oboh et al., 1998; Khattab et al., 2009).

However, research interests revolving the exploitation of non-conventional legumes have increased in the past decade with the view of introducing novel food alternatives and/or increasing their commercial value. Various unconventional legumes such as rosary beans, African locust bean, jack beans, lupins, marama beans, *Mucuna pruriens*, Canavalia seeds and lima beans have been highlighted as they confer beneficial nutritional, antioxidant and functional properties as well as various physiological benefits especially in the prevention of metabolic, cardiovascular and stress induced immune-related diseases (Bhat & Karim, 2009; Bhat et al., 2008; Dini et al., 2005; Krupa, 2008; Lawal et al., 2007; Maruatona et al., 2010). The primary rationale for these intentions involves the outstanding nutritional characteristics of legumes which are seen as potential substitute for animal protein in developing and under-developed countries. This replacement is deemed necessary because animal protein is minimally available due to population growth, poor distribution and high cost which contributes to the protein energy malnutrition world over (Bhat & Karim, 2009; Tharanathan & Mahadevamma, 2003). Further, the global demand for animal protein is expected to double by 2020 and is projected to skyrocket by the year 2050, highlighting the need to exploit alternative sources to substitute the current protein sources (Boland et al., 2012; Myers & Kent, 2003). Such demands create room for the introduction of novel protein substitute especially plant protein. However, research efforts are still deemed insufficient as a large portion of legumes are still either unknown or underutilized in terms of consumption, maintaining the wide gap which still exists in exploring some of the non-conventional legumes confined to localized regions of the world.

Various efforts have been undertaken by researchers to battle problems of malnutrition caused by undernourishment or inadequate food intake of the poor population which includes improved food productivity, nutritional quality and food accessibility as well as development of novel post-harvest practices and sustainable food production systems (Nah & Chau, 2010). Parallel to that perspective, introduction of novel and/or re-establishment of previously known legumes may bring about advantages in terms of food productivity. Furthermore, the utilization of legumes which were previously hampered by the presence of anti-nutritional factors, minimal nutritional data, unknown health and medicinal benefits and difficulty in processing will largely improve as these quality parameters are tackled objectively.

Besides being eaten in their native forms, legumes are commonly processed via processing methods such as soaking, boiling, pressure cooking, sprouting and fermentation before consumption (Egounlety & Aworh, 2003). It must be noted that any form of processing causes significant transformation of physicochemical, antioxidant and functional properties of legumes as well as their sensory attributes, palatability, acceptability and safety (Piecyk et al., 2012; Subuola et al., 2012). Some of these alterations may have positive or negative effects on the overall quality and acceptability of legumes, depending on the end usage and targeted consumers. As such, there always exists a need to thoroughly understand the impact of domestic processing upon the quality parameters of legumes that can eventually escalate their utilization. Furthermore, the ingestion of legumes is often associated to the ingestion of antinutritional elements such as phytates, antinutritional proteins such as lectins and enzyme inhibitors, all of which necessitate some form of processing before consumption (Roy et al., 2010). On this note, the line of research has been extended further to various processing methodologies of legumes which alter the overall quality and acceptability of legumes. These processing methods are applied upon legumes to improve their overall quality in terms of palatability, nutrient availability and reduction of antinutritional component (e.g. enzyme inhibitors).

Domestic cooking methods are practiced for ages to improve the quality and safety of food throughout the world. According to the report by Mensah & Tomkins (2003), the acceptance of household technologies for food preparation tends to be replaced by modern and more convenient fast-food preparations. However, they have also reported that there is an increasing trend in the usage of domestic food processing as a method to provide safe and quality complementary foods in instances where the basic diet is not able to be changed due to economic reasons. Domestic processing is deemed important in preparation of legumes because besides improving the nutritional qualities while eliminating and/or reducing the antinutritional properties that are present, it is the most utilized and pragmatic method of food processing.

Domestic processing ought to be given a considerable degree of attention, in par with other food processing methodologies that utilize state-of-the-art technologies such as microwave cooking, ultrasound, pulse-electric field and irradiation (Pereira & Vicente, 2010). This is simply because legumes play a crucial role in the consumption pattern of poor population in developing and under-developed countries. Legumes cater to people with low-income as it is relatively cheaper. As such, new or existing simple domestic processes that can be easily replicated at home will not augment the cumulative cost for food preparation and purchase.

1.2 Research focus

Given the current scenario and research needs, *Pithecellobium jiringa* L. also known as jering in Malaysia has been identified as a non-conventional legume with good nutritional, antioxidant and functional potential. Jering is consumed as a type of *ulam* (salad vegetable) that is popular mostly for its therapeutic values such as purification of blood, overcoming dysentery and the prevention and/or treatment of diabetes (Ong & Norazlina, 1999; Roosita et al., 2008). Even though, various medicinal and health claims revolve around the intake of this legume, the utilization of jering is generally confined to traditional purposes. The motivation for this research stems from the fact that reports regarding the physicochemical, antioxidant and functional benefits of raw jering are extremely scarce; presenting a research gap which needs to be addressed. As such, the primary focus of this research revolves around the analysis of physicochemical, antioxidant, antinutritional and functional properties of jering— properties which are deemed necessary to enhance the utilization of jering for food product development and/or application.

Jering is commonly consumed in the South-East Asia region in its native form or they undergo some manner of processing especially simple domestic processes prior to consumption, e.g., boiled, cooked as accompaniment with rice and/or consumed as decoction in heated/non-heated water (Ong & Norazlina, 1999). In view of the fact that jering as a legume is often subjected to some form of processing, the effects of domestic processing (boiling, pressure cooking and fermentation) on the physicochemical, antioxidant and functional properties of the legume were analyzed. The utilization of bioprocess, for example fermentation, to improve the physicochemical, antioxidant and functional quality of legumes have been gaining popularity. Furthermore, fermented legumes present new food application and development and consequently elevate the marketability and acceptance of the legume. As such, *Saccharomyces cerevisiae* and *Rhizopus spp.* fermentation of jering have been seen as potential methods to elevate the nutritional benefits and overall quality of jering while reducing the antinutritional qualities associated with the consumption of legumes.

1.3 Objectives

The general aim of the research is to analyze the effects of domestic processing namely hydrothermal (boiling and pressure cooking) and fermentation (yeast and *Rhizopus spp*.) on the quality parameters of jering in terms of physicochemical, antioxidant, antinutritional and functional properties. The main objectives of this research are as follows.

Objectives:

1. To analyze the physicochemical, antioxidant, antinutritional and functional properties of jering.

2. To study the effects of domestic processing, i.e., boiling, pressure cooking and fermentation (*Saccharomyces cerevisiae* & *Rhizopus spp*.) on the physicochemical, antioxidant, antinutritional and functional properties of jering.

3. To compare the relative significance of boiling, pressure cooking and fermentation (*Saccharomyces cerevisiae* & *Rhizopus spp*.) on the physicochemical, antioxidant, antinutritional and functional properties of jering.

CHAPTER 2

LITERATURE REVIEW

2.1 Legumes – A new, old remedy

Legumes are the edible fruits or seeds of pod-bearing plants of the family Leguminosae or Fabaceae ranging from small annual herbs, through woody shrubs to giant perennial trees, comprising approximately 700 genera and 20,000 species (Doyle & Luckow 2003; Hong & Bhatnagar, 2007; Maninder et al., 2007). They have been extensively used throughout the world especially for the purpose of consumption either in their native forms, processed or as other food ingredients. Legumes have been regarded as one of the most nutritious food available in the world today. Subuola et al. (2012) classified legumes as:

1. Pulses or grain legumes (low fat peas and beans e.g. *Phaseolus vulgaris* and *Vicia faba*)
2. Oilseeds (soybean, groundnut & hazelnut)
3. Forage leguminous (*Vigna unguiculata*, *Lablab purpureus* & *Mucuna pruriens*)

Although, legumes have been used as food for many centuries, their unwavering influence on nutrition and health have sparked the interest of researches only for the past few decades (Akillioglu & Karakaya, 2010). For example, cultivation of dry pea in the Middle East was recorded almost 9000 years ago (Roy et al., 2010). Legumes such as lentils, beans, peas and nuts are known to exude nutritional benefits in terms of protein, carbohydrate, dietary fiber, micronutrients, antioxidants, vitamins and minerals (Bhat & Karim, 2009; Donkor et al., 2012;

Duenas et al., 2006; Habiba, 2001; Sridaran et al., 2012; Valdez-Ortiz et al., 2012). They have been extensively used as part of the traditional diet in many parts of the world i.e. Asia, Africa and Middle East. Pulses comprise, on average, 3% of total calorie intake in developing countries, which includes 4% in Sub-Saharan Africa, 3% in South Asia, Latin America and the Caribbean region, 2.5% in Middle East and North Africa and <1% in Central Asia (Akibode & Maredia, 2011). In Malaysia, legumes and pulses were rated with food use frequency score of 66.2 among estate workers, which is relatively a high value (Chee et al., 1996). However, the usage of legumes is relatively inferior in developed countries. This can be seen in the daily per capita consumption of bean products in Asia which is 110 g compared to about 9 g in the United States (Messina, 1999). However, this trend is quickly changing given the uprising nutritional benefits of legumes that are currently being brought to light.

Legumes have been widely used in food development and/or applications such as in pastas and noodles, infant food formulations, meat products, extruded products and baked goods (Boye et al., 2010). They also play a very important role in lactovegetarian and vegan diets as a source of protein substituting meat and eggs (Fraser, 2009). In many parts of the world, legumes are the main source of dietary protein and exude approximately 14 MJ/kg of usable energy (Siddhuraju et al., 2002). Approximately 65% of global protein supply consists of plant protein, whereby nearly half of that is from cereals and legumes (Mahe et al., 1994).

High levels of protein in legumes form the basis of animal protein substitution in underdeveloped and developing countries where animal protein is deemed expensive and/or scarce (Bhat & Karim, 2009; Boland et al., 2012; Dini et al., 2005; Sridaran et al., 2012). They also function to complement the amino acid deficiency of cereals (rice and maize) and are seen eaten together in many parts of the world such as Latin America, Eastern Africa and Brazil (Broughton et al., 2003). Legumes carry an image of simple or non-luxury food, favoured by people from the lower income group thereby known as “the poor man’s meat” (Mesinna, 1999). Moreover, legume crops are seen to potentially reduce poverty, improve human health and nutrition, and enhance ecosystem resilience all at once which are the developmental goals established by the Consultative Group on International Agricultural Research (CGIAR) (Akibode & Maredia, 2011). Legumes have been found to play a crucial role in human nutrition as they confer beneficial nutritional, antioxidant and functional properties as well as various physiological benefits especially in the prevention of metabolic, cardiovascular and stress induced immune-related diseases e.g. various cancers, HDL cholesterol and type-2 diabetes (Adebamowo et al., 2005; Krupa, 2008; Mathers, 2002; Roy et al., 2010).

2.2 Jering as ulam (salad vegetable)

Ulam is a group of salad vegetables, consumed traditionally by the Malay community in the South-East Asia region. They are usually eaten either raw or cooked to be eaten as accompaniment with rice and condiments. There are more than 120 species of plants consumed as ulam, which consists of leaves, shoots, rhizomes, seeds and fruits such as *Pithecellobium confertum* (keredas), *Parkia speciosa* (petai), *Centella asiatica* (pegaga) and *Murraya koenigii* (curry Leaf) (Fatimah et al., 2012; Faridah et al., 2006; Lay et al., 2007). The utilization of ulam is not only due to their flavor properties but also revolves around various traditional usages especially in terms of medicinal properties (Fatimah et al., 2012). Ulam is known for their outstanding protein, vitamin and mineral contents as well as antioxidant and phenolic properties (Reihani & Azhar, 2012).

Pithecellobium jiringa L. also known as jering in Malaysia, djengkol in Indonesia, krakos in Cambodia and niang-yai in Thailand are consumed traditionally by the people of the South-East Asia region. Jering is eaten as a type of *ulam* that is popular mostly for its therapeutic values such as purification of blood, overcoming dysentery and the prevention and/or treatment of diabetes (Ong & Norazlina, 1999; Roosita et al., 2008). Jering grows in pods (3-9 beans/pod) on trees of 25-30 meters in height and possess a wide, round shaped dark brown colored seed coat inside which the edible green coloured cotyledon is present (Figure 2.1). Jering is available throughout the year in the local wet market.

Figure 2.1. *Pithecellobium jiringa* (L.) (jering)

Research revolving jering and its usage, application and development in food systems are extremely scarce due to the localized usage of jering and minimal commercialization of this indigenously consumed legume. Although jering has been deemed useful in terms of prevention and/or treatment of diseases, the consumption of jering are mostly in its native form. The cotyledon portion of jering is often eaten raw or consumed as decoction in heated or non-heated water (Ong & Norazlina, 1999; Roosita et al., 2008). It can be conveniently noted that jering is hardly seen on the shelves of the current market as ingredients or other food forms such as snacks, condiments, baked goods or extruded products.

Data on nutritional, antioxidant, functional and anti-nutritional components of jering and the effects of hydrothermal processes (current practice) is extremely inadequate. Furthermore, jering as legumes have not been subjected to various forms of bioprocesses (e.g. fermentation) which are known to improve many aspects of nutrition and palatability of legumes. This too limits the expansion of novel food application and development which utilize jering. It is therefore definitely safe to characterize jering as a legume that requires fundamental research in the aspects of nutritional, antioxidant and functional characteristics.

2.3 Domestic processing of legumes- A common practice

Legumes having been consumed for centuries generally undergo various processing before consumption. Processing methodologies especially simple domestic processing such as, dehulling, soaking, boiling, pressure cooking, germination and fermentation have been applied for legume preparation (Khandelwal et al., 2010). People especially in the developing and underdeveloped countries use these methods for they are relatively simple and do not require advanced processing equipments, space and skills. These domestic processing methods are applied upon legumes to improve their overall quality in terms of palatability and nutrient availability besides inducing impediment of anti-nutritional components (e.g. enzyme inhibitors). Processing of legumes is deemed advantageous by Subuola et al. (2012) whereby they:

a) enhance edibility and digestibility
b) improve nutritional quality
c) impede and/or remove anti-nutritional factors
d) elevate consumer appeal and acceptability
e) extend shelf-life
f) improve safety and quality by eliminating pathogenic microorganisms

To understand the effects of domestic processing on the various quality parameters of legumes, the common processing methodologies of legumes i.e. dehulling, soaking, boiling, pressure cooking, fermentation and germination need to be explored further.

2.3.1 Boiling

Boiling of legumes is the most common method of legume processing for consumption purposes. Boiling of legumes is a very straightforward process whereby raw legumes or legumes subjected to pre-treatments such as soaking and/or dehulling are heated in boiling water to achieve the required overall quality. Parameters associated to boiling such as time and temperature very much depends on the type of legume being treated (Alajaji & El-Adawy, 2006). For example, the time needed for cooking of legumes relies on the minimum cooking time of the particular legume

(Sridaran et al., 2012). As such data on the minimum cooking time of legumes will be beneficial, whereby overcooking which results in wastage of time and resources can be avoided. Boiling results in various alterations of the physical characteristics and chemical compositions of legumes especially in their nutritional, phenolic, antinutritional and functional properties (Rehman & Shah, 2005; Wang, Hatcher, Tyler, Toews, & Gawalko, 2010; Xu & Chang, 2008). Boiling, a hydrothermal processing method also brings about many changes to the physicochemical properties of legumes which in turn affect their functional properties such as emulsion activity, protein solubility and gelation capacity (Ma et al., 2011).

2.3.2 Pressure cooking

Pressure cooking is the cooking of food materials in a pressure cooker, an airtight container that traps the steam that would otherwise be released upon normal cooking (Horobin, 2007). The device was invented by Denis Papin, a French physicist in the year 1969 as a digester whereby the high temperature and pressure of the pressure cooker allows food to be cooked at higher intensities for a shorter period of time (Horobin, 2007). The concept of high pressure cooking has been extended to industrial usage via the utilization of autoclave for food processing. Blaszczak et al., (2007) stated that pressure cooking is used to overcome the shortcomings of conventional cooking methods and is utilized to improve food safety by eliminating and/or reducing harmful microorganisms while minimizing the impact on the nutritional quality of legumes.

Briones-Labarca et al. (2011) elucidated that pressure cooking results in better retention of nutritional and functional properties, for high temperature allows for a more efficient penetration of food materials within a shorter period of time. Many reports have investigated the effect of pressure cooking on legumes and reported their effects on nutritional components, phenolic contents and antinutritional properties (Blaszczak et al., 2007; Duhan et al., 2002; Khatoon & Prakash, 2006; Saikia et al., 1999).

2.3.3 Fermentation

Fermentation is traditionally defined as the breakdown of organic substrate via enzymatic reactions in which the final hydrogen acceptor is an organic compound (Sanchez, 2008). Fermentation is a process whereby energy is obtained from the metabolism of organic compounds without the involvement of an external oxidizing agent (Bourdichon et al., 2012). This bioprocess has been used by people for thousands of years and has survived till today. For example, reports have shown that fermentation has been used since the Neolithic period (10 000 BC) (Bourdichon et al., 2012). Some even denoted that primitive cheese and sour milk were produced in Mesopotamia in 6000 BC while wine was being consumed as early as 4000 BC (Sanchez, 2008). Reports have also shown that fermented food from China such as soy sauce and miso originated several thousand years ago (Deshpande et al., 2000).

Fermentation is termed to be very cost efficient and economical in terms of food processing, leading to the widespread usage in developing countries (Egounlety, 2002). Fermentation is used extensively in producing many different food products with unique taste and nutritional benefits world over. As such many reports are available on the usage of fermentation technology to process food. This processing methodology is often used to improve palatability, nutritional value, cooking properties, food safety, extend the shelf life of foods and aid in the removal of toxicants from food materials (Deshpande et al., 2000; Gaggia et al., 2011; Ross et al., 2002; Steinkraus, 1997).

Fermentation can be classified based on many terms such as:

1. Type of substrate used: meats, seafoods, dairy cereals, root crops, legumes, fruits and vegetables (Deshpande et al., 2000)
2. Type of microorganisms used and end product: yeast for alcoholic fermentation, *Acetobacter* for vinegars, *Lactobacilli* for milk, pickles and fermented fish or meat and molds for plant protein (with or without *lactobacilli* and yeasts) (Campbell-Platt, 1987)
3. Type of fermentation: fermentation producing textured vegetable protein as meat substitutes from legumes/cereal (e.g. Indonesian tempe), high salt/savory meat, sauce and paste fermentations (e.g. soy sauce, Malaysian budu and belacan) (Steinkraus, 1997); lactic acid fermentation (e.g. cheese, Korean Kim-chi, Malaysian tempoyak), alcoholic fermentation (e.g. beer, wine), acetic acid fermentation (e.g. apple cider and wine vinegar), alkaline fermentation (e.g. Nigerian dawadawa, Indian kenima); leavened breads (Western yeast and sourdough breads) (Steinkraus, 1997)
4. Fermentation process: submerged or solid state fermentation (Martins et al., 2011).

These classifications may not be distinctive as some food products may use more than one type of fermentation or fall into several classes. However, they may be used by investigators to classify and discuss specific food items more systematically.

Fermentation of legume has been employed in many parts of the world (i.e. Southeast Asia, Africa and some Eastern regions) for production of a vast variety of food products (Reddy et al., 1983). This bioprocess is known to improve acceptability of consumers by enhancing flavour, colour and texture of legumes (Subuola et al., 2012). Table 2.1 shows some legume-based fermented food in several regions of the world.

Based on the tabulated data, it can be said that most fermentation revolves around legumes such as soybean, black gram and Bengal gram. Fermentation of indigenous or underutilized legumes such as *Canavalia cathartica, Canavalia maritima*, jering and petai are indeed rare. However, several reports have exploited the fermentation of legumes and consequently the influence fermentation imposes on their nutritional and functional properties (Adebowale & Maliki, 2011; Elyas et al., 2002; Lee et al., 2008; Udensi & Okoronkwo, 2006). Consequently, the usage of fermentation to improve the overall quality of legumes was highly recommended.

Fermentation was also seen to alter the bioactive components of legumes and consequently their antioxidant properties (Martins et al., 2011). This indicates that implementation of fermentation techniques upon new found legumes will lead to the development of new food product which consequently expands food varieties available for consumption.

Table 2.1
Legume-based fermented food in several regions of the world.

Food product	Legumes involved	Microorganisms	Production region
Iru	Locust beans	*Bacillus pumilus, B. licheniformis, B. subtilis, B.* spp.	Africa
Dhokla	Bengal gram	*Leuconostoc mesteroides, Lactobacillus fermenti, Streptococcus faecalis*	India
Dosa	Black gram	*Leuconostoc mesenteroides, Lactobacillus delbrueckii, Lactobacillus fermenti, Streptococcus faecalis, Bacillus* spp., *yeasts*	India
Idli	Black gram	*Leuconostoc mesteroides, Lactobacillus delbrueckii, Lactobacillus fermenti, Lactobacillus lactis, Streptococcus lactis, Pediococcus cerevisae, Streptococcus faecalis,* yeasts	India, Sri Lanka
Khaman	Bengal gram	*Leuconostoc mesteroides, Lactobacillus fermenti, Lactobacillus lactis, Pediococcus acidilactici, Bacillus* spp.	India
Miso	Soybeans	*Aspergillus oryzae, Pediococcus acidilactici, Pediococcus halophilus,Micrococcus* spp., *Streptococcus faecalis, Saccharomyces rouxii* and other yeasts	East Asia, Japan, China
Natto	Soybean	*Bacillus natto*	Japan
Soy sauce	Soybean	*Aspergillus oryzae, Saccharomyces rouxii, Pediococcus halophilus, Lactobacillus delbrueckii*	Japan, China, Taiwan
Sufu	Soybean	*Actinomucor elegans, Mucor hiemalis, Mucor silvaticus, Mucor* spp.,	China, Taiwan
Tauco	Soybean	*Rhizopus oligosporus, Aspergillus oryzae*	Indonesia, West Java
Tempe	Soybean	*Rhizopus oligosporus, Rhizopus oryzae*	Indonesia, Malaysia
Waries	Black/Bengal gram	*Saccharomyces cerevisiae, Candida krusei,* acid producing bacteria	India, Pakistan

Adapted from: Beuchat (2008) and Deshpande et al. (2000)

2.4 Effects of domestic processing

2.4.1 Effects of domestic processing on proximate composition of legumes

Domestic processing such as dehulling, soaking, boiling, pressure cooking, fermentation and germination significantly alters the nutritional profile of legumes in terms of the proximate components, i.e., crude protein content, crude lipid, crude fiber and ash. The trends in which these modifications take place require detailed analysis as these components are deemed crucial in determining the nutritional benefits of food materials. Table 2.2 shows the effects of several domestic processing on the proximate components of various legumes analyzed by previous workers.

Legumes are known to possess relatively high amounts of protein, whereby grain legumes reportedly contain 20-30% while bean seeds contain 17-39% of protein (Hedley, 2001; Holse et al., 2010; Krupa, 2008; Siddhuraju et al., 2002). Legumes are subjected to various domestic processing methodologies that alter the protein content such as soaking, roasting, germination, fermentation, boiling, pressure cooking and dehulling (Alonso et al., 2000; Avola et al., 2012; Siddhuraju et al., 2002; Wang et al., 2009, 2010). The trend of protein content alteration differs among the many legumes investigated, whereby drastic increase or decrease occurs concurrently.

Table 2.2 (1)

Effects of domestic processing on proximate components of legumes (*% increase or reduction)

Legume	Processing	Protein	Fat	Crude Fiber	Ash	Starch	References
Chickpea	Cooking	4.0	30.2	0.3	31.1	33.0	Avola et al. (2012)
		15.1	0.6	14.0	10.5	7.0	de Almeida Costa et al. (2006)
		2.4				1.6	Rehman & Shah, 2005
	Soaking					5.2-24.8	Rehman (2007)
	Boiling	1.8		20.9	5.4	1.1	Alajaji & El-Adawy (2006)
	Germination	9.5	5.0		7.6	9.2	Ghadivel & Prakash (2007)
	Dehulling	23.1	4.6		10.8	2.6	
Desi chickpea	Cooking	3.3	15.5		14.3	1.7	Wang et al. (2010)
Kabuli chickpea		5.8	14.8		23.5	3.4	
Black gram	Cooking					30.5-67.4	Rehman (2007)
		2.5				2.7	Rehman & Shah (2005)
	Soaking					7.0-29.8	Rehman (2007)
Green gram	P. Cooking	3.0			3.4		Khatoon & Prakash (2006)
	Germination + P.Cooking	0.8			0.0		
	Germination	5.1	6.2		3.7	9.4	Ghadivel & Prakash (2007)
	Dehulling	7.9	37.2		6.0	4.1	
Bengal gram	P. Cooking	3.8			12.0		Khatoon & Prakash (2006)
	Germination + P.Cooking	2.0			12.0		
Horse gram	P. Cooking	4.3			16.0		
	Germination + P.Cooking	0.8			14.3		
Cowpea	Germination	5.8	7.8		2.5	7.6	Ghadivel & Prakash (2007)
	Dehulling	10.5	27.6		4.1	2.6	

*Note: ▨ Shaded values indicate % increase

Table 2-2(2). Continued

Legume	Processing	Protein	Fat	Crude Fiber	Ash	Starch	References
Canavalia cathartica	Roasting	7.8	23.7	7.0	1.2		Seena et al. (2006)
	P. Cooking	12.8	26.3	34.4	6.3		
Canavalia ensiformis	Cooking	2.6	0.0	51.1	26.5		Agbede & Aletor (2005)
	Roasting	12.7	16.0	5.7	2.7		
	Dehull + cooking	16.7	2.5	81.4	13.3		
	Dehull + roasting	15.3	8.1	88.0	26.5		
Mucuna pruriens	Cooking	5.1	25.2	28.2	35.8		
	Roasting	13.8	3.6	21.1	11.3		
	Dehull + cooking	10.2	9.0	59.2	24.5		
	Dehull + roasting	1.8	7.2	70.4	22.6		
Lentil varieties:							
Laird	Cooking	1.1			28.5	5.1	Wang et al. (2009)
Sovereign		2.3			25.1	5.5	
Richlea		3.2			33.3	3.8	
Vantage		2.8			27.9	4.7	
Eston		1.8			23.6	4.8	
Milestone		4.1			35.9	7.4	
Robin		3.5			22.0	5.6	
Blaze		3.8			21.4	3.0	
Silvina		13.8	9.8	16.7	11.4	9.6	de Almeida Costa et al. (2006)
Egyptian	Boiling	1.5	10.0	1.6	2.9	2.4	Hefnawy (2011)
Indian	Germination	7.5	12.4		6.6	10.2	Ghadivel & Prakash (2007)
	Dehulling	11.7	34.8		12.7	2.4	

*Note: ▨ Shaded values indicate % increase

Table 2-2(3). Continued

Legume	Processing	Protein	Fat	Crude Fiber	Ash	Starch	References
White Bean	Soaking	2.0				7.9	Aguilera et al. (2009)
	Soaking + Cooking	14.3				16.4	
Pink-mottled cream bean	Soaking	0.4				6.6	
	Soaking + Cooking	23.3				12.0	
Kidney beans:							
Red kidney bean	Soaking					6.1	Rehman et al. (2001)
	Soaking + Cooking					30.4	
	Soaking + P.Cooking					39.9	
	Cooking	2.0				0.9	Rehman & Shah (2005)
Dark red kidney bean	Cooking	4.3	6.3		22.7	2.4	Wang et al. (2010)
White kidney bean	Soaking					10.8	
	Soaking + Cooking					36.0	
	Soaking + P.Cooking					52.7	
	Cooking	0.9				3.3	
Pigeon pea	Fermentation (natural)	3.7-5.8	16.1-38.3	22.5-37.7	6.7-12.2		Adebowale & Maliki (2011)
Tigernut types:	Germination						Chinma et al. (2009)
Brown		13.6	12.4	59.8	22.9	3.9	
Yellow		17.3	10.3	52.9	16.7	4.3	
African locust bean	Fermentation (natural)						Azokpota et al. (2006)
	Afitin (Product)	1.9-5.4	7.6-15.0	27.3-227.3	5.2-10.3		
	Iru (Product)	0.7-5.3	4.2-13.6	62.5-181.3	6.3-31.3		
	Sonru (Product)	1.0-6.3	3.3-13.0	83.3-258.3	5.0-21.3		
Pearl millet	Fementation (natural)	2.8-22.2					Elyas et al. (2002)

*Note: ▨ Shaded values indicate % increase

Table 2-2(4). Continued

Legume	Processing	Protein	Fat	Crude Fiber	Ash	Starch	References
Black turtle bean	Cooking	3.8	12.2		24.7	0.9	Wang et al. (2010)
Cranberry bean		6.6	21.2		15.3	5.4	
Great Northern		3.4	18.0		15.5	2.2	
Pinto bean		6.4	32.7		15.7	3.4	
Small red bean		5.7	7.4		30.5	6.9	
White pea		1.3	15.9		20.3	17.5	
Sesbania aculeata	Soaking	3.5	1.2	8.0	1.9		Siddhuraju et al. (2002)
Sesbania rostrata		3.9	2.6	12.1	7.5		
Sesbania cannabina		0.3	0.5	0.8	5.6		
Mung bean		0.4	8.8	2.5	5.8		
Pea (Maria)	Cooking	8.2	13.3	13.7	15.3	11.6	de Almeida Costa et al. (2006)
Common bean (IAC carioca Ete)		5.7	1.2	26.8	5.3	10.3	
Mung Bean	Dehulling	0.4	1.6	11.4	4.3	0.1	Mubarak (2005)
	Soaking	1.8	1.1	3.9	11.7	0.3	
	Germination	9.1	21.6	5.0	5.6	8.7	
	Boiling	2.5	1.6	2.8	5.6	0.5	
Navy Bean	Soaking	2.4				20.4	Alonso et al. (2000)
	Cooking	15.0				46.3	
Benniseed	Roasting	9.4	11.6	22.9	13.4		Yusuf et al. (2008)
Bambarra groundnut		10.6	73.2	8.8	43.4		
Mucuna cochinchinensis	Fermentation (natural)	2.4	0.0	21.9	22.0		Udensi & Okoronkwo (2006)
	Germination	0.7	50.0	11.7	12.2		

*Note: ▨ Shaded values indicate % increase

Table 2-2(5). Continued

Legume	Processing	Protein	Fat	Crude Fiber	Ash	Starch	References
Phaseolus vulgaris variety:							
Castellfollit	Soaking	4.1				16.9	Pujolà et al. (2007)
	Cooking	12.5				52.0	
Faba	Soaking					20.0	
	Cooking	15.0				43.8	
Ganxet10	Soaking	1.4				23.2	
	Cooking	2.1				45.0	
Ganxet11	Soaking	3.2				14.3	
	Cooking	1.0				39.6	
Ganxet50	Soaking	12.5				23.7	
	Cooking	9.1				44.9	
Genoll de Crist	Soaking	7.7				16.6	
	Cooking	18.3				45.2	
Planchada	Soaking	5.9				16.9	
	Cooking	12.7				49.1	
Tolosa	Soaking	3.9				12.2	
	Cooking	21.4				54.3	
Athropurpurea	Dehulling	6.3					Alonso et al. (2000)
	Soaking	0.4					
	Germination	1.26-2.94					
Faba var Equina	Dehulling	15.9					
	Soaking	0.4					
	Germination	0.74-2.22					

*Note: ▨ Shaded values indicate % increase

Cooking has generally increased the total protein content of legumes such as chickpea, black gram, lentil (Laird & Silvina variety), black turtle beans, Faba beans, navy beans, pinto beans and pea from 1-21% (Avola et al., 2012; de Almeida Costa et al., 2006; Pujolà et al., 2007; Wang et al., 2009, 2010). The wide range of the values may be due to varying protein complexes and consequently their properties that are present in the respective legumes. The increase in total protein content upon cooking is attributed to the loss of soluble solids, a common occurrence during legume processing that alters the total solid content proportionately (Wang et al., 2009). Thus it can be said that the gruel solid loss of the legumes investigated governs the total protein content of legume seed depending on the species and processing parameters applied. However, others reported a decrease in total protein content of white bean, pink-mottled cream bean, *Canavalia ensiformis* and *Mucuna pruriens* (Aguilera et al., 2009; Agbede & Aletor, 2005). Hydrothermal processing such as boiling and pressure cooking also decreases the protein content of legumes (Agbede & Aletor, 2005; Alajaji & El-Adawy, 2006; Hefnawy, 2011; Khatoon & Prakash, 2006; Mubarak, 2005; Seena et al., 2006).

Another processing technique which involves heating includes roasting which impedes protein contents of legumes such as *Canavalia cathartica*, *Canavalia ensiformis*, *Mucuna pruriens*, bambarra groundnut and benniseed (Agbede & Aletor, 2005; Seena et al., 2006; Yusuf et al., 2008). The leaching of soluble protein into water and partial removal of amino acids and other nitrogenous compounds on heating cause such reductions (Rehman & Shah, 2005). Furthermore, heating induces denaturation of protein structure due to unfolding and disorganization of bond within the protein molecules (Harvey & Ferrier, 2011). Awuah et al. (2007) denoted that thermal degradation of protein occurs in two steps, namely the modifications of