UNIVERSITI PUTRA MALAYSIA

EFFECTS OF COAGULANTS, PROCESSING VARIABLES AND MILKY EXTRACT OF KENAF SEED-TO-SOYBEAN RATIOS ON THE PHYSICOCHEMICAL PROPERTY AND TEXTURE PROFILE OF KENAF (Hibiscus cannabinus L.) SEED-BASED TOFU

IBRAHIM SHAFA'ATU GIWA

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By

IBRAHIM SHAFA'ATU GIWA

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

January 2021

DEDICATION

With gladness, I dedicated this thesis to my beloved husband; Engineer Abdulwaheed Olatunji and to my lovely girls; Fatimah, Aisha and Zainab Abdulwaheed Usman. May Allah increase you in wisdom and grant you success in this world and in the hereafter.

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

EFFECTS OF COAGULANTS, PROCESSING VARIABLES AND MILKY EXTRACT OF KENAF SEED-TO-SOYBEAN RATIOS ON THE PHYSICOCHEMICAL PROPERTY AND TEXTURE PROFILE OF KENAF (*Hibiscus cannabinus* L.) SEED-BASED TOFU

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Chairman : Associate Professor Roselina Karim, PhD
Faculty : Food Science and Technology

Kenaf (*Hibiscus cannabinus*) is a multipurpose herbaceous plant of economic significance. Attention on the kenaf plant has focused mainly on the stem for fiber-based industries. Also, the leaves have received little applications in herbal medicine, while the seed has been underutilised despite its high nutritional value especially as raw material and/or ingredient for the food sector. This study attempted to value-add kenaf seed as raw material for tofu production. In view of this, the objectives of this study were (i) to determine the effects of soaking temperatures on hydration time, microstructure, chemical composition of the kenaf seed and the physicochemical quality of its milky extracts; (ii) to evaluate the effects of coagulants and processing variables on the quality of kenaf seed tofu; (iii) to improve the quality of kenaf seed tofu by partly substituting kenaf seed with soybean; and (iv) to investigate the mechanism of coagulation of kenaf seed tofu and kenaf seed-soybean tofu blend in comparison to soybean tofu. Results on the effects of soaking temperatures study revealed that raising the soaking temperature of water from 25 to 65 ^{o}C significantly increased the rate of water absorption from 0.009 to 0.068 min^{-1}, and subsequently decreased the soaking time from 616 to 160 min. However, increased in the soaking temperature had no significant effect on the proximate composition of the kenaf seeds and the milky extracts; but, soaking treatment in combination with extraction process significantly reduced the phytic acid, tannic acid and trypsin inhibitors concentrations from 2.74 %, 0.082 mg/mL and 11.18 mg/g of the un-soaked seed to 1.94-2.11 %, 0.031-0.052 mg/mL and 9.24-10.34 mg/g in milky extracts, respectively. The result of screening stage during the characterisation phase of kenaf seed tofu development indicated that the main and interactions effects of seed-to-water ratio for extraction of kenaf seed milky extract, coagulant types and concentrations, and temperature of milky extract at the point of addition of coagulant significantly affected the physicochemical property and texture profile analysis of the kenaf seed tofu. The results of the optimisation phase of the kenaf seed tofu production indicated that the optimum setting condition of coagulants and soaking temperature of kenaf seed for production of optimum tofu are by soaking the kenaf seed at 25 ^{o}C (ambient temperature) and addition of 1.00 g/% potash as the coagulating agent. At this optimised condition, the yield of tofu was 64.69 g/100g, whereas the hardness, chewiness, springiness and cohesiveness tofu properties were 10130 g, 944.90, 0.64 mm and 0.19, respectively. Substitution of kenaf seed with soybean at five different ratios of kenaf seed-to-soybean (K-S) of 50:50, 60:40, 70:30, 80:20 and 90:10 were found to increase the tofu yield significantly as the amount of soybean in the tofu blend was increased. The order of increment in the yield was 90K:10S (66.24-89.84 g/100g) < 80K:20S (88.89-129.67 g/100g) < 70K:30S (101.53-134.19 g/100g) < 60K:40S (152.19-197.32 g/100g) < 50K:50S (158.76-204.61 g/100g). The result of the finding showed that the protein content of the K-S tofu was significantly increased from 36.17 g/100g in 100 % kenaf seed (100%K) tofu to a range of 40.84-45.36 g/100g in the tofu blend. Beside that, the K-S tofu made from blend of kenaf seed to soybean in the ratios of 50:50, 60:40 and 70:30 had similar protein content with 100 % soybean (100%S) tofu, but a significantly higher in fat content of 16-30 % increment. The ratio of total essential amino acid to total amino acid in the K-S tofu was significantly improved from 35 % in 100%K tofu to 46 % in the K-S tofu. The scanning electron microscopic images of the K-S tofu revealed that increasing the proportion of soybean in the tofu blend produced a tofu with homogeneous, denser, continuous and consistent network of smaller pore sizes that favours water entrapment within the gel matrix. The best K-S tofu can be produced from 70K:30S blend without compromising the textural profile and physicochemical properties. The mechanism of coagulation of the tofu showed that 100%K tofu had no disulphide (-S-S-) bond and this accounted for the loose nature of the curd. Furthermore, the 100%K tofu had a slower coagulation rate with a significantly lower final storage modulus (G'_f) of 0.41 Pa. However, substitution of 30 % of the kenaf seed with soybean brought about formation of -S-S- bonds, including an improvement in the coagulation rate with a G'_f of 1.13 Pa. Likewise, 30 % substitution of kenaf seed with soybean decreased the coagulation temperature from 75 ^{o}C in 100%K tofu to 71 ^{o}C in the K-S tofu. The present of β-sheet structure in all the tofu studied accounted for the hardness characteristic of the tofu.

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

KESAN KOAGULAN, PEMBOLEHUBAH PEMPROSESAN DAN NISBAH EKSTRAK SUSU BIJI KENAF KEPADA KACANG SOYA TERHADAP SIFAT FISIKOKIMIA DAN PROFIL TEKSTUR TAUHU BERASASKAN BIJI KENAF (*Hibiscus cannabinus* L.)

Oleh

IBRAHIM SHAFA'ATU GIWA

Januari 2021

Pengerusi : Profesor Madya Roselina Karim, PhD
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Kenaf (*Hibiscus cannabinus*) adalah tumbuhan herba serbaguna yang mempunyai kepentingan ekonomi. Perhatian terhadap tumbuhan kenaf telah tertumpu terutamanya pada batang untuk industri berasaskan serat. Daunnya juga tidak banyak digunakan dalam perubatan herba, manakala bijinya pula kurang dimanfaatkan walaupun mempunyai nilai nutrisi yang tinggi terutama sebagai bahan mentah dan/atau ingredien untuk sektor makanan. Kajian ini mencuba untuk menambah nilai biji kenaf sebagai bahan mentah untuk pengeluaran tauhu. Sehubungan dengan itu, objektif kajian ini adalah (i) untuk menentukan kesan suhu rendaman ke atas tempoh penghidratan, struktur mikro, komposisi kimia biji kenaf dan kualiti fizikokimia ekstrak susu; (ii) untuk menilai kesan koagulan dan pemboleh ubah pemprosesan terhadap kualiti tauhu biji kenaf; (iii) untuk meningkatkan kualiti tauhu biji kenaf dengan menggantikan sebahagian biji kenaf dengan kacang soya; dan (iv) untuk menyiasat mekanisme pengentalan tauhu biji kenaf dan tauhu campuran biji kenaf-kacang soya berbanding dengan tauhu kacang soya. Keputusan dari kajian kesan suhu rendaman menunjukkan bahawa kenaikan suhu rendaman air daripada25 hingga 65 ^{o}C meningkatkan kadar penyerapan air daripada 0.009 sehingga 0.068 min^{-1} secara signifikan dan seterusnya menurunkan tempoh rendaman daripada 616 kepada 160 min. Walau bagaimanapun, peningkatan suhu rendaman tidak memberi kesan yang signifikan terhadap komposisi proksimat biji kenaf dan ekstrak susunya; tetapi perlakuan rendaman yang digabungkan dengan proses pengekstrakan didapati mengurangkan kepekatan asid fitik, asid tanik dan perencat tripsin secara signifikan masing-masing daripada 2.74%, 0.082 mg/mL dan 11.18 mg/g bagi biji kenaf yang tidak direndam kepada 1.94-2.11%, 0.031-0.052 mg/mL dan 9.24-10.34 mg/g bagi ekstrak susu. Keputusan tahap penyaringan sewaktu fasa pencirian pembangunan tauhu biji kenaf menunjukkan bahawa kesan utama dan kesan interaksi nisbah biji kenaf kepada air untuk pengekstrakan susu biji kenaf, jenis dan kepekatan koagulan serta suhu ekstrak susu pada titik penambahan koagulan mempengaruhi sifat fizikokimia dan profil tekstur tauhu biji kenaf secara signifikan. Keputusan dari fasa pengoptimuman pengeluaran tauhu biji kenaf menunjukkan bahawa penetapan keadaan koagulan serta suhu rendaman biji kenaf optimum untuk penghasilan tauhu secara optimum adalah dengan merendam biji kenaf pada suhu 25 ^{o}C (suhu ambien) dan menambah 1.00 g % potash sebagai agen pengental. Pada keadaan optimum ini, hasil keluaran tauhu adalah 64.69 g/100g, manakala sifat kekerasan, kekunyahan, kekenyalan dan kelekatan tauhu adalah masing-masing 10130 g, 944.90, 0.64 mm dan 0.19. Penggantian biji kenaf dengan kacang soya pada lima nisbah biji kenaf-kacang soya (K-S) yang berbeza iaitu 50:50, 60:40, 70:30, 80:20 dan 90:10 telah meningkatkan hasil keluaran tauhu K-S dengan ketara apabila jumlah kacang soya dalam tauhu campuran meningkat. Urutan menaik hasil keluaran tauhu K-S adalah 90K: 10S (66.24-89.84 g/100g) < 80K:20S (88.89-129.67 g/100g) < 70K:30S (101.53-134.19 g/100g) < 60K: 40S (152.19-197.32 g/100g) < 50K:50S (158.76-204.61 g/100g). Hasil kajian menunjukkan bahawa kandungan protein tauhu K-S meningkat dengan ketara daripada 36.17 g/100g bagi tauhu 100 % biji kenaf (100%K) kepada suatu julat antara 40.84-45.36 g/100g bagi tauhu campuran. Selain itu, tauhu K-S yang diperbuat menggunakan campuran biji kenaf kepada kacang soya dalam nisbah 50:50, 60:40 dan 70:30 menunjukkan kandungan protein yang serupa dengan tauhu 100 % kacang soya (100%S), tetapi kandungan lemak yang jauh lebih tinggi secara signifikan iaitu dengan kenaikan sebanyak 16-30%. Nisbah jumlah asid amino perlu kepada jumlah asid amino dalam tauhu K-S meningkat dengan ketara daripada 35% bagi tauhu 100%K kepada 46% bagi tauhu K-S. Imej mikroskopik pengimbas elektron tauhu K-S menunjukkan bahawa peningkatan perkadaran kacang soya dalam tauhu campuran menghasilkan tauhu yang mempunyai jaringan pori berukuran lebih kecil yang homogen, lebih padat, berterusan dan konsisten yang lebih mengarah kepada pemerangkapan air dalam matriks gel. Tauhu K-S terbaik boleh dihasilkan dengan menggunakan campuran 70K:30S tanpa menjejaskan profil tekstur dan sifat fizikokimia. Mekanisme pengentalan tauhu menunjukkan bahawa tauhu 100%K tidak mempunyai ikatan disulfida (-S-S-) dan ini menyumbang kepada sifat longgar semulajadi dadih. Tambahan pula, tauhu 100%K mempunyai kadar pengentalan yang lebih perlahan dengan modulus penyimpanan akhir (G'f) sebanyak 0.41 Pa yang jauh lebih rendah secara signikan. Walau bagaimanapun, penggantian sebanyak 30% biji kenaf dengan kacang soya membawa kepada pembentukan ikatan -SS-, di samping menambahbaik kadar pengentalan dengan G'f sebanyak 1,13 Pa. Begitu juga, penggantian 30% biji kenaf dengan kacang soya menurunkan suhu pengentalan daripada 75 ^{o}C bagi tauhu 100%K hingga 71 ^{o}C bagi tauhu K-S. Kehadiran struktur lembaran-β pada semua tauhu yang dikaji menyumbang kepada ciri kekerasan tauhu.

ACKNOWLEDGEMENTS

All praises are to Almighty Allah; the Most Beneficent, the Most Merciful, who has given me opportunity, fitness, and strength to commence and successfully completed my PhD study in Food Technology in five semesters. May the blessings and mercy of Allah be upon the Prophet Muhammad (s.a.w), his families and entire Muslim *ummah*.

My profound and endless appreciation goes to my modest supervisor; the Head of Food Service and Management; Associate Professor Dr. Roselina Karim for the valuable mentorship she provided me throughout my study. I am equally thankful to my co-supervisor; the Dean of the Faculty of Food Science and Technology; Professor Dr. Nazamid Saari whose busy schedules are never a hindrance to my progress. Special thanks to my co-supervisors; Dr. Wan Zunairah Wan Ibadullah for the overwhelming contributions, suggestions and useful input throughout my study.

I would like to acknowledge the Tertiary Education Trust Fund (TETFund), Usmanu Danfodiyo University (UDUS) and National Kenaf and Tobacco Board, Malaysia (LKTN) for the study scholarship and research grant given to me during my PhD candidature. I am also grateful to my mentors and colleagues at the Department of Biochemistry, Usmanu Danfodiyo University, Sokoto-Nigeria for their advise and prayers.

I wish to acknowledge all the laboratory staff of the Faculty of Food Science and Technology, UPM, particularly Mrs Suraya Saad, Mrs Norlinawati Abd Halim, Mrs Asmawati Mantali, Mr Hamezan Muhammad, Mr Mohd Amran Suratman, Mr Ahmad Safwan Setaffa and Mr Mohd Sawal Taib for the immeasurable assistance and encouragement throughout my laboratory experiments. Special appreciation goes to my friends, particularly Nor Aini, Syamimi, Aqilah, Arif, BriSha and Wani for their kindness and hospitality.

My immeasurable gratefulness goes to my sister in-law; Dr. Ganiyat Olatunji for the care, love and passionate of taking excellent care of my daughter Zainab. Special thanks to my brother; Ishaq Ibrahim Giwa and his wife for taking good care of Fatimah and Aisha. May Allah bless their children, increase their wealth and piousness and reward them with Aljannatul -Firdaus. Ameen.

Special thanks to my lovely parent; Alhaji Ibrahim Giwa, Hajia Riskat Ibrahim Giwa, my sisters and brothers for their prayers and support. I am also grateful to my in-laws for their prayers, understanding and encouragement especially during the challenging times of Covid-19 pandemic. May Allah bless you all.

Finally, my profound appreciation goes to my most half; my humble husband and beloved children for their perseverance and prayers. I sincerely acknowledge their understanding, patient, encouragement, support and love. Without their sacrifices and cooperation, my PhD journey could have been difficult and unsuccessful. May Almighty Allah reward them plenteously.

This thesis was submitted to the Senate of 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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Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) were adhered to.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

ΔH	Enthalpy
Δ^{o}	Delta degree
a*	Redness
AABA	α-amino butyric acid
b*	Yellowness
BAPNA	Nα-benzoyl-DL-arginine-p-nitroanilide hydrochloride
BSA	Bovine serum albumin
CH_3COOH	Acetic acid
$D.H_2O$	Deionised water
D_{eff}	Diffusivity coefficient
DKSF	Defatted kenaf seed flour
DS	Dry seed
DSC	Differential scanning calorimeter
Ea	Activation energy
FAME	Fatty acid methyl esters
FTIR	Fourier transform infrared
G′	Storage modulus
G″	Loss modulus
G'_f	Final storage modulus
G''_f	Final loss modulus
GC-MS	Gas chromatography mass spectrometry
GDL	Glucono-delta-lactone
HCl	Hydrochloric acid
JKA	Jute, kenaf and allied fiber
K:S	Kenaf seed-to-soybean ratio
$KAl(SO_4)_2.12H_2O$; Potash	Aluminium potassium salt
KB6	Kenaf seed cultivar
KPa	Kilopascal
KS	Kenaf seed
K-S	Mixture of kenaf seed and soybean
KSME	Kenaf seed milky extract

KSMEO	Kenaf seed milky extract oil
KSO	Kenaf seed oil
KSPC	Kenaf seed protein concentrate
KTP	Kenaf textured protein
L	Lightness
$MgCl_2$	Magnesium chloride
NaOH	Sodium hydroxide
^{o}Brix	Degree Brix
P	Probability value
Pa	Pascal
r	Pearson correlation coefficient
R^2	Regression coefficient of determination
rpm	Rotation per minute
SEE	Standard error of estimation
SEM	Scanning electron microscopy
-SH	Sulphydryl group
-S-S	Disulphide bond
T	Absolute temperature
Tan δ	Tan delta
T_c	Coagulation temperature
T_d	Peak/denaturation temperature
T_e	Endset temperature of denaturation
TSS	Total soluble solids
TIA	Trypsin inhibitors activity
T_o	Onset temperature of denaturation
TPA	Texture profile analysis
UV-VIS	Ultraviolet visible spectrophotometer
α	Alpha
β	Beta

CHAPTER 1

INTRODUCTION

1.1 Background

Kenaf (*Hibiscus cannabinus*) is a short day, warm-season herbaceous plant that has been planted as far back as 4000 BC. It belongs to Malvaceae family, a remarkable plant for horticultural and economic significant (H'ng, Khor, Tadashi, Aini, & Paridah, 2009). Kenaf has several local names such as 'mesta' in India and Bengal, 'rama' in Nigeria, 'java jute' in Indonesia, 'stockroot' in South Africa and 'ambari' in Taiwan (Alexopoulou et al., 2013a). Kenaf plant can be grown under ample weather condition, growing to 3.66 to 5.49 m in 4 to 5 months with a yield of 6 to 10 t (Alexopoulou et al., 2013a). The kenaf plant composed of various types of valuable components such as stems, leaves and seeds; the attributes of the components enable abundant product types to be obtained and for sustainable development (Mostafa, Rahaman, & Ghosh, 2013; Su, Chen, & Lin, 2004). The kenaf stem fibre has been recognised as a good raw material for textiles, wallpaper backing and furniture (Alexopoulou, Papatheohari, Christou, & Monti, 2013b). Equally, the whole kenaf plant has good nutritional profiles and good digestibility and may be used in food and feed productions (Webber III & Bledsoe, 2002).

Nowadays, several countries take into consideration kenaf research and plantation due to its high biological efficiency and varied environmental flexibility. Kenaf is often called "the future crop" (Cheng, 2001) owing to its multifunctional applications such as biofuel, cardboard, packaging bags and building materials (Alexopoulou et al., 2013a; Islam, 2019; Webber & Bledsoe, 2002). FAO (2003) reported that kenaf is commercially cultivated in more than 20 countries, particularly in China, India, Thailand, and Vietnam, but the benefit of the crop worldwide is still limited. In Malaysia, kenaf plantation has been recognized as the fourth industrial crop and the government has renamed the National Tobacco Board to National Kenaf and Tobacco Board, encouraging the development of kenaf industry (Wong, Lau, Tan, Long, & Nyam, 2014). Malaysia Agricultural Research and Development Institute (MARDI) is the pioneer in the development and cultivation of kenaf plant in the country since the year 2000, and the first *H. cannabinus* seed cultivated was in Serdang, Selangor (Chan & Ismail, 2009; Yazan et al., 2016). MARDI reported that kenaf components have more than 20 % of protein (Cheng, Haque Akanda, & Nyam, 2016). The kenaf cultivation was majorly to ensure availability of stem to meet-up the enormous need for fibre and forage industries (Mohd, Arifin, Nasima, Hazandy, & Khalil, 2014). This has significantly increased the yield of kenaf seed from 7.19 t in 2006 to 151.25 t in 2011 (Ishar, 2012).

Phytochemical screening has found that the whole kenaf plant composed of pharmacologically bioactive compounds such as polyphenols, phytosterols, tannins, saponins and alkaloids (Dhar, Kar, Ojha, Pandey, & Mitra, 2015). Equally, oil extracted from the seed has been reported to be rich in vitamin E, β-sitosterol and polyunsaturated fatty acids, and it has been considered as safe for human consumption due to the absent of gossypol; a toxic phenolic pigment (Cheong, Tan, & Nyam, 2018). Toxicological studies of aqueous extract of kenaf leaves on experimental rats have revealed that the extract was orally tolerated even at higher dose, and that the sub-acute (14-days) and sub-chronic (90-days) toxicity studies showed no significant effect on biochemical parameters such as alanine aminotransferase (ALT) and aspartate aminotransferase (AST), rather, the extract had hypolipidaemic and hypoglycemic lowering effects (Agbor, Oben, Brahim, & Ngogang, 2004). Likewise, experimental rats fed with roasted and un-roasted whole kenaf seed meal were found to show no significant differences in the serum levels of albumin, uric acid, cholesterol, creatinine, ALT and AST (Odetola & Eruvbetine, 2012). The concentrations of these enzymes ALT and AST in serum have been used to access the damaging effects of a substance on vital organs such as heart, liver and kidney (Odetola & Eruvbetine, 2012, thus, kenaf components such as the leaves, seeds and oil extracted from the seeds were considered toxicologically safe. Additionally, studies have reported the significant health benefits of kenaf seed such as antioxidant activity, anti-hypercholesterolemic, anti-cancer, anti-inflammatory, anti-ulcer, and anti-thrombotic effects due to the absent of toxic compounds and present of bioactive phytochemical compounds (Chew & Nyam, 2019; Ryu et al., 2017).

Each part of kenaf plant are useful, however, both the leaves and the seeds were underused and considered as secondary products from the kenaf industry. The seed has been reported to be safe for human consumption with evidence of health-promoting potentials (Chan, Khong, Iqbal, Mansor, & Ismail, 2013; Ghafar, Yazan, Tahir, & Ismail, 2012; Michotte et al., 2011). It was economically considered as a vital source of edible oil which are rich in essential fatty acids, phospholipids and phenolic antioxidants (Alexopoulou et al., 2013a; Patanè & Sortino, 2010). Other components of the kenaf plant such as the leaves have been commonly used as a traditional medicine for initiation of lactation in Nigeria (Gaya, Mohammad, Suleiman, Maje, & Adekunle, 2009). Also, in India, the leaves are used to cure indigestion and as pain reliver (Dhar et al., 2015). Kenaf seed flour has been used in the production of noodles (Zawawi et al., 2014) and as a source of bioactive fermented peptides which plays a role as an antibacterial natural preservative (Arulrajah, Muhialdin, Zarei, Hasan, & Saari, 2020). Kenaf seed is high in protein, carbohydrate, fiber and minerals (Mariod, Fathy, & Ismail, 2010) and yet underused, exploiting the nutritional benefits and the safety of kenaf seed in food applications are of prime importance. Three cultivars of kenaf seeds were available in Malaysia which includes V36, FH992 and KB6. V36 and FH992 had been studied for both their chemical and functional properties with little on their potential food applications. But, KB6 kenaf seed is a new cultivar which has not been studied before for its chemical composition and possible food applications. It is of significance to determine its nutritional and anti-nutritional contents, and its suitability in the production of tofu. Additionally, the superb nutritional content of tofu has made its one of the popular vegetable proteins mostly consumed in Malaysia. This justified the basis for this study; to introduce kenaf seed tofu, with the fact that tofu is often produced from soybean and the bean is not locally cultivated in Malaysia. The high protein content (29.8-30.5 %), protein solubility at wider pH range (Mariod et al.,

2010) signifies the possibility to use kenaf seed as ingredient in food products development.

1.2 Research hypotheses

1. H_0: Soaking temperature and time have no significant effect on the rate of water absorption, proximate and anti-nutritional content of kenaf seeds.
   H_1: Soaking temperature and time have significant effect on the rate of water absorption, proximate and anti-nutritional content of kenaf seeds.
2. H_0: The different soaking temperature at their respective optimum soaking time have no significant effect on the physicochemical quality of kenaf seed milky extract.
   H_1: The different soaking temperature at their respective optimum soaking time have significant effect on the physicochemical quality of kenaf seed milky extract.
3. H_0: No significant difference in the fatty acids and amino acids profiles of kenaf seed and kenaf seed milky extract.
   H_1: There is a significant difference in the fatty acids and amino acids profiles of kenaf seed and kenaf seed milky extract.
4. H_0: Coagulant and processing variables have no significant effect on the physicochemical and texture profile analysis of kenaf seed tofu.
   H_1: Coagulant and processing variables have significant effect on the physicochemical quality and texture profile analysis of kenaf seed tofu.
5. H_0: Substitution of kenaf seed with soybean at different ratios have no significant improvement on the physicochemical quality and texture profile analysis of kenaf seed-soybean tofu.
   H_1: There are significant improvements in the physicochemical quality and texture profile analysis of kenaf seed-soybean tofu at the different ratios of kenaf seed-to-soybean.
6. H_0: The mechanism of coagulation of kenaf seed, soybean and kenaf seed-soybean tofu were not significantly different.
   H_1: The coagulation mechanism of kenaf seed, soybean and kenaf seed-soybean tofu were significantly different.

1.3 Problem Statement

Kenaf plant has been historically known as a cordage crop (Webber & Bledsoe, 2002), however, cultivation of the plant was not common due to the focus of many countries on cash crops and little was known on the economic significant of the plant. Recently, many countries have developed interest to the plantation of kenaf due to the awareness of the various industrial uses of the kenaf stem and it prospect to boost a country economy (FAO, 2015). With the recent interest in many countries cultivating kenaf plant of which Malaysia is not left out. The Malaysia government is enthusiastic toward kenaf cultivation by investing MYR 100 million (USD 32.41 million) between 2006-2015 into kenaf research and development (Hanim, 2009). Also, set-up various agricultural agencies to investigate the possibility of cultivating kenaf in the country. Cultivation of kenaf plant was successful due to it wider climatic adaptability. The tonnes yield of kenaf was projected to reach 150,000 tonnes by the year 2020, however, 45 % of the target was met by the year 2015 (Yen, Check, Ulysses, & Mary, 2017). Each year the tonnes yield of kenaf stems and seeds increased significantly, but, only the kenaf stems are utilised as fiber and forage for industrial purposes. The seed was considered as "by-product" and it needs to be value-added most especially for the development of food products for human consumption. Additionally, the protein fractions of kenaf protein concentrates have revealed that kenaf seed protein contained significantly higher albumin, followed by globulin, and glutelin and prolamin were of lesser amounts (Mariod et al., 2010). Proteins high in albumin were known to curd in the presence of an external agent such as heat (Campbell, Raikos, & Euston, 2003). Furthermore, the satisfactory functional properties of kenaf seed protein concentrates indicated the prospect to use kenaf seed as a source of protein in food production (Mariod et al., 2010). In this study we choose to produce tofu using kenaf seed on the bases that, tofu is a common protein food in Malaysia and majorly produced from soybean. But soybean is not locally cultivated in Malaysia although, imported majorly from United states (Abdul-Ghani, 2018). Malaysia government has increased the hectares of land for kenaf plantation by 13 % in 2018 and it was projected to reach 10,000 hectares by 2025 (National Kenaf and Tobacco Board, 2017). This implies that more kenaf seed will be available in future, and it needs to be harness for food products development. Consequently, the production of tofu from kenaf seed will reduce the importation of soybean and will serve as a substitute to soybean tofu. Thus, this led to the objectives of the present study.

1.4 Objectives of study

Based on the aforementioned, the aim of this study was to investigate the potential to use kenaf seed for tofu production as a means to value-add the underutilised kenaf seed. In view of the above, the following objectives were studied:

1. To determine the effects of soaking temperatures on hydration time, chemical composition, and microstructure of kenaf seed; and on the physicochemical quality of kenaf seed milky extracts.
2. To evaluate the effects of coagulants and processing variables on the quality of kenaf seed tofu;
3. To improve the quality of kenaf seed tofu by substituting kenaf seed with soybean at different ratios and to determine the effect of coagulants; and
4. To determine the mechanism of coagulation of kenaf seed tofu and kenaf seed-soybean blend tofu in comparison to soybean tofu.

1.5 Thesis outline

The thesis is organised into 8 Chapters comprised of 5 working Chapters. Chapter 2 presents the history of kenaf plant, a review on kenaf seed, its composition, non-food uses, and possible food uses. The review also discussed on hydration of plant seeds. In addition to previous studies on tofu using other plant seeds other than soybean, factors affecting the quality of tofu and coagulation processes of tofu in the present of acid and salt coagulants. Chapter 3 to 7 comprised of the working Chapters and the overall research activities were summarised in Figure 1.1. Finally, Chapter 8 summarises, concludes and provides recommendations for future studies based on the outcomes of this present study.

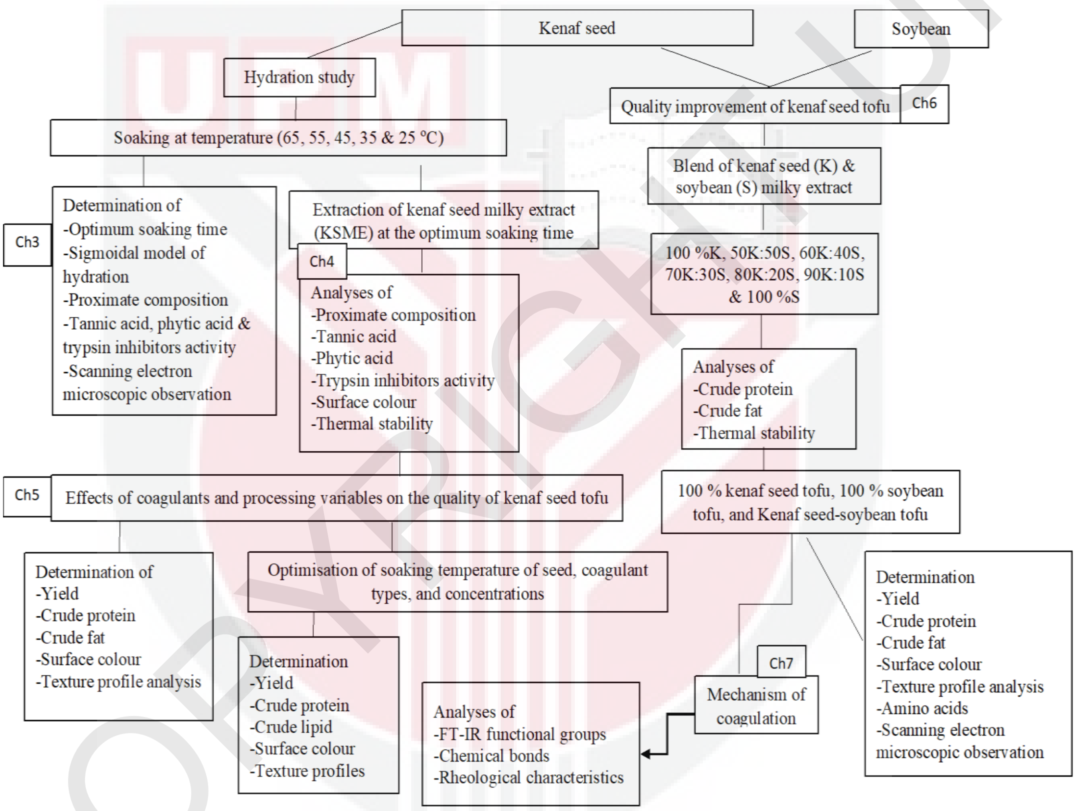

Figure 1.1 : Overall flow of research activities
Note : Ch = Chapter

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LIST OF PUBLICATIONS

Manuscript published

Giwa Ibrahim, S**.,** Karim, R., Saari, N., Wan Abdullah, W. Z., Zawawi, N., Ab Razak, A. F., Hamim, N. A., & Umar, R. U. A. (2019). Kenaf (*Hibiscus cannabinus* L.) Seed and its potential food applications: a review. *Journal of Food Science*, *84*(8), 2015-2023.

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Shafa'atu Giwa Ibrahim, Wan Zunairah Wan Ibadullah, Nazamid Saari, Roselina Karim (2020). Functional properties of protein concentrates of KB6 kenaf (*Hibiscus cannabinus*) seed and its milky extract. *LWT-Journal of Food Science and Technology*, *135*, 110234.

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Shafa'atu Ibrahim Giwa, Roselina Karim, Nazamid Saari, Wan Zunairah Wan Ibadullah. "Effect of seed-to-water ratio, coagulant types and concentration on the yield and physicochemical properties of kenaf (*Hibiscus cannabinus* L.) seed hard tofu". Paper presented at the International Conference on Agronomy and Food Science and Tchnology - Agrofood. Istanbul, 20-22 June, 2019.

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