

## TABLE OF CONTENTS

	<b>Page</b>
<b>ACKNOWLEDGEMENT</b>	iii
<b>ABSTRACT (IN ENGLISH)</b>	iv
<b>ABSTRACT (IN THAI)</b>	vii
<b>TABLE OF CONTENTS</b>	ix
<b>LIST OF TABLES</b>	xiii
<b>LIST OF FIGURES</b>	xvi
<b>ABBREVIATIONS</b>	xxi
<b>CHAPTER 1 INTRODUCTION</b>	1
<b>1.1 Background information</b>	1
<b>1.2 Research Objectives</b>	3
<b>CHAPTER 2 LITERATURE REVIEW</b>	4
<b>2.1 Pennywort (<i>Centella asiatica</i> (Linn.) Urban)</b>	4
2.1.1 Pennywort description	4
2.1.2 Pennywort nutrient compositions	4
2.1.3 Applications use of pennywort for bioactive natural products	5
2.1.4 Chemical constituents of pennywort	6
2.1.5 Major bioactive constituents of pennywort	8
<b>2.2 Pharmacological and health promoting effects of pennywort</b>	11
<b>2.3 Antioxidant properties of plant</b>	12
2.3.1 Phenolic compounds	14
2.3.2 Ascorbic acid	14
2.3.3 Carotenoids	15
<b>2.4 Chlorophyll</b>	15
<b>2.5 Effect of sugar contents on food quality</b>	19
<b>2.6 Effect of pre-thermal processing on food quality</b>	20

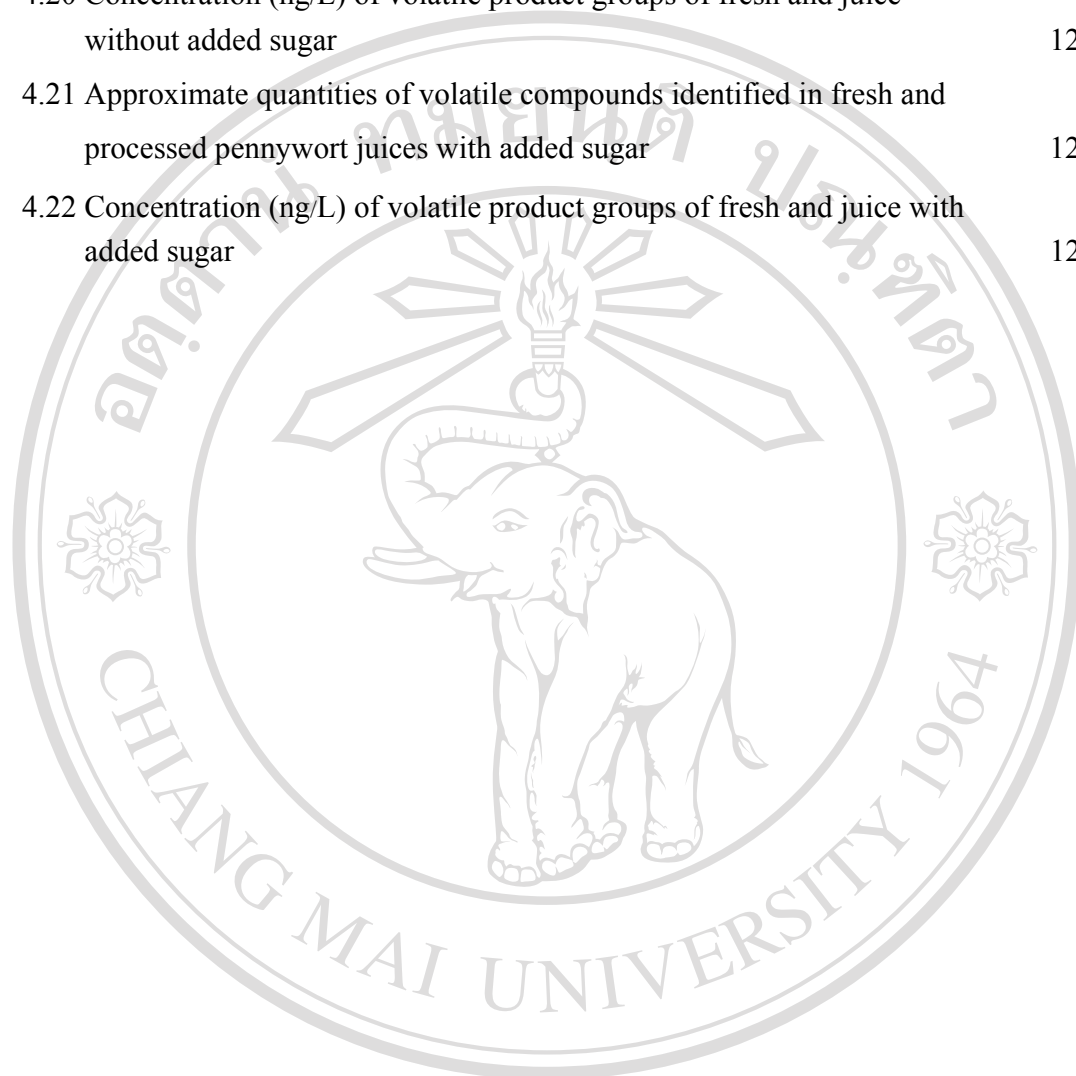
<b>2.7 Thermal processing for fruit and vegetable products</b>	20
<b>2.8 High pressure processing of foods</b>	25
2.8.1 Evolution of high pressure processing	25
2.8.2 Mode of action of HPP on microorganisms	26
2.8.3 Effects of high pressure processing on fruit/vegetable products	29
<b>2.9 Comparison of high pressure processing, pasteurization and sterilization on qualities of juices during long-term storage</b>	43
<b>2.10 Flavour profile by solid-phase microextraction technique</b>	45
2.10.1 Flavour profile of fresh foods	45
2.10.2 Flavour profile of juices	47
2.10.3 Flavour profile of processed food	48
2.10.4 Flavour profile of pennywort	49
<b>CHAPTER 3 MATERIALS AND METHODS</b>	51
<b>3.1 Materials and packaging</b>	51
<b>3.2 Standards and chemicals</b>	51
<b>3.3 Instruments</b>	53
<b>3.4 Research design and methods</b>	54
3.4.1 Research design	54
3.4.2 Analysis methods	56
<b>CHAPTER 4 RESULTS AND DISCUSSION</b>	63
<b>4.1 Analysis of the composition of raw material</b>	63
4.1.1 Physical properties of raw material	63
4.1.2 Chemical properties of raw material	64
<b>4.2 Optimization of different processes based on microbiological quality</b>	73
<b>4.3 Optimization of different processes based on chemical quality</b>	74
4.3.1 Physico-chemical properties of the processed juice	75
4.3.2 Phytochemical composition of the processed juice	76
4.3.3 The effect of sugar addition	85
<b>4.4 The effects of storage time on the physico-chemical quality</b>	86

4.4.1 Change in physical properties	86
4.4.2 Changes in physico-chemical properties	96
4.4.3 Changes in phytochemical composition	99
4.4.4 Changes in antioxidant properties	106
<b>4.5 The effects of storage time on the microbial quality</b>	<b>115</b>
<b>4.6 Flavour profile pennywort juice</b>	<b>116</b>
4.6.1 The flavour profile of fresh and processed juice without added sugar	117
4.6.2 The flavour profile of fresh and processed juice with added sugar	125
<b>CHAPTER 5 CONCLUSIONS AND RECOMMENDATIONS</b>	<b>130</b>
<b>5.1 Conclusions</b>	<b>130</b>
<b>5.2 Recommendation for further investigation</b>	<b>133</b>
<b>REFERENCES</b>	<b>134</b>
<b>APPENDICES</b>	
Appendix A Standard curves	181
Appendix B Calculation Correlation between FRAP value (as antioxidant activity), ascorbic acid and phenolic content	191
Appendix C Thai Food Regulation-Standard (2003) of pennywort juice	197
<b>CURRICULUM VITAE</b>	<b>203</b>

## LIST OF TABLES

<b>Table</b>	<b>Page</b>
4.1 Proximate analysis of fresh pennywort	64
4.2 Bioactive compounds and antioxidant properties of fresh pennywort and fresh juice	66
4.3 Physico-chemical properties of fresh pennywort juice with and without added sugar	71
4.4 Physico-chemical properties of processed juice	75
4.5 Chroma values of processed pennywort juice	87
4.6 Hue angle values of processed pennywort juice	87
4.7 Viscosity of processed pennywort juice	94
4.8 pH value of processed pennywort juice	97
4.9 Total soluble solids content of processed pennywort juice	98
4.10 Madecassoside content of processed pennywort juice	99
4.11 Asiaticoside content of processed pennywort juice	100
4.12 Ascorbic acid content of processed pennywort juice	101
4.13 $\beta$ -Carotene content of processed pennywort juice	104
4.14 Total phenolic content of processed pennywort juice by Folin Ciocalteu method without correction for ascorbic acid content	107
4.15 Ferric reducing antioxidant potential (FRAP) value of processed pennywort juice	109
4.16 Contribution of ascorbic acid to antioxidant capacity of processed pennywort juice	110
4.17 Phenolic content of processed pennywort juice (subtracted for ascorbic acid content)	111
4.18 Ferric reducing antioxidant potential values due to phenolic compounds of processed pennywort juice	112
4.19 Approximate quantities of volatile compounds identified in fresh and processed pennywort juices without added sugar	118

4.20 Concentration (ng/L) of volatile product groups of fresh and juice without added sugar	124
4.21 Approximate quantities of volatile compounds identified in fresh and processed pennywort juices with added sugar	126
4.22 Concentration (ng/L) of volatile product groups of fresh and juice with added sugar	129



ลิขสิทธิ์มหาวิทยาลัยเชียงใหม่  
Copyright© by Chiang Mai University  
All rights reserved

## LIST OF FIGURES

<b>Figure</b>	<b>Page</b>
2.1 <i>Centella asiatica</i> (Linn.) Urban	4
2.2 Structure of major triterpene compounds of pennywort	7
2.3 Structure of Compound 1	8
2.4 Structure of asiaticoside C <sub>48</sub> H <sub>78</sub> O <sub>19</sub>	9
2.5 Structure of asiatic acid C <sub>30</sub> H <sub>48</sub> O <sub>5</sub>	10
2.6 Structure of madecassoside C <sub>48</sub> H <sub>78</sub> O <sub>20</sub>	10
2.7 Structure of madecassic acid C <sub>30</sub> H <sub>48</sub> O <sub>6</sub>	11
2.8 Chlorophyll degradation pathway in higher plants. The pathway is composed of two stages, an early stage before the cleavage reaction of the tetrapyrrole macrocyclic ring and a late stage that includes the cleavage reaction and steps after the reaction. The products in the early stage are green, whereas those in the late stage are colorless	17
2.9 Hypothetical compartmentation of the chlorophyll (Chl) degradation pathway	18
3.1 Colour system	62
4.1 Isomerisation of linalool and dehydration to monoterpenes	121

## ABBREVIATIONS

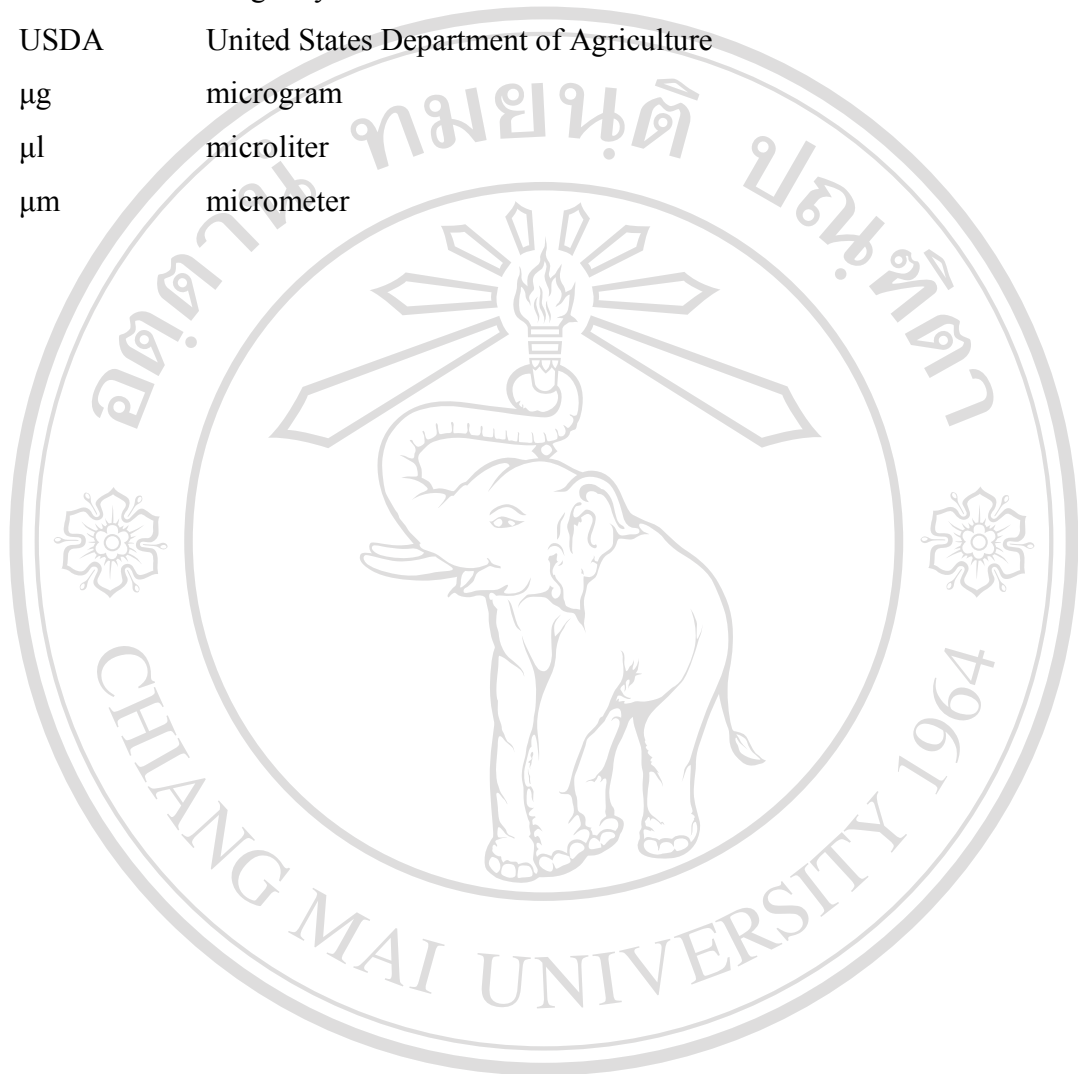
AOAC	Association of Official Agricultural Chemists
BAM	Bacteriological Analytical Manual
BHT	Butylated hydroxytoluene
C	chroma
°C	degree Celsius
CaCO <sub>3</sub>	Calcium carbonate
cP	centipoise
dw	dry weight
°F	degree Fahrenheit
FDA	Food and Drug Administration
Fe	Iron
FRAP	Ferric reducing antioxidant potential
fw	fresh weight
GC-MS	Gas chromatography mass spectroscopy
h	hour
°h	hue angle
HCl	Hydrochloric acid
kJ	kiloJoule
KMnO <sub>4</sub>	Potassium permanganate
HPLC	High performance liquid chromatography
HPP	high pressure processing
H <sub>2</sub> SO <sub>4</sub>	Sulfuric acid
IS	Internal Standard
kcal	kilocalorie
kg	kilogram
L	Liter
LDPE	Low density polyethylene



M	Mole
mM	millimole
mg	milligram
min	minute
mm	millimeter
ml	milliliter
MPa	mega Pascal
mPas	milli Pascal
MPN	Most probable number
ng	nanogram
ns	non significant
Pa	Pascal
PCA	Plate count agar
PDA	Potato dextrose agar
PDMS	Polydimethylsiloxane
PET	Polyethylene terephthalate
POD	Peroxidase
PP	Polypropylene
ppm	parts per million
PPO	Polyphenol oxidase
SD	Standard deviation
s	second
TEA	Triethylamine
THF	Tetrahydrofuran
TPC	Total phenolics content
TPTZ	2,4,6-tri (2-pyridyl)-s-triazine
TSS	Total soluble solids
v/v	volume by volume
w/w	weight by weight



w/v	weight by volume
USDA	United States Department of Agriculture
$\mu\text{g}$	microgram
$\mu\text{l}$	microliter
$\mu\text{m}$	micrometer



ลิขสิทธิ์มหาวิทยาลัยเชียงใหม่  
Copyright© by Chiang Mai University  
All rights reserved