MOISTURE CONTENT DETECTION IN ANCHOVY SAUCE USING MICROSTRIP SENSOR

OMAR AYAD FADHIL

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MOISTURE CONTENT DETECTION IN ANCHOVY SAUCE USING MICROSTRIP SENSOR

By

OMAR AYAD FADHIL

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirement for the Degree of Master of Science

June 2014
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DEDICATION

“... and of knowledge ye have been vouchsafed but little”

Holy Qur’an

“Do not worry about your difficulties in mathematics I can assure mine are still greater.”

Albert Einstein

To my beloved parents and siblings for their lasting encouragement, help & support

Thank you for being there
MOISTURE CONTENT DETECTION IN ANCHOVY SAUCE USING MICROSTRIP SENSOR

By

OMAR AYAD FADHIL

June 2014

Chairman: Associate Professor Zulkifly Abbas, PhD
Faculty: Science

Water is the most important parameter to determine the quality of Anchovy Sauce. The changes of $m.c$ in Anchovy Sauce also linked to physicochemical and microbiological changes. Unfortunately to-date, a quick, reliable and accurate method to determine moisture content $m.c$ in Anchovy Sauce has not been reported in the literature.

This thesis presents an extensive investigation on the design of a microstrip sensor as a new technique for determination of $m.c$ in Anchovy Sauce in the microwave frequencies from 2 GHz to 3 GHz. The relationships between the dielectric constant as well as loss factor with frequency in Anchovy Sauce has been established. The dielectric constant of the Anchovy Sauce increased almost linearly with increasing $m.c$. In contrast, the loss factor decreased exponentially with increasing the frequency. The visualization of the electric field distribution of a microstrip loaded with Anchovy Sauce of different percentages of $m.c$ was realized using COMSOL 3.5. It was found that the higher the $m.c$, the higher will be the detachments of the electric field distribution.

The variation of transmission coefficients for different percentages of $m.c$ were measured in the microwave frequencies from 2 to 3 GHz. The results were analyzed and compared to the calculated values using the Finite Element Method (FEM). This is the first work using FEM to evaluate the transmission coefficients of a microstrip sensor loaded with Anchovy Sauce. It was found that the comparison between the calculated and measured magnitude of transmission coefficient of the lowest percentages of $m.c$ exhibit the lowest error and vice versa for the phase of transmission coefficient. The sample with 17.3% of $m.c$ recorded the lowest error of the magnitude of transmission coefficient, while the mean errors of phase of transmission coefficient suggest that the water has the lowest mean error followed by samples with highest percentage of $m.c$ (80.2%). This could be attributed to the inaccurate permittivity model employed by the Agilent Probe.
The transmission coefficient of the sensor was found to be highly correlated to the amount of m.c in the Anchovy Sauce for all frequencies except below 2.1 GHz due to the bound water relaxation frequency. Calibration equations to predict the amount of m.c from measured magnitude and phase of transmission coefficient have been established. The calibration equation based on the magnitude of transmission coefficient at 2.55 GHz was found to give the highest accuracy within 1.6% when compared to the actual m.c obtained from the oven drying method.
Abstrak tesis dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Sarjana Sains

PENGESANAN KANDUNGAN KELENGKASAN BUDU MENGGUNAKAN DERIA MICROSTRIP

Oleh

OMAR AYAD FADHIL

Jun 2014

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Air merupakan parameter terpenting untuk menentukan kualiti sos ikan bilis. Perubahan kadungan lembapan dalam sos ikan bilis juga dikaitkan dengan perubahan fisiokimia dan mikrobiologi. Malangnya sehingga kini, cara yang cepat, boleh dipercayai dan tepat dalam menentukan kandungan lembapan sos ikan bilis masih belum dilaporkan.

Tesis ini mengandungi hasil penyelidikan yang ekstensif dalam pembentukan pengesan mikrostrip sebagai salah satu teknik untuk menentukan kandungan lembapan sos ikan bilis dalam frekuensi gelombang mikro dari 2 GHz hingga 3 GHz. Hubungan antara pemalar dielektrik dengan faktor kehilangan frekuensi dalam sos ikan bilis juga turut ditentukan. Pemalar dielektrik bagi sos ikan bilis bertambah secara linear apabila kandungan lembapan bertambah. Sebaliknya, faktor kehilangan berkurang secara eksponen apabila frekuensi bertambah. Taburan medan elektrik bagi mikrostrip dengan sos ikan bilis yang berbeza kandungan lembapan dikaji dengan menggunakan COMSOL 3.5. Hasil kajian mendapati semakin tinggi kandungan lembapan, semakin tinggi pemisahan taburan medan elektrik.

Variansi bagi pekali penghantaran untuk peratusan kandungan lembapan yang berbeza diukur dalam gelombang mikro berfrekuensi dari 2 GHz hingga 3 GHz. Keputusan dianalisa dan dibandingkan dengan pengiraan menggunakan Kaedah Unsur Terhingga (FEM). Ini adalah kajian yang pertama menggunakan FEM untuk menilai pekali penghantaran bagi mikrostrip bersama sos ikan bilis. Hasil perbandingan ini mendapati kandungan lembapan dengan peratusan terendah mempamerkan ralat yang terrendah dan sebaliknya untuk fasa pekali penghantaran. Sampel dengan 17.3% kandungan lembapan merekodkan ralat yang terrendah bagi magnitud pekali penghantaran. Ini mungkin disebabkan oleh model ketulusan yang tidak tepat dalam Agilent Probe.
Pekali penghantaran bagi pengesan didapti saling berhubung kait dengan jumlah kandungan lembapan dalam sos ikan bilis untuk semua frekuensi kecuali frekuensi kurang dari 2.1 GHz kerana kurangnya keterikatan air pada frekuensi tersebut. Persamaan kalibrasi untuk meramalkan kandungan lembapan daripada pengukuran magnitud dan fasa pekali penghantaran telah berjaya ditubuhkan. Persamaan kalibrasi adalah berdasarkan pada magnitud pekali penghantaran pada 2.55 GHz memberi ketepatan yang paling tinggi dalam 1.6% apabila dibandingkan dengan bacaan sebenar kandungan lembapan yang didapati daripada kaedah pengeringan ketuhar.
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“In the name of Allah, the most beneficent and the most merciful”

First and foremost, all praise is due to Allah Almighty subhanahu wa-ta’ala, on whom we ultimately depend, for His endless blessing and allowing me to achieve what I have achieved today.

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Finally, the student would love to sincerely appreciate his dearest friend Fahmiruddin Esa for his endless encouragements, support and help during the period of study.
This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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Date:
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Declaration by the Student

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Name of Chairman of Supervisory Committee: Zulkifly Abbas, PhD

Signature:  
Name of Member of Supervisory Committee: Nurul Huda Osman, PhD
TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEDICATION</td>
<td>ii</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>iii</td>
</tr>
<tr>
<td>ABSTRAK</td>
<td>v</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>vi</td>
</tr>
<tr>
<td>APPROVAL</td>
<td>viii</td>
</tr>
<tr>
<td>DECLARATION</td>
<td>x</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>xv</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>xvii</td>
</tr>
<tr>
<td>LIST OF ABBREVIATIONS</td>
<td>xx</td>
</tr>
</tbody>
</table>

CHAPTER

1 INTRODUCTION
   1.1 An Overview of Anchovy Sauce      1
   1.2 Microwave Sensor                  3
   1.3 Problem Statement                 5
   1.4 Research Objectives               5
   1.5 Scope of Thesis                   6

2 LITERATURE REVIEW
   2.1 Background of Microstrip Line    7
      2.1.1 Microstrip Structure         8
      2.1.2 Waves of Microstrip         8
      2.1.3 Approximation of Quasi-TEM   9
      2.1.4 Strip Thickness Effect       9
      2.1.5 Dispersion in Microstrip     9
      2.1.6 Effective Dielectric Constant and Characteristic Impedance 11
      2.1.7 Microstrip Loss              12
   2.2 Moisture Content Measurement Techniques 12
      2.2.1 Conventional Oven Method     12
      2.2.2 Microwave Moisture Measurement 12
   2.3 Microstrip Moisture Measurement Technique 14
   2.4 Numerical Techniques            15
      2.4.1 Finite Difference Time Domain (FDTD) 15
      2.4.2 Method of Moment (MoM)           16
      2.4.3 Finite Element Method (FEM)      17
      2.4.4 Comparison between Numerical Techniques 18

3 THEORY
   3.1 Maxwell’s Equations               20
   3.2 Wave Equations                    21
   3.3 Mixture Model Theory              22
   3.4 Microstrip Sensor                 23
   3.5 Finite Element Method (FEM)       24
3.5.1 The Domain Discretization 25
3.5.2 Equation System Formulation 25
3.5.3 Equation System Solution 26

4 METHODOLOGY
4.1 Development and Transference of the Circuit Layout to the Mask and Substrate
4.1.1 The Linear Path Sensor Fabrication 29
4.1.2 Steps into Microwave Office 31
4.2 Sample Preparation 33
4.3 Measurement Set-up 34
4.3.1 S-Parameters Measurement 34
4.3.2 Measurement of Permittivity 36
4.4 Wave Equation Performance by COMSOL 38
4.5 Steps into Finite Element Method (FEM) Using COMSOL 38
4.5.1 Model Navigator 39
4.5.2 Geometry Modeling 39
4.5.3 Physics Settings 42
4.5.4 Mesh 44
4.5.5 Solve 44
4.5.6 Postprocessing 45
4.5.7 Parametric Study 46

5 RESULTS AND DISCUSSIONS
5.1 Variation in Permittivity of Anchovy Sauce of Different Percentages of Moisture Content with Frequency
5.1.1 Variation in Dielectric Constant and Loss Factor of Anchovy Sauce for Different Percentages of Moisture Content with the Frequency 48
5.1.2 Variation in Loss Tangent with Frequency at Different Percentages of Moisture Content in Anchovy Sauce 50
5.2 Effect of Moisture Content on the Dielectric Constant and Loss Factor of Anchovy Sauce 50
5.3 Effect of Mesh Size on The Calculation of the Transmission Coefficient 53
5.4 The Electric Field Distribution of the Microstrip Sensor in Standard Materials 53
5.5 Comparison between the Measured and Calculated Magnitude of Transmission Coefficient 55
5.5.1 Relationship between the Magnitude of Transmission Coefficient with Moisture Content at Selected Frequency 59
5.6 Comparison between the Calculated and Measured Transmission Coefficient Phase 62
5.6.1 Relationship between Moisture Content and Phase of Transmission Coefficient at Selected Frequencies 65
5.7 Performance Analysis of Microstrip Linear Sensor 67
6 CONCLUSION AND SUGGESTIONS
   6.1 Conclusion
   6.2 Main Contributions
   6.3 Recommendations for Future Work

REFERENCES
APPENDICES
BIODATA OF THE STUDENT
### LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Comparison between FDTD, MoM and FEM</td>
<td>18</td>
</tr>
<tr>
<td>4.1</td>
<td>X-Y grid dimension and spacing</td>
<td>32</td>
</tr>
<tr>
<td>4.2</td>
<td>Geometrical description of the rectangles in 2D work-plane</td>
<td>39</td>
</tr>
<tr>
<td>4.3</td>
<td>Distance of the microstrip geometry</td>
<td>40</td>
</tr>
<tr>
<td>4.4</td>
<td>Geometrical description of the coaxial feeder in 2D work-plane</td>
<td>40</td>
</tr>
<tr>
<td>4.5</td>
<td>Geometrical description of the flange in 2D work-plane</td>
<td>41</td>
</tr>
<tr>
<td>4.6</td>
<td>Distance of the coaxial feeder geometry</td>
<td>41</td>
</tr>
<tr>
<td>4.7</td>
<td>PML and air geometric</td>
<td>41</td>
</tr>
<tr>
<td>4.8</td>
<td>Geometry operations for the microstrip structure</td>
<td>42</td>
</tr>
<tr>
<td>4.9</td>
<td>Subdomains of the microstrip line geometry</td>
<td>43</td>
</tr>
<tr>
<td>4.10</td>
<td>Boundary condition of the microstrip</td>
<td>43</td>
</tr>
<tr>
<td>5.1</td>
<td>The difference between transmission coefficient using extremely and extra coarse</td>
<td>53</td>
</tr>
<tr>
<td>5.2</td>
<td>The mean error in magnitude between measurement and calculation of transmission coefficient for different ratios of moisture content</td>
<td>59</td>
</tr>
<tr>
<td>5.3</td>
<td>The mean error in phase between measurement and calculation of transmission coefficient for different ratios of moisture content</td>
<td>65</td>
</tr>
<tr>
<td>5.4</td>
<td>Calibration equations, regression coefficients, optimum frequency and mean relative errors</td>
<td>72</td>
</tr>
<tr>
<td>A.1</td>
<td>Empirical equations and regression coefficients of the relationship between dielectric constant and moisture content values at selected frequencies</td>
<td>81</td>
</tr>
<tr>
<td>Section</td>
<td>Description</td>
<td>Page</td>
</tr>
<tr>
<td>---------</td>
<td>-----------------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>A.2</td>
<td>Empirical equations and regression coefficients of the relationship between loss factor and moisture content values at selected frequencies</td>
<td>81</td>
</tr>
<tr>
<td>B.1</td>
<td>Empirical equations and regression coefficients of the relationship between magnitude of transmission coefficient and moisture content at selected frequencies</td>
<td>82</td>
</tr>
<tr>
<td>B.2</td>
<td>Empirical equations and regression coefficients of the relationship between phase of transmission coefficient and moisture content at selected frequencies</td>
<td>82</td>
</tr>
</tbody>
</table>
## LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Anchovy sauce</td>
<td>2</td>
</tr>
<tr>
<td>1.2</td>
<td>Examples of microwave sensors (Saunders and Aragón, 2007)</td>
<td>3</td>
</tr>
<tr>
<td>2.1</td>
<td>Microstrip linear printed on a dielectric substrate</td>
<td>8</td>
</tr>
<tr>
<td>2.2</td>
<td>Cross-sectional view of the microstrip linear</td>
<td>10</td>
</tr>
<tr>
<td>2.3</td>
<td>Electric and magnetic field liner for a microstrip linear</td>
<td>11</td>
</tr>
<tr>
<td>3.1</td>
<td>Physical geometry of the microstrip sensor</td>
<td>23</td>
</tr>
<tr>
<td>3.2</td>
<td>Elements of basic finite method of (A) one dimension, (B) two dimensions and (C) three dimensions</td>
<td>25</td>
</tr>
<tr>
<td>4.1</td>
<td>Methodology flowchart</td>
<td>27</td>
</tr>
<tr>
<td>4.2</td>
<td>Fabrication flowchart</td>
<td>28</td>
</tr>
<tr>
<td>4.3</td>
<td>A circuit design of the microstrip linear path printed on film</td>
<td>29</td>
</tr>
<tr>
<td>4.4</td>
<td>Microstrip linear printed on film sheet</td>
<td>29</td>
</tr>
<tr>
<td>4.5</td>
<td>(A) RT Duroid Rogers’s 5880 microwave board substrate with copper (B) Substrate with linear after removing copper</td>
<td>30</td>
</tr>
<tr>
<td>4.6</td>
<td>Flowchart of microwave office</td>
<td>31</td>
</tr>
<tr>
<td>4.7</td>
<td>Relationship between magnitude of transmission coefficient and frequency using microwave office</td>
<td>33</td>
</tr>
<tr>
<td>4.8</td>
<td>Sample preparation: (A) oven drying set-up (B) analytical balance</td>
<td>33</td>
</tr>
<tr>
<td>4.9</td>
<td>Measurement set-up: (A) Vector Network Analyzer (VNA) (B) sensor while connecting to VNA</td>
<td>35</td>
</tr>
<tr>
<td>4.10</td>
<td>(A) Calibration kit (B) low loss coaxial cable</td>
<td>35</td>
</tr>
</tbody>
</table>
4.11 Vector Network Analyzer with open-ended coaxial probe for measuring the permittivity

4.12 Relationship between the permittivity and the frequency for (a) ethanol, (b) water and (c) acetone

4.13 Flowchart of FEM calculation

4.14 Model navigator dialog box

4.15 Dialog box scalar variables

4.16 Three-dimension structure of the microstrip sensor assisted with PML using extremely coarse mesh

4.17 Solver parameters dialog box

4.18 Postprocessing-electric filed, X component of the microstrip sensor

5.1 A water molecule, (blue) and an oxygen atom (red).

5.2 (A) Dielectric constant and (B) loss factor with frequency for different percentages of moisture content

5.3 Relationship between loss tangent and frequency at different percentages of moisture content

5.4 Relationship between values of dielectric constant and moisture content at selected frequencies

5.5 Relationship between values of loss factor and moisture content at selected frequencies

5.6 Electric field distributions in microstrip sensor at 2.5 GHz

5.7 Comparison between measured and calculated transmission and reflection coefficient of air

5.8 Comparison between measured and calculated transmission coefficient of water

5.9 Comparison between measured and calculated transmission coefficient for 17.3, 28.2, 36.6 and 44.4 % of moisture contents
5.10 Comparison between measured and calculated transmission coefficient for 50.8, 65.8, 73.0 and 80.2% of moisture content

5.11 Variation in magnitude of transmission coefficient with moisture content at 2.1, 2.245, 2.345 and 2.55GHz

5.12 Variation in magnitude of transmission coefficient with moisture content at 2.72, 2.815 and 2.96 GHz

5.13 Comparison between measured and calculated phase of transmission coefficient of air and water with frequency

5.14 Comparison between measured and calculated phase of transmission coefficient for 17.3, 28.2, 36.6 and 44.4% of moisture contents

5.15 Comparison between measured and calculated phase of transmission coefficient for 50.8, 65.8, 73.0 and 80.2% of moisture content

5.16 Variation in phase of transmission coefficient with moisture content at selected frequencies

5.17 Relationship between predicted and actual moisture content at selected frequency based on magnitude of transmission coefficient

5.18 Relationship between predicted and actual moisture content at selected frequency based on phase of transmission coefficient

5.19 Error distributions between mean relative error and actual moisture content at selected frequency based on magnitude of transmission coefficient

5.20 Error distributions between mean relative error and actual moisture content at selected frequency based on phase of transmission coefficient

C.1 Group of subdomain settings for microstrip line

C.2 Variation in transmission and reflection coefficient with respect to the frequency for calculation of air
## LIST OF ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEM</td>
<td>Finite Element Method</td>
</tr>
<tr>
<td>m.c</td>
<td>Moisture content</td>
</tr>
<tr>
<td>$</td>
<td>S_{21}</td>
</tr>
<tr>
<td>$\phi_{21}$</td>
<td>Transmission coefficient phase</td>
</tr>
<tr>
<td>$\varepsilon'$</td>
<td>Dielectric constant</td>
</tr>
<tr>
<td>$\varepsilon''$</td>
<td>Loss factor</td>
</tr>
<tr>
<td>RF</td>
<td>Radiofrequency</td>
</tr>
<tr>
<td>T</td>
<td>Thickness of conducting line</td>
</tr>
<tr>
<td>W</td>
<td>Width</td>
</tr>
<tr>
<td>H</td>
<td>Thickness of substrate</td>
</tr>
<tr>
<td>$\varepsilon_r$</td>
<td>Relative dielectric constant</td>
</tr>
<tr>
<td>$\varepsilon$</td>
<td>Permittivity</td>
</tr>
<tr>
<td>$\mu$</td>
<td>Permeability</td>
</tr>
<tr>
<td>DC</td>
<td>Direct current</td>
</tr>
<tr>
<td>$Z_c$</td>
<td>Characteristics Impedance</td>
</tr>
<tr>
<td>$\varepsilon_{eff}$</td>
<td>Effective dielectric constant</td>
</tr>
<tr>
<td>$V_p$</td>
<td>Propagation velocity</td>
</tr>
<tr>
<td>$\lambda_e$</td>
<td>Dipole Rotation</td>
</tr>
<tr>
<td>$\delta$</td>
<td>Conductivity of strip conductor</td>
</tr>
<tr>
<td>$m_{wet}$</td>
<td>Wet mass</td>
</tr>
<tr>
<td>$m_{dry}$</td>
<td>Dry mass</td>
</tr>
<tr>
<td>MMM</td>
<td>Microwave moisture measurement</td>
</tr>
</tbody>
</table>
EMP - Evanesced microwave probe
NDT - Non-destructive technique
MSA - Integrated microstrips antenna
MoM - Method of Moment
FDTD - Finite Difference Time Domain
ABC - Absorbing boundary condition
RBC - Reflectionless boundary condition
LLNL - Lawrence Livermore National Laboratories
NEC - Numerical electromagnetic code
EM - Electromagnetic
$e^{j\omega t}$ - Implicit dependency
$\vec{E}$ - Electric field
$\vec{D}$ - Electric displacement
$\vec{H}$ - Magnetic field
$\vec{B}$ - Magnetic flux density
$\rho_q$ - Charge density
$\omega$ - The angular frequency
$\vec{J}$ - Current density
$K_0$ - The wave number of the free space
$f_r$ - Resonant frequency
$\varepsilon_d$ - Dry content permittivity
$\varepsilon_w$ - Water content permittivity
$Z_s$ - Characteristic impedances of the unloaded microstrip
$Z_m$ - characteristic impedances of the loaded microstrip

$\beta$ - phase constant

$\alpha_d$ - Attenuation constant

$\gamma$ - Propagation constant

FDM - Finite Difference Method

BEM - Boundary Element Method

CSM - Charge Simulation Method

FEA - Finite element analysis

3D - Three-dimensional

DXF - Drawing exchange format

FeCl$_3$ - Ferric chloride

SOLT - short-open-load-thru

SOL - short-open-load

PML - Perfect match layer

$Z_s$ - The characteristic impedances of the unloaded

$Z_m$ - The characteristic impedances of loaded microstrip

DXF - Drawing Exchange Format

CAD - Computer-aided design

PnP - Press-n-Peel

FeCl$_3$ - Ferric chloride

tan $\delta$ - Loss tangent

GHz - Giga hertz
CHAPTER 1

INTRODUCTION

1.1 An Overview of Anchovy Sauce

In Malaysia, the Anchovy Sauce called Budu is locally made from Anchovy fish. The process of making the Anchovy sauce was by conflating salt as well as fish in the range of 1:2 and keeping for fermentation for approximately 140 to 200 days. It can be considered that, the main key that plays an important role in the process of making the Anchovy sauce is the ratio of salt. The various flavors of the Anchovy Sauce are attributed to the effects of the different concentration of salt on the enzymatic and activity microbial. It was found that the microorganisms during the process are basically categorized as halophile (Abdullah et al., 1978). The halophilic is the microorganisms that discovered while the Anchovy Sauce production under process. The feature of this sauce is an obviously brown liquid which is the sequence of fish fermentation at high salt content (Saisithi, 1994).

Furthermore, the microorganisms play significant function in degradation of protein and flavor-aroma development. The Anchovy Sauce considered a matured measure ready to be harvested as an oil film produced on its surface. In order to separate the liquid as well as the dregs of the bone, the anchovy sauce is filtered by using the standard filtration method. Afterwards, the Anchovy sauce will be under the process of caning as well as packaging, and then will be distributed to the markets. Anchovy Sauce considered very popular production in several countries but with different names such as: ‘colombo-cure’ in India and Pakistan, ‘ishiru’ or ‘shottsuru’ in Japan, ‘aejeot’ in Korea, ‘yeesu’ in China, ‘pati’ in Philippines, ‘ketjap-ikan’ in Indonesia ‘ngapi’ in Burma and ‘nuoc mam’ in Vietnam.

The content of the Anchovy Sauce has many nutrients, which benefits the consumer. Anchovy sauce considered a source of vitamin B such as: vitamin B1 (thiamin), B2 (riboflavin), niacin, pantothenic acid, vitamin B6 and vitamin B12 (cyanocobalamin). The deficiency of vitamin B12 will lead to lack in the production of red blood cells. Hence, vitamin B12 considered very important since the lack of this vitamin will cause loss of weight, anemia perisiosa and stomach ache.

Another advantage that can be found in Anchovy Sauce is a magnificent ability to hunt free radicals. Therefore, it prevents degenerative illness such as: diabetes, cardiovascular coroner, atherosclerosis and cancer in an earlier stage since the Anchovy Sauce has Genistein and phytoestrogen, which prevent breast cancer. Also, it helps to slow down the aging process as the components it has. Furthermore, it has been found by some researcher that the anchovy sauce not only can decrease blood cholesterol, but prevent cardiovascular diseases as well as hypertension also.
Moreover, as the Anchovy sauce has a dietary fibre sauce, it facilitates the process of the digestion. Thus, the benefits, which caused by the nutritious component of Anchovy sauce satisfies all body needs. Figure 1.1 shows the Anchovy sauce that utilized as a sample for the measurement

![Figure 1.1: Anchovy sauce](image)

The process of fish protein hydrolysis leads to Anchovy Sauce (fish sauce), with a product of fermented fish at high salt concentration (Chaveesuk et al., 1994). For many years, the fish fermentation has been considered a product in Southeast Asian. For the purpose of achieving the simpler components of fish, high percentages as well as fermentation are needed. The usual action of fermentation, especially in sub-region of Southeast Asian, continues around three to nine months; therefore, the flesh of fish might be dissolved or become a paste (Vilhelmasson, 1997). Fermented products, which is considered aquatic (taking a place in water), prepared in a different ranges such as: whole fish, fish sauces as well as pastes (Wheaton and Lawson, 1985).

To avoid rottenness of the fish, the processing and canning technology of fish considered crucial demand; hence, the quality of fish obtained. There are several differences of using the conventional and modern way to prepare Anchovy. In the traditional way, the equipment, which is utilized, is simple. While in modern way, the equipment is developed and the additions are more. Due to several factors such as the habits of local people and availability of salt, techniques of different processing are utilized in fish fermentation from a place to another.
1.2 Microwave Sensor

The developments of many types of microwave sensors for determining the moisture content $m.c$ in materials have been achieved. Microwave sensors utilize electromagnetic fields and devices internally operating at frequencies starting from ~300 MHz up to the terahertz range. Microwave sensors considered very applicable in several fields such as environment, medicine, industry and in a large degree in agricultural industry to assess the quality. In essence, the principles, functions and limitation play a significant role in the selection and deployment of microwave sensor. Coaxial type, waveguide, horn antenna and microstrip are the most popular microwave sensors as illustrated in Figure 1.2. Furthermore, bandwidth, ease and size of the fabrication, the capability of power handling as well as the range of the frequency considered important factors in terms of comparing between the transmission lines.

![Microwave Sensor Diagram](image)

**Figure 1.2: Examples of microwave sensors (Saunders and Aragón, 2007)**
Microwave technique is one of many methods to determine moisture content of the moist materials. The benefits of different sensors are tremendously dependent on the particular applications as listed below (Nyfors and Vainikainen, 1989):

i. Due to the penetration of the microwaves to all materials except metals, the surface and the volume of the material can be represented;

ii. Contact to the object (material) is not necessary for microwaves; hence, the possibility of implementing the on-line measurements from a distance is usually achieve, where there is no interference to the industrial process;

iii. In contrast to infrared method, microwave sensors are not sensitive to the environmental conditions, for instance, dust and water vapour. Also, in contrast to semiconductor sensors, it is insensitive to high temperatures;

iv. At low frequencies such as capacitive and resistive sensors, the electrical properties of materials are often controlled by the DC conductivity. In addition, the DC conductivity is dependent heavily on the ion content as well as temperature. However, the effect of DC conductivity vanishes at microwave frequencies;

v. In contrast to radioactive ionizing radiation, the non-ionizing radiation (microwaves) are considered safer at the power level that used in the measurements;

vi. In contrast to radioactive sensors, microwave sensors are fast;

vii. The microwave techniques have been proven to be important in agricultural especially for moisture content measurements of agricultural products. The applications of microwave in agriculture have been reported in (Krazewski et al., 1997; 1998; Khalid et al., 2006; Guo et al., 2007).
1.3 Problem Statement

Fresh Anchovy sauce consists of 60% to 75% moisture, 4% to 11% lipid, 19% to 23% protein, 1% to 2% ash, and 1% to 3% carbohydrate (Kocatepe, 2011; Lopetcharat and Park, 2002). Critical analyses suggested a reduction of 3% moisture in Anchovy sauce within 5 days after fermentation and continued to decrease up to 60 days after fermentation (Lopetcharat and Park, 2002). Changes in m.c were also linked to physicochemical and microbiological changes especially on the salt and nitrogen content as well as the acidity of the fish sauce. Unfortunately to date, the only method to determine m.c in Anchovy sauce is based on the standard oven drying method.

In spite of its rich source of iron and salt content, the dielectric properties of Anchovy Sauce have not been reported in the literature. The relationship between the dielectric constant $\varepsilon'$, loss factor $\varepsilon''$ and m.c is especially important. The $\varepsilon'$ is the ability to store energy under applied external electric field whilst the $\varepsilon''$ is the tendency to loose energy. Most materials have $\varepsilon''$ lower than the $\varepsilon'$. Thus it would be interesting to examine the dielectric properties of a lossy material such as Anchovy Sauce having a high percentage of m.c, salt and iron content. This project will use a microstrip sensor where the transmission coefficient is very much affected when the sensor is loaded with a lossy material. In addition to aforementioned, a pioneering work on the application of microstrip sensor will be used to evaluate the amount of moisture content using regression equation based on transmission coefficient. The measured results shall be compared with the calculated values using FEM.

1.4 Research Objectives

The objectives of this study are:

1. To establish equations relating the dielectric constant and loss factor to the amount of moisture content in Anchovy Sauce

2. To design, fabricate and test microstrip sensor for determination of moisture content in Anchovy Sauce and to determine the most accurate calibration equation to predict the amount of moisture content using the microstrip sensor

3. To compare the measured transmission coefficient with the theoretical values and to visualize the electric field distribution of a microstrip sensor loaded with Anchovy sauce using Finite Element Method (FEM)
1.5 Scope of Thesis

Chapter 2 begins with basic concepts of a microstrip, followed by literature review on the various methods to calculate the impedance of the microstrip line. This is followed with a brief critical description on microwave moisture measurement techniques. Numerical techniques to calculate impedance of microstrip are also described. The basic theory of the microstrip and finite element method are described in detail in Chapter 3. The fabrication and measurement procedure for the microstrip sensor and moisture determination using oven drying method are described in Chapter 4. Also, the implementation of finite element method using COMSOL software is also detailed in Chapter 4. All the results related to the research objectives are presented and analyzed in Chapter 5. Finally, Chapter 6 summarized the main contributions and suggestions for future work.
REFERENCES


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