PROCESS OPTIMIZATION OF MICROWAVE-DRIED PURPLE SWEET POTATO EXTRACT AND ITS STABILITY IN AQUEOUS SYSTEM

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DEDICATION

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ABSTRACT

Purple sweet potato anthocyanin is a potential natural food colorant with health beneficial bioactive compound. Encapsulation of bioactive compound by microwave drying technology could assist in limiting the loss in food. In this study, the process of microwave drying of purple sweet potato extract (PSPE) was studied. Response surface methodology (RSM) was used to optimise the microwave drying power (330 to 770 W), drying time (215 to 375 s) and maltodextrin concentration (5 to 35 %) for the process of microwave drying of PSPE. The optimised condition obtained with desirability 0.915 was at microwave power 550 W, drying time 298 s and maltodextrin concentration 19.42 %. Validation of optimum process parameter microwave purple sweet potato (MD-PSPE) resulted in an actual value of antioxidant capacity (DPPH), monomeric anthocyanin content (MAC), and moisture content of 79.92 ± 0.8 %, 498.09 ± 5.18 mg/L and 4.56 ± 0.06 % respectively. The errors obtained were between 6.12 – 8.50 % lower than expected value. The stability of MD-PSPE during 10 weeks of storage was evaluated and the stability followed first-order kinetic reaction. After 10 weeks of storage at temperature 26 ± 2 °C, the anthocyanin content of MD-PSPE successfully retain 95% of MAC compared to 65 % MAC retention in the non-encapsulated PSPE. Additionally, the stability of MD-PSPE applied in aqueous system towards thermal process (70 to 90 °C) and storage at temperature (26 ± 2 °C) was evaluated. Anthocyanin degradation towards thermal processing and storage was following first-order kinetic reaction. Throughout heating, MAC of MD-PSPE in aqueous system showed a higher stability at 70 °C with half-life $t_{1/2}$ 14.4 weeks. MD-PSPE in aqueous system (pH 2.0 to 6.0) during storage (26 ± 2 °C) had been successfully retained more than 50 % of MAC. MD-PSPE in aqueous was most stable at pH 3.0-4.0 with half-life $t_{1/2}$ 20.1 to 21.1 weeks. Hence, MD-PSPE produced is suitable for the application into low pH beverages system.

ABSTRAK

Antosianin daripada keledek ungu adalah pewarna makanan semula jadi berpotensi yang mempunyai sebatian bioaktif yang bermanfaat kepada kesihatan. Pengkapsulan sebatian bioaktif oleh teknologi pengeringan gelombang mikro dapat membantu mengurangkan kerosakan kepada kualiti makanan. Dalam kajian ini, proses pengeringan ekstrak keledek ungu (PSPE) menggunakan teknologi gelombang mikro telah dikaji. Metodologi tindak balas permukaan (RSM) telah digunakan untuk mengoptimumkan kuasa pengeringan gelombang mikro (330 hingga 770 W), masa pengeringan (215 hingga 375 s) dan kepekatan maltodekstrin (5 hingga 35 %) bagi pengeringan gelombang mikro PSPE. Keadaan pengeringan proses optimum dengan kebolehinginan 0.915 diperolehi pada kuasa gelombang mikro pada 550 W, masa pengeringan selama 298 s dan kepekatan maltodekstrin sebanyak 19.42 %. Pengesahan parameter proses optimum gelombang mikro keledek ungu (MD-PSPE), memberikan nilai sebenar keupayaan antioksidan (DPPH), kandungan antosianin monomerik (MAC) dan kandungan lembapan masing-masing sebanyak 79.92 ± 0.8 %, 498.09 ± 5.18 mg/L dan 4.56 ± 0.06 %. Ralat diperolehi sekitar 6.12 hingga 8.50 % adalah lebih rendah daripada nilai yang dijangkakan. Kestabilan MD-PSPE ketika dalam penyimpanan 10 minggu dinilai dan didapati kestabilan MD-PSPE mengikuti tindak balas kinetik tertib pertama. Selepas penyimpanan selama 10 minggu pada suhu 26 ± 2 °C, kandungan antosianin MD-PSPE menunjukkan pengekalan sebanyak 95% MAC berbanding dengan pengekalan 65% MAC pada PSPE tanpa pengkapsulan. Kestabilan MD-PSPE dalam sistem berair terhadap proses terma (70 hingga 90 °C) dan penyimpanan pada suhu (26 ± 2 °C) juga dinilai. Degradasi antosianin terhadap pemprosesan terma dan penyimpanan telah mengikut tindak balas kinetik tertib pertama. Sepanjang pemanasan, MAC MD-PSPE dalam air menunjukkan kestabilan yang lebih tinggi pada 70 °C dengan nilai separuh hayat $t_{1/2}$ 14.4 minggu. Penggunaan MD-PSPE di dalam sistem berair (pH 2.0 hingga 6.0) menunjukkan lebih 50% MAC berjaya dikekalkan selepas penyimpanan pada suhu (26 ± 2°C). MD-PSPE di dalam sistem berair lebih stabil pada pH 3.0 - 4.0 dengan nilai separuh hayat, $t_{1/2}$ 20.1 hingga 21.1 minggu. Oleh itu, MD-PSPE dihasilkan adalah sesuai untuk aplikasi terhadap minuman dengan pH rendah.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

NFC	-	Natural Food Colorant
PSP	-	Purple Sweet Potato
PSPE	-	Purple Sweet Potato Extract
MD-PSPE	-	Microwave Dried-Purple Sweet Potato Extract
MAC	-	Monomeric Anthocyanin Content
RSM	-	Response Surface Methodology
UTM	-	Universiti Teknologi Malaysia
HR	-	Hausner Ratio
CI	-	Carr Index
DW	-	Distilled Water
SC	-	Synthetic Colourant
DPPH	-	2,2-Diphenyl-1-picrylhydrazyl

LIST OF SYMBOLS

ε	-	Molar extinction coefficient
C	-	Chrome
H	-	Hue
L*	-	Lightness
a*	-	Redness
b*	-	Blueness
A	-	Absorbance
ρ_{tapped}	-	Tapped Density
ρ_{bulk}	-	Bulk density
M	-	Mass
Vb	-	Bulk Volume
Vt	-	Tapped Volume
Ct	-	Anthocyanin content at t day
C_0	-	Anthocyanin content at day 0
k	-	Constant
t	-	Time
$t_{1/2}$	-	Half life time
s	-	Seconds
W	-	Watt

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Introduction

Food colorant has been used in food for centuries. The synthetic colourant is a chemical synthesis, replicates molecular structure to become identical to the naturally derived colouring. Considering instability of natural food colorant (NFC) due to light, temperature, pH and storage condition, synthetic colorant becomes preferable to improve the colour of the food and transform it into an attractive and appetising food or beverages. Nonetheless, research has been done and summaries that the synthetic colours and additives contribute to the detrimental effects to the human health (Amchova, *et al.*, 2015).

NFC generally defines as sources from substance that occur in nature. It is derived from agricultural, biological, or mineral sources. Independently, NFC does not have the same colour intensity as a synthetic, and some are less economical on a dosage basis. However, research and study nowadays can reduce this performance gap. Furthermore, there are advantages in using natural colour. The use of natural colorant in food has attracted interest in terms of the potential health benefits offered, such as the presence of antioxidant carried along during the processing. Moreover, foods using NFC may boost human health by offering nutrients, which contribute preventing diseases such as inflammation, neuronal diseases, diabetes and many other diseases (Yousuf *et al.*, 2015).

NFC from plant pigmnet can be categories into four main groups including carotenoids; yellow-orange-red (E169, E161, E164), anthocyanin; red-blue-purple (E163), chlorophyllin; green (E140, E141) and betanin; red (E162) (Rodriguez-amaya, 2015). Anthocyanin as NFC can be found in a large number of plants such as pomegranate (Robert *et al*. 2010), Roselle (Duangmal, *et al.*,2008; Idham, *et al.*, 2012), grape (Song *et al.*, 2013), dragon fruit (Zaidel *et al.*, 2015)., black carrot (Ersus and Yurdagel 2007; Zozio, *et al.*, 2011) and many others. The rich anthocyanin content is shown by the intensity of its purple colour (Ahmed, *et al.*, 2010).

The effects of processing (e.g. extraction, evaporation, drying, pasteurisation, sterilisation), food quality stability, application NFC into food or beverage model system and its health benefit has been actively studied by researcher's worldwide. Most studies revealed that the greatest stability challenges in handling NFC for a new product development are pH, temperature, light, distribution or storage, interaction with other components, and solubility. NFC can be created in both a liquid and powder form. The application of encapsulation technologies of anthocyanin from fruits and plants showed to be efficiently alleviate the pigments degradation (Ahmed, *et al.*, 2010; Robert *et al.*, 2010b; Zaidel *et al.*, 2014). Technologies of encapsulation, including spray drying, freeze drying, co-crystallization (Fang and Bhandari, 2010) hot air drying, microwave drying (Peng *et al.* 2013) have been widely discussed.

Microwave encapsulation technology has been discovered due to its faster cooking rates. Venkatesh and Raghavan, (2004) mentioned that short microwave drying time resulting an improvement of product quality. This is promising as a food dehydration technology.

A suitable encapsulant supports recent encapsulation technologies. The addition of suitable encapsulant with appropriate ratio towards the core has proved to be the effective solution to increase the stability of biological component as well ease the technological issues. It will also produce better physical and chemical properties of food ingredients.

1.2 Problem Statement

The antioxidant in fruits or plant is a promising health benefit to the body. In food processing, encapsulation method with short drying time is one of the ways to prevent antioxidant losses. Microwave drying technology is highly potent in improving heating efficiency and limiting the food quality loss. Ling *et al.*, (2015) mentioned food processing using microwave could be a novel thermal processing technique. Microwave as an electro-heating method could replace the conventional heating in producing a better food quality (Pereira *et al.*, 2008). Currently, there is lack of information and research of encapsulation technology using microwave as drying technology for anthocyanin as bioactive compound. Hence, the process parameter and formulation using microwave drying can be studied. The effects of the process variables on food product physicochemical properties will be further investigated. The proper selection of process variables and wall material was expected to lead to an efficient drying process and maintain food quality and stability.

Researchers have studied on anthocyanin stability with various techniques of processing. Nowadays, food industries were using the most economical way of producing natural colorant by using wall material as an encapsulant in spray drying technology (Cai and Corke 2000). Encapsulation is a technique to protect bioactive compound in food from undesirable effect such as pH, light, and temperature that promote to the degradation of food quality (Akhavan *et al.*, 2016). Encapsulating agents known as carbohydrate for example polysaccharides (starch, maltodextrins, and chitosan) are effective in encapsulating bioactive compound of food (Liu *et al.*, 2015). According to Zuhaili Idham *et al.*, (2012), gum, maltodextrin and starches as encapsulant is specifically suitable for anthocyanin encapsulation. This due to the hydrophilic colorants are compatible with a water- based gel formulation. Cai *et al.*, (2019) mentioned that starch as wall material is low cost and effectively improve the stability of core materials towards heat. However, the effects were highly depending on the combination of starch and gum. Maltodextrin has capability of protecting the core material from oxidation besides a water-soluble material. Comes with various dextrose equivalent, maltodextrin was famously used as an encapsulation agent. Ahmed, *et al*. (2009) studied on the maltodextrin concentration on quality properties of purple sweet potato (PSP). Researcher found that additional of maltodextrin can improve the stability of phenolic and anthocyanin content during the processing (spray drying) of PSP.

Anthocyanins are flavonoid that categorised as an antioxidant compound. Interestingly, anthocyanin appeared with excellent colour properties can be used as a natural food colorant. Substituting synthetic colorant with anthocyanin as natural colorant could attract the consumers since it offers many health benefits. To complete these demands, the stability of anthocyanin and its suitability into the food system could be further studied and investigated.

Anthocyanin is one of the most popular natural colorants used in the food industry. The water-soluble characteristic of anthocyanin was responsible for wide range of colour (orange, red, blue and purple). Purple sweet potato (PSP) is a source of high content of anthocyanin pigments with its potential health benefits. Its offer a high intensity purple colour. Current studies on anthocyanin PSP are focussed on PSP extract, PSP flour, and its stability (Cai *et al.* 2016; Li *et al.* 2014; Liu *et al.* 2013; Peng *et al.* 2013). Hence, in this study, processing of purple sweet potato extract (PSPE) encapsulation has been planned. Furthermore, its application into the food system will be further studied.

1.3 Objective

The specific objectives of this study are;

1. To determine and optimize formulation and microwave drying process parameter in achieving the desirable characteristic of PSPE powder.
2. To characterise MD-PSPE stability in terms of monomeric anthocyanin content (MAC) and colour after storing at room temperature and its stability in the application into the aqueous system.

1.4 Scopes

The scope of this research includes;

(a) Correlation between maltodextrin concentration (20 to 30%) and drying power (330 – 550 W) at drying time 315 sin producing microwave-dried PSPE (MD-PSPE). Moisture content, water activity, chromatic properties and monomeric anthocyanin content (MAC) of MD-PSPE were studied.

(b) Correlation between maltodextrin concentration (15 to 35%) and drying (275 – 345 s) at drying power 550 W in producing microwave-dried PSPE (MD-PSPE). Moisture content, water activity, chromatic properties and monomeric anthocyanin content (MAC) of MD-PSPE were

(c) Optimisation of the process variables, drying time (215, to 375s), drying power (330, to 770 W), maltodextrin concentration (5 to 35%) using response surface methodology (RSM, central composite design). Moisture content, monomeric anthocyanin content (MAC) and antioxidant capacity (DPPH) of microwave dried PSPE will be studied.

(d) Evaluation of the optimum powder characterisation compared to high and low maltodextrin concentration. Water activity, hygroscopicity, density, flowability, colour characteristic will be studied.

(e) Study on the MD-PSPE stability during storage at temperature 26±2°C for 10 weeks in terms of MAC retention (%) and kinetic degradation. Total colour difference (TCD) will be included in this study.

(f) Study on the thermal stability of MD-PSPE in application in the aqueous system (temperature: 70°C, 80°C and 90°C, time: 30min, 45 min and 60 min). The retention (%) of MAC and its kinetic degradation were studied and TCD were evaluated.

(g) Storage stability study of MD-PSPE for application in the aqueous system (pH 2 to 6 buffer, temperature: 26±2°C, time: 10 weeks). The retention (%) of MAC and its kinetic degradation were studied and TCD were evaluated.

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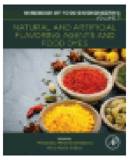
Appendix A

Author for Publish BOOK CHAPTER in HANDBOOK OF FOOD ENGINEERING, Scopus Index

ACADEMIC PRESS

Natural and Artificial Flavoring Agents and Food Dyes



Handbook of Food Bioengineering

2018, Pages 495-526

Chapter 15 - Advanced Natural Food Colorant Encapsulation Methods: Anthocyanin Plant Pigment

Ida I. Muhamad [a], [b], Yanti M.M. Jusoh [a], Norazlina M. Nawi [a], Azni A. Aziz [a], Alyani M. Padzil [a], Hong L. Lian [a]

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Abstract

Color is one of the major attributes in consumers' perception toward food quality. Synthetic food colorants are alleged to have links to behavioral and health problems. Due to consumers' high awareness over the health issues, natural food colorants are the perfect alternative or substitute for the synthetic food colorants. Anthocyanin, a natural pigment, can be found abundantly in fruits and vegetables and its color ranges from bright red to blue. Anthocyanin plant pigments have raised interest due to their ability to be used as natural food colorants with outstanding novel health-promoting properties. Despite its great health potential, anthocyanin has limited application

Muhamad, I. I., Jusoh, Y. M. M., Nawi, N. M., Aziz, A. A., Padzil, A. M. and Lian, H. L. (2018) 'Advanced Natural Food Colorant Encapsulation Methods: Anthocyanin Plant Pigment', Natural and Artificial Flavoring Agents and Food Dyes, pp. 495–526.

Appendix B

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MALAYSIAN JOURNAL OF ANALYTICAL SCIENCES

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PHYSICOCHEMICAL PROPERTIES OF ENCAPSULATED PURPLE SWEET POTATO EXTRACT; EFFECT OF MALTODEXTRIN CONCENTRATION, AND MICROWAVE DRYING POWER

(Sifat Fizikokimia Ekstrak Keledek Ungu yang Dikapsul; Kesan Kepekatan Maltodekstrin, dan Kuasa Pengeringan Gelombang Mikro)

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Purple sweet potato (PSP) is rich with anthocyanin and has a great potential as natural food colorant. In this study, investigation on the effect of maltodextrin (MD, DE 4.0–7.0) concentration as wall material and various microwave drying powers towards physicochemical properties of microwave assisted encapsulation of purple sweet potato extract (PSPE) has been conducted. The effects of microwave power (550 W and 330W) and MD concentration (20%, 25%, and 30%) were analysed for moisture content, water activity, colour, and total monomeric anthocyanin content (TMA). Both moisture content and water activity of the encapsulated PSPE were significantly decreased ($p < 0.05$) as the MD concentration increased at 20% and 30%. With respect of anthocyanin content, increasing of MD concentration at 20% and 30% showed a statistically significant reduction ($p < 0.05$). PSPA with 20% concentration gave the highest TMA at both microwave drying power of 330 W and 550 W, with 385.93±10.81 mg/L and 419.28±10.89 mg/L respectively. However, moisture content, water activity, colour, and TMA were not significantly different with the changing of microwave drying power.

Keywords: purple sweet potato, anthocyanin, microwave-assisted encapsulation, natural colorants, maltodextrin

Abstrak

Padzil, A. M., Aziz, A. A. and Muhamad, I. I. (2018) 'Physicochemical Properties of Encapsulated Purple Sweet Potato Extract; Effect of Maltodextrin Concentration, and Microwave Drying Power', Malaysian Journal of Analytical Sciences, 22(4), pp. 612-618,

Appendix C

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EFFECT OF INCORPORATING PURPLE-FLESHED SWEET POTATO IN BISCUIT ON ANTIOXIDANT CONTENT, ANTIOXIDANT CAPACITY AND COLOUR CHARACTERISTICS

(Kesan Penambahan Keledek Ungu ke dalam Biskut Terhadap Kandungan Antioksida, Kapasiti Antioksidan dan Ciri-Ciri Warna)

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Abstract

Purple flesh sweet potato (PFSP) is considered to be a nutritionally rich crop. It also contain abundant amount of anthocyanin pigment which possess disease preventive properties. This work aims to study the effect of incorporating different form of processed PFSP, namely fresh, flour, and paste in biscuit formulation. Analysis was performed on the total phenolic, total anthocyanin content, antioxidant capacity, and colour characteristics. The analyses were made on samples, before and after the incorporation of PFSP in the biscuit. PFSP flour was prepared by directly using hot air-drying at 65 °C for 18 hours while PFSP paste was steamed for 30 minutes at 100 °C. The PFSP fresh contained total anthocyanin content at 21.40 mg CyE/100 g fw, and the content increased when processed into the form of flour and paste approximately at 38.90 mg CyE/100 g fw and 52.48 mg CyE/100 g fw, respectively. All forms of processed PFSP enhanced the purple colour when incorporated into the biscuit formulation. The experimental results showed that biscuit added with PFSP lost 15–36% of antioxidant capacity. Based on these

Aziz, A. A., Padzil, A. M. and Muhamad, I. I. (2018) 'Effect of incorporating purple-fleshed sweet potato in biscuit on antioxidant content, antioxidant capacity and colour characteristics', Malaysian Journal of Analytical Sciences, 22(4), pp. 667–675.

LIST OF PUBLICATIONS

1 Muhamad, I. I., Jusoh, Y. M. M., Nawi, N. M., Aziz, A. A., Padzil, A. M. and Lian, H. L. (2018) 'Advanced Natural Food Colorant Encapsulation Methods: Anthocyanin Plant Pigment', Natural and Artificial Flavoring Agents and Food Dyes. Academic Press, pp. 495–526.

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