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DEVELOPMENT OF DRIED RICE NOODLES FORTIFIED WITH β-CAROTENE FROM DIFFERENTLY PROCESSED CARROTS (Daucus carota L.)

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By

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Chair : Prof. Sharifah Kharidah Syed Muhammad, PhD
Faculty : Food Science and Technology

The trend towards consuming foods fortified with fruits and vegetables is escalating due to the increasing consumer awareness on functional foods which include fortified rice noodles. However, food processing such as dried rice noodle making often involves high temperature and high moisture that can affect the stability of fruit and vegetable nutrients such as ß-carotene from carrot. This study was conducted to determine the physico-chemical properties of 3 differently processed carrot preparations namely carrot puree (CP) as a control, oven dried carrot powder (ODCP) and spray dried carrot powder (SDCP), the retention and storage stability of β–carotene in rice noodles fortified with these preparations post extrusion, and β-carotene retention as well as the physico-chemical properties of the aforementioned fortified noodles after cooking. Each processed carrot preparation at various levels (5%, 10% or 15%) was mixed with rice flour and tapioca starch blend (80:20) and the moisture content of the mixture (extrusion feed) was adjusted to 30% before extrusion at 80 °C, 100 °C, 100 °C, 100 °C for zones 1, 2, 3 and 4 of the extruder barrel, respectively. The feed rate was set at 20 rpm with a screw speed of 60 rpm. The fortified rice noodles were dried at 30 °C for 16 h and then analyzed for ß-carotene content, retention of ß-carotene, and colour. In addition, the physico-chemical properties of CP, ODCP and SDCP were also examined. The results showed that SDCP exhibited the lowest moisture content (4.09%) and the lowest hygroscopicity (15.92%) while ODCP had the lowest water activity (0.37), highest ß-carotene content (159.48 mg/100g) and highest redness value. ß-carotene content of the noodles increased as level of fortification with CP, ODCP and SDCP increased. Dried rice noodle containing 15% ODCP had the highest ß-carotene content (5.74 mg/100g) and redness value (21.06) compared to the other fortified dried rice noodles while 5% CP noodle had a significantly higher ß-carotene retention (63.45%) post extrusion compared to the other fortified rice noodles. The redness value of the noodles was positively correlated with their ß-carotene content. Storage stability and degradation kinetics of ß-carotene in the dried rice noodles were assessed

under conditions of with or without light and oxygen at room temperature or 40 ºC. Presence of oxygen, exposure to light and elevated temperature of 40 ºC were found to increase ß-carotene degradation. Half-life of ß-carotene in noodles containing CP was the highest (25 - 103 weeks) followed by that in noodles containing SDCP (8 - 19 weeks) and ODCP (8 - 15 weeks) for all levels of fortification and storage conditions. Cooking quality, textural properties, sensory properties, ß-carotene retention, ß-carotene content and colour of fortified noodles post cooking were also studied. All noodle rehydration and cooking loss values were in the acceptable range of 167.83% - 207.29% and 5.70% - 11.20%, respectively. In terms of textural qualities, rice noodles containing 15% ODCP and 15% SDCP had significantly lower hardness, gumminess and chewiness compared to the other noodles. For sensory evaluation, both of these samples were not significantly different in terms of their flavour, texture and overall acceptability except for their appearance. However, rice noodles containing 15% ODCP exhibited a significantly higher ß-carotene retention (51.90%), ß-carotene content (2.09 mg/100g) and redness value (8.03) post cooking. In conclusion, 15% ODCP noodle was chosen to be the best fortified rice noodle due to its high β-carotene content, high retention of β-carotene post cooking, most orange in colour and acceptability by the sensory panelists.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

PEMBANGUNAN MEE BERAS KERING YANG DIPERKAYA DENGAN β-KAROTEN DARIPADA LOBAK MERAH YANG DI PROSES SECARA BERBEZA

Oleh

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Trend ke arah pemakanan yang diperkaya dengan buah-buahan dan sayur-sayuran semakin meningkat disebabkan peningkatan kesedaran pengguna terhadap makanan fungsian termasuk mee beras. Walau bagaimanapun, pemprosesan makanan melibatkan suhu tinggi yang mempengaruhi kestabilan nutrien buah dan sayuran seperti ß-karoten dari lobak merah. Kajian ini dijalankan untuk menentukan pengekalan ß-karoten dalam mee beras yang diperkaya dengan lobak merah. Kajian ini dijalankan untuk menentukan pengekalan ß-karoten dalam mee beras yang diperkaya dengan lobak merah. Puri lobak merah (CP), serbuk kering lobak merah (ODCP) dan semburan kering lobak merah (SDCP) secara berasingan dimasukkan ke dalam mee beras yang disemperit. Setiap lobak merah yang diproses di tambah pada tiga tahap berbeza (5%, 10%, 15%) kemudian dicampurkan dengan tepung beras dan tepung ubi kayu (80:20) dan kandungan kelembapan suapan diselaraskan kepada 30% sebelum penyemperitan pada 80 ° C, 100 ° C, 100 ° C, 100 ° C untuk zon 1, 2, 3 dan 4 barel, dengan 20 rpm kadar suapan dan 60 rpm kelajuan skru. Mee dikeringkan pada suhu 30 ° C selama 16 jam dan dinilai untuk pengekalan ß-karoten dan warna. Di samping itu, sifat fiziko-kimia CP, ODCP dan SDCP diperiksa. Ini termasuk kandungan kelembapannya, aktiviti air, hygroscopicity, kandungan ß-karoten dan warna. Keputusan menunjukkan SDCP menunjukkan kandungan kelembapan terendah (4.09%) dan hygroscopicity terendah (15.92) manakala ODCP menunjukkan aktiviti air terendah (0.37%), kandungan ß-carotene tertinggi (159.48 mg/100g) dan nilai kemerahan tertinggi. Kandungan ß-karoten dalam mee beras meningkat dengan pertambahan CP, ODCP dan SDCP. Mie beras kering yang mengandungi 15% ODCP mempunyai kandungan ß-karoten yang jauh lebih tinggi (5.74 mg / 100g) dan nilai kemerahan (21.06) berbanding dengan mee beras kering lain manakala 5% CP mempunyai pengekalan ß-karotena (63.45%) penyemperitan berbanding mee beras lain. Nilai kemerahan mee

berkait secara positif dengan kandungan ß-karoten. Kestabilan penyimpanan dan kinetics degradasi ß-karoten dalam mee beras kering telah dinilai di bawah keadaan ada atau tanpa cahaya dan oksigen pada suhu bilik atau 40 ºC. Kehadiran oksigen, pendedahan kepada cahaya dan suhu tinggi 40 ºC didapati meningkatkan degradasi ß-karoten.Mee yang mengandungi CP menunjukkan separuh hayat ß-karoten tertinggi (25 - 103 minggu) diikuti dengan mee yang mengandungi SDCP (8 - 19 minggu) dan ODCP (8 - 15 minggu) untuk semua keadaan penyimpanan. Kualiti masakan, tekstur, sensori, pengekalan ß-karoten, kandungan ß-karoten dan warna mee yang diperkaya selepas memasak juga dinilai.Semua rehidrasi mee dan nilai kehilangan memasak berada dalam lingkungan 167.83% - 207.29% dan 5.70% - 11.20%. Dari segi kualiti tekstur, mee beras yang mengandungi 15% ODCP dan 15% SDCP mempunyai kekerasan, kelekatan dan kekenyalan yang lebih rendah daripada berbanding dengan mee lain. Untuk penilaian deria, kedua-dua sampel tidak memberikan perbezaan yang signifikan dari segi rasa, tekstur dan penerimaan keseluruhan kecuali penampilan. Walaubagaimanapun, mee beras yang mengandungi 15% ODCP menunjukkan pencapaian post retensi masakan ß-karoten yang lebih tinggi (51.90%), kandungan ß-karoten (2.09 mg/100g) dan nilai kemerahan (8.03). Kesimpulannya, 15% ODCP dipilih sebagai mee beras yang terbaik kerana kandungan β-karotena yang tinggi, pengekalan penyimpanan makanan yang tinggi, warna paling oren dan diterima oleh panelis deria.

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LIST OF ABBREVIATIONS

µM	Micrometer
a*	Redness
ANOVA	Analysis of variance
a_w	Water activity
b*	Yellowness
°C	Degres celcius
C_3H_6O	Acetone
C_6H_{14}	Hexane
CH_3OH	Methanol
CP	Carrot puree
cm	Centimeters
DAD	Diode array detector
DM_E	Dry matter extrudate
DM_F	Dry matter feed
FDA	Food and Drugs Association
G	Gram
g/mg	Gram per mili gram
h	Hour
k_1	Reaction rate constant
L*	Lightness
LED	Light emitting diode
M	Mol
MC	Moisture content
mm	Milimeter

mg	Miligram
mg/mL	Miligram per mililiter
mL	Mililiter
mL/min	Mililiter per minute
NaCL	Sodium Chloride
Nm	Nanometer
ODCP	Oven dried carrot powder
pH	Power of hydrogen
rpm	Rotation per minute
S	Seconds
SDCP	Spray dried carrot powder
SEM	Scanning electron microscope
t	Time
$t_{1/2}$	Half life
UV	Ultraviolet
VIS	Visible
VPSEM	Variable pressure scanning electron microscope
v/v	Volume per volume
W	Watt
%WI	Weight of sample after one week – weight of sample
W1	Weight of solids in 10 mL
W0	Weight of powder

CHAPTER 1

INTRODUCTION

1.1 Background

The rice noodle market size in Europe and Asia Pacific was estimated at USD 1.69 billion in 2014 and is expected to witness a significant growth over the next seven years owing to increase consumer demands from emerging economies including China and India (Grand View Research, 2018). The positive increment is due to urbanization and changing consumer habits which has resulted in fuelling the demand for convenience food products. Milled rice noodles, however, contains a limited amount of vitamins and minerals due to the removal of bran and lost of germ from rice during its milling. Thus, addition of vegetables such as carrots into milled rice noodle could aid in increasing its nutritional value in terms of its carotenoids content. Addition of other natural pigments such as betalains from red beet (Kim *et al.,* 2015) carotenoids from pumpkin (Lee *et al*., 2002), chlorophylls from spinach (Ahmed *et al*., 2010) and lycopene from tomato (Nochai and Pongjanta 2013) to wheat noodle is currently gaining great interest. Durum wheat noodles with added natural pigments from spinach, red beet and purple carrot are even now commercially available, for example, from the brand *San Remo, Barilla* and *Eatalian Express*.

Carrot *(Daucus* carota) is a root vegetable, widely found with an orange hue due to its carotenoid content. It is also the most essential source of dietary carotenoids in most western countries (Block 1994; Törrönen *et al.,* 1996). Carrot carotenoids comprised primarily of ß-carotene at 60-80%, followed by 10% - 40% α-carotene, 1-5% lutein and 0.1%-1% of other carotenoids (Chen *et al.,* 1995). Carotenoids are important micronutrients for human health as they are precursors of vitamin A (Castenmiller and West 1998). Additionally, carotenoids have other significant roles in biological functions of humans and animals (Van Vliet, 1996). Based on previous epidemiological studies, an increase in dietary intake of carotenoid-rich food and increase blood levels of ß-carotene could eventually reduce incidence of certain cancers (Törrönen *et al.,* 1996), age associated macular degeneration, cataracts, coronary heart disease, cardiovascular disease, and several pathological processes (Kohlmeier and Hasting 1995; Biesalski 1997; Kritchevsky 1999).

Purees from fruits and vegetables have been widely produced commercially for direct consumption or as intermediates in the production of food ingredients (Maceiras *et al.,* 2007). The food industry often use carotenoid containing purees such as mangoes (Ahmed *et al.,* 2002), tomatoes (Sánchez-Moreno *et al.*, 2006), and pumpkins (Gliemmo *et al.,* 2009; Provesi *et al.*, 2011) in their preparations. The fruit and vegetable purees are used as they are or in dehydrated forms. Dehydration is a preservation technique in which moisture

content is reduced to level at which the product is relatively chemically stable. Mechanical drying is among the most common drying techniques employed in food processing. The advantages of this technique are uniform drying and better quality of dried product (Prakash *et al.,* 2004). Spray drying is extensively used in commercial production of milk powder, fruit and vegetable powders (Caparino *et al.,* 2012). It is a process where dried particulates are formed from a fluid feed (solution, dispersion or paste) through a spraying technique. It is a continuous process which involves a combination of several stages, that is, atomization, mixing of spray and air, evaporation and product separation (Rè, 1998). It has several advantages including rapid drying which allows the preservation of the thermal sensitive components in food at high percentages. In this study, milled rice noodle which in fortified with carrot carotenoids will be produced using an extruder. To incorporate the carrot carotenoids into the rice noodles, the most important criteria to note is that the carotenoids in the carrot puree or powder must be able to withstand the hot extrusion during the production of the rice noodles. Extrusion is a highly integrated process at low cost. It boasts several advantages such as being energy efficient, generates low waste, gives wider range of raw material selection, and has the ability to produce products with varied texture and shape (Riaz *et al.,* 2009). In addition to this, extrusion is also a viable method for encapsulation of bioactives, in this case, ß-carotene from carrots.

1.2 Problem statements

1. Demand for milled rice noodle is increasing but it is low in nutritional value.
2. Drying method will affect carotenoid content and other physico-chemical properties of carrot powder.
3. Extrusion will degrade the carrot carotenoids incorporated into rice noodle.
4. Storage conditions influence the stability of carrot carotenoids in fortified rice noodle
5. Cooking will affect the β-carotene content and quality of fortified rice noodle.

1.3 Objectives

The current study aims:

1. To investigate the effect of incorporating differently processed carrot preparations on the retention of β-carotene in extruded and dried rice noodles.
2. To determine the degradation kinetics of β-carotene and storage stability of the fortified rice noodles under various conditions.
3. To study the effect of cooking on the fortified rice noodles and its consumer acceptance.

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