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EFFECTS OF DRYING TREATMENTS ON FUNCTIONAL PROPERTIES OF OKARA AND EXTRUSION PROCESSING OF OKARA EXTRUDATES

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EFFECTS OF DRYING TREATMENTS ON FUNCTIONAL PROPERTIES OF OKARA AND EXTRUSION PROCESSING OF OKARA EXTRUDATES

By

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EFFECTS OF DRYING TREATMENTS ON FUNCTIONAL PROPERTIES OF OKARA AND EXTRUSION PROCESSING OF OKARA EXTRUDATES

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Chairperson : Nor Afizah Mustapha, PhD
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Effect of extrusion process of okara and its product characterization in terms of microstructural and soluble dietary fiber were not found in previous studies, however these product characterizations are needed as knowing these characteristics are crucial as the information can be used in producing the best extruded product for further commercialization. The objectives of this research were to study the effects of drying conditions; hot air drying and vacuum drying at 40, 50, and 60°C, drum drying at 1 rotational speed with steam pressure of 2.0, 2.5 and 3.0 bar on physicochemical properties of okara. Water activity (0.41 - 0.50), L^* (87.52 - 88.86), a^* (1.04 - 1.66), and b^* (13.11 - 16.84) of okara at all drying conditions tested showed a significantly higher ($p < 0.05$) values compared to Control (wet okara) with values of 0.95, 76.43, 2.39, and 20.85, respectively and it was considered safe from microbial growth and biochemical changes, while lighter colour may increase consumer acceptance. Okara processed using drum drying 2.0 bar (DD 2.0) showed a significantly higher ($p < 0.05$) swelling power (SP), water retention capacity (WRC) and oil retention capacity (ORC) compared to other drying conditions with values of 12.31 g/g, 10.69 g/g, and 3.73 g/g respectively, while vacuum dried sample at 60°C has the highest water solubility index (WSI) (16.67%). Based on physicochemical properties tested, DD 2.0 that produced dried okara with the highest SP, WRC, ORC, L^*, a^* with acceptable water activity (0.50), b^* (14.38), total colour difference (ΔE) (12.90), and WSI (13.72%) were then chosen for extrusion study. The effects of different okara level (0, 5, 10, 15%) was studied in production of okara-enriched expanded snacks. Extrudate containing 15% okara had lower water activity (0.46) and higher insoluble, soluble and total dietary fiber (23.2, 1.2, 24.4%, respectively) compared to Control (0% okara) with values of 0.48, 0.5, 0.3, 0.8%, respectively. Extrudate with 5% okara that had a significantly higher L^* (80.90) and expansion ratio (2.47), but lower a^* (3.66), b^* (18.22), ΔE (6.45) and bulk density of exrudates (0.23) compared to samples with 10 and 15% okara. In addition, the hardness and crispness of extrudate decreased with increasing okara level with higher percentage of okara exhibited a rougher surface with smaller size of air cells. The results indicated that incorporation of 5% okara able to produce expanded snack with improved nutritional quality while maintaining its extrudate characteristics.

Keywords: Okara, hot air drying, vacuum drying, drum drying, physicochemical characteristics, extruded product

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

KESAN TEKNIK PENGERINGAN KE ATAS SIFAT FUNGSIAN OKARA DAN PROSES PENYEMPERITAN EKSTRUDAT OKARA

Oleh

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Kesan proses penyemperitan okara dan pencirian produknya dari segi mikrostruktur dan serat larut ekstrudat tidak terdapat dalam kajian terdahulu. Walaubagaimanapun, kepentingan untuk mengetahui ciri-ciri karakteristik produk adalah diperlukan untuk mendapatkan maklumat untuk digunakan dalam menghasilkan ekstrudat produk yang terbaik untuk pengkomersialan selanjutnya. Objektif dalam kajian ini adalah untuk mengkaji kesan-kesan kondisi pengeringan; udara panas dan vakum di 40, 50, dan 60°C, dram di 1 kelajuan pusingan dengan 2.0, 2.5, dan 3.0 stim bar ke atas fiziko-kimia okara. Aktiviti air (0.41 - 0.50), L^* (87.52 - 88.86), a^* (1.04 - 1.66), dan b^* (13.11 - 16.84) okara di semua kondisi pengeringan yang telah diuji menunjukkan tinggi yang signifikan ($p < 0.05$) berbanding Kontrol (okara basah) dengan nilai of 0.95, 76.43, 2.39, dan 20.85, masing-masing dan di mana dari aspek pertumbuhan mikrob dan perubahan biokimia adalah selamat, sementara warna yang pudar memungkinkan penerimaan pengguna. Okara yang telah diproses menggunakan pengeringan drum pada 2.0 stim bar (DD 2.0) menunjukkan tinggi yang signifikan ($p < 0.05$) pada nisbah pengembangan (SP), kadar penyimpanan air (WRC), dan kadar penyimpanan minyak (ORC) jika dibandingkan dengan kondisi pengeringan yang lain dengan nilai 12.31 g/g, 10.69 g/g, dan 3.73 g/g masing-masing, sementara sampel pengeringan vakum di 60°C menghasilkan kadar larutan air (WSI) yang tertinggi (16.67%). Berdasarkan fiziko-kimia yang dikaji, DD 2.0 menghasilkan SP, WRC, ORC, L^*, a^* okara yang tertinggi dengan aktiviti air (0.50), b^* (14.38), perbezaan warna (ΔE) (12.90), dan WSI (13.72%) yang boleh diterima dan kemudiannya dipilih untuk kajian penyemperitan. Kesan tahap okara yang berlainan (0, 5, 10, 15%) digunakan untuk penghasilan snek yang kembang yang diperkaya dengan okara. Extrudat yang menpunyai 15% okara menghasilkan pengurangan aktiviti air (0.46) dan peningkatan tidak larut, larut dan keseluruhan serat (23.2, 1.2, 24.4%, masing-masing) dibandingkan dengan Kontrol (0% okara) dengan nilaian 0.48, 0.5, 0.3, 0.8%, masing-masing. Extrudat dengan 5% okara menghasilkan nilai tinggi yang signifikan L^* (80.90) dan nisbah pengembangan (2.47), tetapi rendah a^* (3.66), b^* (18.22), ΔE (6.45) dan ketumpatan saiz (0.23) dibandingkan dengan sampel 10 dan 15% okara. Tambahan pula, kekerasan dan kerangupan ekstrudat menurun dengan peningkatan okara, di mana tinggi peratusan okara menghasilkan permukaan yang kasar dengan sel udara yang mempunyai saiz yang kecil. Keputusan menunjukkan penambahan 5% okara mampu menghasilkan snek pengembangan dengan peningkatan kualiti nutrisi disamping mengekalkan karakteristiknya.

Kata kunci: Okara, pengeringan udara panas, pengeringan vakum, pengeringan dram, fiziko-kimia karakteristik, produk tersemperit

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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) are adhered to.

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LIST OF ABBREVIATIONS

%	Percentage
µm	Micromilliliter
°C	Degree Celsius
ΔE	Total changes in colour
a^*	Redness
a_w	Water activity
b^*	Yellowness
ANOVA	Analysis of variance
C*	Chroma
CO^2	Carbon dioxide
d.b	Dry basis
DATEM	Diacetyl tartaric acid ester of monoglycerides
DD 2.0	Drum drying at 2.0 bar
DD 2.5	Drum drying at 2.5 bar
DD 3.0	Drum drying at 3.0 bar
DW	Dry weight
g/cm^3	Gram per cubic centimeter
g/g	Gram per gram
h*	Hue angle
HA 40	Hot air drying at 40ºC
HA 50	Hot air drying at 50ºC
HA 60	Hot air drying at 60ºC
kg	Kilogram
kV	Kilovolts

*L**	Lightness
m/s	Meter per second
mbar	Millibar
min	Minute
mL	Milliliter
ml/g	Milliliter per gram
mg	Milligram
mg/g	Milligram per gram
mm	Millimeter
mm/mm	Millimeter per millimeter
mm/sec	Millimeter per second
ORC	Oil retention capacity
PET	Polyethylene terephthalate
R^2	Coefficient of determination
RNI	Recommended Nutrient Intakes
RPM	Rotations per minute
SP	Swelling power
VD 40	Vacuum drying at 40ºC
VD 50	Vacuum drying at 50ºC
VD 60	Vacuum drying at 60ºC
w/v	Weight by volume
w/w	Weight by weight
WRC	Water retention capacity
WSI	Water solubility index

CHAPTER 1

INTRODUCTION

Today, there are a great interest towards processing of food by-products because of their alternative uses and beneficial components. Thus, developing the products from these underutilized residues by addition or substitution in food is needed in producing value-added products for food application (Li et al., 2016). Okara is one of the well-known by-products for this purpose due to its high nutritional value, consisting of fiber (50%), protein (25%), and lipid (10%) (in dry basis) (Li et al., 2012a). It is a by-product from soybean and tofu manufacturing industry. There is a large quantity of okara being produced annually, especially in Asian countries. The amount of okara produced by soymilk and tofu industry is about 310,000 tonnes in Korea, 800,000 tonnes in Japan, and 2.8 million tonnes in China (Li et al., 2012a). However, there is no info for the amount of okara being produced in Malaysia. Nevertheless, there are a number of local and multinational companies producing soymilk and tofu for local consumer and export to other Asian countries such as Indonesia and China under the brand name such as Naraya, Soy Up, and Yeo's (Insights, 2016; Hong, 2018). Therefore, it is assumed that a large number of okara being produced annually. Currently, okara is regarded as food wastes or used as animal feed. This food waste causes potential environmental problems due to its highly susceptible to putrefaction, because okara consists of high moisture (70-80%) content (Vong and Liu, 2016). Aside from microbial spoilage, the rancidity of the okara also occurs contributed by their high lipid content (Azanza and Gascon, 2015) leads to off flavour and browning in colour. Therefore, drying is needed to avoid spoilage and also for preservation purposes.

Studying on okara drying is important to wisely utilize okara in food system. There are several studies have been performed on okara drying. A combination of pneumatic tube and rotating drum has been tested for drying of okara (Perussello et al., 2009). According to the study, okara dried at 130°C for 15 min gave a relatively light colour when compared with okara dried at higher temperature (170°C for 9 min) that gave a burnt colour. In addition, drying of okara using a vacuum dryer gave higher proximate values with longer shelf life compared to microwave drying. In respect of chemical composition, both of the drying process exhibited higher nutritional quality in comparison to wet okara (Sengupta et al., 2012). Muliterno et al. (2017) reported that oven drying at higher temperature (70°C) caused colour alteration and degradation of all isoflavones compounds. In contrast, it showed faster drying rates and increased speed of drying by reducing the time taken for completing the process.

A number of drying techniques can be applied in order to remove the large amount of water from okara. Hot air drying is a process of drying with the presence of heat. The heated air is in contact with wet materials and water is migrated to the surface of the materials and then is removed as water vapour (Jayaraman and Gupta, 2006). In addition, vacuum drying is a method where material is dried at lower temperature. The moisture removal occurs when air is replaced by vacuum. Water vapour is continuously removed from drying chamber with decreasing of vapour pressure saturation at the given temperature (Bourdoux et al., 2016). In drum drying, food material is dried by pressurised steam contributed from inner part of heated rotary drums. Following the process, the heat is transferred to the surface of rotary drum causing removal of water into the surrounding (Goula, 2016). According to Grizotto and Aguiree (2011), hot air-drying process can remove the moisture content of okara from an initial value of 82.87% to a final moisture content of 5% in 8 h, while Sengupta et al. (2012) reported that vacuum drying was able to reduce the moisture content of okara from 68.03% to 5.03% in 5 h. Meanwhile, Taruna and Jindal (2002) demonstrated that vacuum drying gave negative effects in terms of quality and energy use when compared to drum drying.

There has been growing demands of okara due to its functional properties for enrichment in food product associated with high fiber and protein content. Food fiber has been associated with numerous functional properties which is important for efficient utilization in food products. Fiber has been proven for having high hydration properties such as swelling and water retention capacity due to its ability to retain water within the fiber matrix, in which it could be used as functional ingredients to avoid syneresis and enhance viscosity in food products (Li et al., 2014). In addition, oil retention capacity which is the ability of fiber to absorb fat/oil is important to prevent fat loss during cooking (Ghanem et al., 2012) and to ensure stabilization of emulsion and high fat products during processing of food (Li et al., 2014). Meanwhile, water holding and fat absorption capacities of protein are also important factors for successful food product enrichments, in which water holding capacity is an important property in providing thickening and viscosity in foods such as custards, soups, and baked products by binding water without dissolution of protein while fat absorption capacity is beneficial for flavour retention and essential for food formulation such as salad dressings, sausages and cake batters (Kumar et al., 2014).

Most of the snacks are often considered to contain mainly empty calories, hence the addition such as fiber and protein as food ingredients can provide nutrient-rich to extruded snacks. Dried okara can be incorporated in production of extruded snacks due to its high nutritional characteristics. Therefore, the enrichment of okara in food product via extrusion process as a functional food ingredient can be used as an alternative in producing highly nutritious snacks. Most of previous extrusion studies on okara focusing on converting the insoluble fiber into the soluble. Several authors (Li et al., 2012b; Jing and Chi, 2013) reported that soluble dietary fiber significantly increased with a reduction was observed for the insoluble dietary fiber. For the time being, only a group of researchers (Kanojia et al., 2016) demonstrated the effect of okara on textural properties and protein content of the extrudate. It was found that the limitations of inclusion of okara was due to the addition of protein constituents in extruded snacks resulted in decrease crispness and increase hardness of extrudate. In extruded products, good expansion and crispness is needed for improving their characteristics in product development.

Currently, there are numerous studies on drying (Peruselo et al., 2009; Sengupta et al., 2012; Muliterno et al., 2017) and extrusion (Rinaldi et al., 2000; Kanojia et al., 2016) of okara. However, there are no published reports on characterization of dried okara in terms of its functional properties such as swelling power, water solubility index, water and oil retention capacities. It is crucial to know their properties for successful incorporation of the powder in food applications. In addition, it is important to seek for the most economical drying techniques in terms of duration of drying without destroying the functional characteristics the end of product. Furthermore, there was no data available on the effect of drying conditions of okara using drum dryer. In addition, there are no reports on the effect of okara on fiber content and microscopic properties of extrudates, and how the addition of okara affects the surface and porosity (internal) characteristics of extrudates and its association with the expansion properties. Thus, knowing its beneficial properties and incorporation as functional ingredient in food system, will improve the value of end product. Thus, developing new products with high nutritional content especially fiber can provide a healthy okara-based product with a good consumer acceptance.

General objective of this study was:

To investigate the best drying technique in producing dried okara that maintains their functional characteristics and utilization of the powder in production of highly nutritious okara-expanded product through extrusion.

The specific objectives of this study were:

This study was divided into two parts:

1. To determine the effects of drying techniques (hot air, vacuum, and drum drying) on physicochemical properties of dried okara

2. To investigate the effect of dried okara level on production of okara-enriched expanded snacks.

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