PHYSICAL PROPERTY CHANGES AND SENSORY EVALUATION MODELLING OF OSMOTICALLY DEHYDRATED PUMPKIN USING INTELLIGENT METHODS

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FACULTY OF ENGINEERING
UNIVERSITI MALAYSIA SABAH
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DECLARATION

I hereby declare that the material in this thesis is my own except for quotations, excepts, equations, summaries, and references, which have been duly acknowledged.

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ABSTRACT

The objectives of this study were to use intelligent methods to model sensory evaluation, as well as to predict physical properties changes of osmotically dehydrated pumpkin slices. The effects of process variables which are concentration of osmotic solution, immersion temperature and immersion time were studied. For the first part of this work, the physical properties such as the net colour difference changes, ΔE, the texture which was determined in terms of hardness and shrinkage were determined. An Artificial Neural Network was developed by using the process variables as the input. A feed-forward backpropagation network with tangent sigmoidal function at hidden layer and output layer was trained and best network was chosen based on the highest correlation coefficients and lowest Root Mean Square Error (RMSE) between the experimental values versus the predicted values. As comparison, Response Surface Methodology (RSM) with three-level three-factor Box-Behnken design was employed. The performances were evaluated based on Model Predictive Error (MPE), correlation of determination (R^2) and root mean square error (RMSE). In this study, the results showed that ANN has higher prediction capability as compared to RSM. Concentration showed the highest influence on colour change and shrinkage, followed by time and temperature. On the other hand, immersion time has the most significance effect on texture, followed by concentration and temperature. For the sensory evaluation modelling, 15 untrained panels evaluated the osmotic dehydrated pumpkin samples for various sensory attributes such as colour, taste, hardness and aroma. The sensory score for the sensory attributes was analysed using Fuzzy Logic techniques. The judges' preference on the significance of sensory attributes was taken as crisp numbers instead of linguistic forms by applying the 5-point fuzzy logic scale. Sensory quality of samples was then compared based on the estimated overall sensory scores, overall membership function, similarity values, and relative importance of sensory attributes. It was found that Sample S14 (Concentration=45 Brix, Temperature=50℃, Immersion Time=150 minutes) ranked the best in the category of "good" (Similarity value=0.7245), the samples that treated with low temperature is well accepted. The relative importance of quality attributes of OD pumpkin samples was ranked as Taste > Aroma > Hardness > Colour, indicating that taste is the most important quality attribute in this study. Besides, ANN was also employed to predict the overall acceptability of osmotically dehydrated pumpkin. Again, the process variables were used as input while independent overall acceptability was used as output of ANN. A feedforward backpropagation network with Training Levenberg–Marquardt (LM) as the training function was generated. The tangent sigmoid transfer function (tansig) at hidden layer and pure linear transfer function at output layer were used. It was found that ANN with one hidden layer comprising 9 neurons gives the best fitting with the experimental data, which can predict total acceptance with lowest RMSE (0.047) and highest correlation coefficients (0.9757). These results indicate that ANN is a powerful tool to estimate the overall acceptability of the pumpkin. Besides, solution concentration, solution temperature and immersion time has almost equal effect to the overall acceptability of OD pumpkin samples.

ABSTRAK

PERUBAHAN SIFAT FIZIKAL DAN MODEL PENILAIAN SENSOR BAGI LABU DEHIDRASI SECARA OSMOTIK MENGGUNAKAN 'INTELLIGENT METHOD'

Objektif kajian ini adalah menggunakan Rangkaian Neural Buatan (RNB) untuk meramalkan perubahan warna, pengecutan dan tekstur kepingan labu yang terhidrasi secara osmotik. Kesan pembolehubah proses yang kepekatan larutan osmotik, suhu rendaman dan masa perendaman pada sifat fizikal di atas telah dikaji. Warna sampel diukur dengan menggunakan Hunter L (keputihan), a (kemerahan), b (kekuningan) dan perubahan warna bersih, ΔE dikira. Tekstur itu ditentukan dari segi kekerasan dengan menggunakan mesin analisis tekstur. Bagi pengecutan, anjakan kaedah anjakan isipadu digunakan dan peratusan pengecutan diperoleh daripada perubahan isipadu. RNB telah dibangunkan dengan menggunakan pemboleh ubah proses sebagai input. Rangkaian penyebaran semula feed-forward dengan fungsi sigmoidal tangen pada lapisan tersembunyi dan lapisan output terlatih dan rangkaian terbaik dipilih berdasarkan pekali korelasi tertinggi dan Ralat Kuadrat Minimum Purata (RKMP) antara nilai eksperimen berbanding nilai ramalan. Sebagai perbandingan, Kaedah Permukaan Tindak Balas (KPTB) dengan reka bentuk Box-Behnken tiga peringkat tiga faktor telah digunakan. Prestasi keputusan dinilai berdasarkan Ralat Ramalan Model (RRM), korelasi penentuan (R^2) dan Ralat Kuadrat Minimum Purata (RKMP). Keputusan menunjukkan bahawa RNB mempunyai keupayaan ramalan yang lebih tinggi dibandingkan dengan KPTB. Kepekatan larutan menunjukkan pengaruh tertinggi pada perubahan warna dan pengecutan, diikuti oleh masa dan suhu larutan. Sebaliknya, masa perendaman mempunyai kesan tertinggi pada tekstur, diikuti oleh kepekatan dan suhu. 15 panel yang tidak terlatih dinilai untuk pelbagai sifat deria seperti warna, rasa, kekerasan dan aroma. Skor deria mengenai sifat deria dianalisa menggunakan teknik Logik Fuzzy. Keutamaan panel terhadap kepentingan sifat deria diambil sebagai nombor yang tajam dan bukannya bentuk linguistik dengan menggunakan skala logika fuzzy 5-point. Kualiti sampel sensori kemudiannya dibandingkan berdasarkan anggaran skor deria keseluruhan, fungsi keahlian keseluruhan, nilai kesamaan, dan kepentingan relatif sifat-sifat deria. Ia didapati bahawa Sampel S14 (Kepekatan larutan = 45 Brix, Suhu = 50 ℃, masa rendaman= 150 minit) adalah yang terbaik dalam kategori "baik" (Nilai Kesamaan = 0.7245) dan sampel yang direndam pada suhu rendah diterima secara baik. Kepentingan relatif kualiti atribut sampel labu OD telah disenaraikan sebagai Rasa> Aroma> Kekerasan> Warna, menunjukkan bahawa deria atribut adalah yang paling penting dan warna adalah yang paling tidak penting sifat atribut dalam kajian kes ini. RNB telah digunakan untuk meramalkan penerimaan keseluruhan labu osmosis secara dehidrasi. Pemboleh ubah proses digunakan sebagai input sementara kebolehterimaan keseluruhan bebas digunakan sebagai output ANN. Rangkaian RNB dengan Latihan Levenberg-Marquardt (LM) sebagai fungsi latihan dihasilkan. Telah didapati bahawa RNB dengan satu lapisan tersembunyi yang terdiri daripada 9 neuron memberikan pemasangan yang terbaik dengan data percubaan, yang dapat meramalkan penerimaan keseluruhan dengan RKMP terendah (0.047) dan pekali penentuan, R^2 (0.9757). Hasil ini menunjukkan bahawa Walau bagaimanapun, larutan osmotic, suhu rendaman dan masa perendaman mempunyai kesan hampir sama kepada penerimaan keseluruhan sampel labu osmotik terhidrasi.

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LIST OF SYMBOLS AND ABBREVIATIONS

ANOVA	Analysis of Variance
ANN	Artificial Neural Network
a*	Redness
A_{rel}	Relative weightage for the sensory attributes for aroma
a_w	Water Activity
b*	Yellowness
bko,	Constant Regression Coefficient
bki	Linear Regression Coefficient
bkii	Quadratic Regression Coefficient
bkij	Cross-Product Regression Coefficient
BBD	Box-Behken Design
Brix	Sugar Content in Aqueous Solution
B_x	The values of membership function
C_{rel}	Relative weightage for the sensory attributes for colour
CV	Coefficient of Variation
Conc.	Concentration of Ternary Solution, Brix + 5%w/w of Salt Solution
df	Degree of Freedom
ΔE	Total colour difference
et al. (et alia)	means "and others"; replaces a list of names of person
ε	Statistical error
F	Standard fuzzy scale
FL	Fuzzy Logic
g	grams
H_{rel}	Relative weightage for the sensory attributes for hardness

I_j	the relative importance of the j^{th} input variable on the output variable
L*	lightness
K	number of parameters
min	Minutes
mm	Millimeter
MPE	Model Predictive Error
n	Number of the independent variables
η	Response
OD	Osmotic Dehydration
po	Partial Pressure of Pure Water
p	Partial Pressure of Water Vapour
%S	Shrinkage percentage
SrC	Triplets for the sensory scores for colour attributes
SrA	Triplets for the sensory scores for aroma attributes
SrT	Triplets for the sensory scores for taste attributes
SrH	Triplets for the sensory scores for hardness attributes
Std Dev.	Standard Deviation
R^2	Coefficient Of Determination
RMSE	Root Mean Square Error
RSM	Response Surface Methodology
S_m	Similarity value of each of the sample
SO_r	Triplets for Overall Sensory Score
temp	Temperature of Osmotic Solution, °C
time	Immersed Time, min
Trainlm	Levenberg-Marquardt (LM) algorithm
T_{rel}	Relative weightage for the sensory attributes for taste
V_i	Volumes of the samples at the starting
V_f	Volumes of the sample at the end of osmotic dehydration experiment
w.b	Wet basis
W_O	Initial Weight of Sample, g
W_D	Weight of Sample after Dried For 24 Hours, g

X	Independent Variables
Y	Response Variables
Y_n	Normalized value
Y_a	Actual value
Y_{min}	Minimum value
Y_{max}	Maximum value
% w/w	Weight Percent
°C	Degree Celsius
>	More than
<	Less than

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CHAPTER 1

INTRODUCTION

1.1 Research Background

The moisture content in most fruits and vegetables is above 75% and thus leads to their perishability (Yadav and Singh, 2012). As such, they are spoiled easily due to microbial growth of molds and yeasts. Generally, large amount of fruits and vegetables are produced especially in peak season. Without proper preservation method and storage facilities, the market will be over-flooded during the peak seasons and get rotten before they reach the consumers.

Drying is one of the most important methods to preserve foods. Drying is used to remove water from food materials. This enables the inhibition of microbial growth, enhances food preservation and reduces the bulk volume as well as weight for convenient transport and storage. Osmotic dehydration (OD) is a non-thermal drying method to partially reduce the moisture content of fruits, vegetables, meat or fish with the purpose to increase the shelf life or as a pre-treatment in the processing of dehydrated foods (Assis, Morais, and Morais, 2015). OD is able to reduce the impact of heat to the flavor and colours of fruits or vegetables, prevents spoilage and reduces energy consumption (Garcia, Mauro, and Kimura, 2007; Lee and Lim, 2011; Mayor, Cunha, and Sereno, 2007). OD is a technique where immersion of food material in a hypertonic aqueous solution leading to the loss of water (Sereno, Moreira, and Martinez, 2001). The removal of water from the tissue is accomplished by a counter-current diffusion between osmotic agent and water. These simultaneous activities aid in declining of moisture content and water activity of the samples. The reduction in water activity (a_w) can prevent microbial growth in food. Measurement and prediction of water activity is one the best tool for evaluation of the stability of foods (Prothon & Ahrné, 2004). Hence, OD can be applied as pre-treatment to some conventional processes such as air drying, freezing, freeze drying and vacuum drying. In recent years, OD was commercialized in food processing industry due to low energy consumption, and food quality improvement (Sereno et al., 2001).

Apart from increasing shelf life of food and reduced drying time, OD also improve the quality properties of the food, especially sensory, nutritional value and physical properties (Tunde-Akintunde and Ogunlakin, 2013). The texture properties of the thawed fruits and vegetables can be enhanced (Chiralt, Martínez-Navarrete, Martínez-Monzó, Talens, Moraga, Ayala, and Fito (2001). Fresh fruit which was elastic, hard and brittle, after dehydration treatment, fruit tissue lost its elasticity, retain its strength but became more deformable (Garcia, et al., 2007; Lee and Lim, 2011; Mayor et al., 2007). The natural colour of frozen fruits can be retained as well as after subsequent drying (Chiralt et al., 2001). Aktas, Fujii, Kawano, and Yamamoto, (2007) reported the effect of trehalose as osmotic agent in osmotic dehydration of sliced vegetables, less shrinkage was found and better colour properties and better cell reconstructions properties for dried carrot and potato were observed. The benefits of this technology draw the attention of researches on OD, and various types of fruits and vegetables have been applied such as apples (Monnerat, Pizzi, Mauro, and Menegalli, 2010), banana (Rastogi and Raghavarao, 1997) cherry tomatoes (Derossi, Severini, Del Mastro, and De Pilli, 2015), egg plant (Russo, Adiletta, and Matteo, 2012), sweet potato and potato (Antonio, Alves, Azoubel, Murr, and Park, 2008; Eren and Kaymak-Ertekin, 2007), kiwi fruits (Talens et al., 2002) and so forth.

Pumpkin (*Cucurbita pepo L.*) is a fruit that can be made into soups, pies and bread or can be cooked as a dish. Pumpkin has also been used as animal feed (Kowalska, Lenart, and Leszczyk, 2008). However, it is still considered as underrated fruits in the food industry. Recently, the increase of public awareness of healthy lifestyle has led to the consumption of high nutritional value and health related properties food material including processed pumpkin. Pumpkin contains β-carotene in the range from 3.3 to 7.6 mg/100 g of fresh mass, minerals and it is also a low caloric food (about 17 kcal at 100 g of pumpkin's flesh) (Ciurzyńska, Andrzej, and Gręda, 2014). It also consists of phenolics, flavonoids, polysaccharides, mineral salts, vitamins, and other substances that are good for health (Yang, Zhao, and Lv, 2007). Fresh pumpkin are very sensitive to microbial spoilage, even at refrigerated conditions, hence, it must be processed to dried or frozen products (Doymaz, 2007).

Due to the high moisture content of pumpkin (88%-92%), the product can be easily spoiled. Hence, drying is the best available method to preserve pumpkin flesh. Dried pumpkin can be a finished product or a half-finished product which is subject to further processing (Sojak and Głowacki, 2010). Dried pumpkin or OD-treated pumpkin may also increase the final quality of the finished product. Hot-air drying is the common preservation method of agricultural product due to its simplicity and low cost (Diamante, Ihns, Savage, and Vanhanen, 2010). However, high temperature will degrade the sensorial properties and nutritional properties of dried foods. Hence, microwave heating, vacuum drying, air-convective drying or combination drying techniques is introduced. These few methods have higher drying rate, shorten the drying time and improves the final quality of the dried foods.

The sensory properties of the pumpkin such as taste, hardness, aroma, and colour will be changed after OD and drying process. Hence, it is necessary to evaluate the perspective of the customers towards the final quality and overall acceptance of the processed pumpkins. Sensory evaluation has been defined as a scientific method used to evoke, measure, analyse, and interpret consumers responses to products as perceived via the senses of sight, smell, touch, taste and hearing (Stone and Sidel, 2004). Hence, it attempts to isolate the sensory properties of foods themselves and provides significant and useful information to product developers and food scientists about the sensory characteristics of their products (Harry T. Lawless and Heymann, 1998). Sensory evaluation is widely used in quality inspection of food industry, cosmetic industry, chemical industry, packaging techniques, textile products and automobile industry to determine their characteristics in systematic manner by means of a group of panels.

1.2 Problem Statement

The major challenge in the food processing field is maintaining the desired quality of the finished product. A food manufacturing process need to be monitored and modified to ensure the quality of food products. The quality of food products is defined in the terms of sensory attributes, but control of food processing usually relies on instrumental measurements. There is necessary to develop functional relationship between sensory and instrumental variables which includes instrumentally measured and manipulated process variables (Kupongsak and Tan, 2006b).

Food processes are usually considered as vague and uncertain due to the complex physiochemical changes occurring in a process and the variety of raw materials. Human sensory responses such as sight, touch, smell, taste and hearing are used to interpret the product sensory characteristics via sensory evaluation. Although the physical and chemical properties associated with sensory attributes can be measured by certain instrument such as textures analyzers, gas chromatography (GC), high-performance liquid chromatography (HPLC) and etc, but these instruments can only measure the intensity of the sensory attributes, but do not provide the information about the consumers' preferences of the food product. Hence, if the correlation between the food composition and sensory evaluation results can be determined, the food industry would be able to use the instrumental analysis results to establish an evaluation for the quality characteristics of food (Zhang and Chen, 1997).

However, the food industry is facing the challenges to convert human sensory response into instrumental measurement effectively, as human sensory responses are naturally fuzzy. The intensity of instrument variables is not equivalent to the sensory attributes. This leads to the no linear relationship between sensory attributes and instrumental. Hence, other alternatives need to be