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Effects of Different Cooking Methods on the Physico-Chemical and Quality Attributes of Eggplants

Uthumporn, U[#], Laila, D.L[#]., Rabeta, M.S[#]., Aida,H[*]., Ruri, A.S[1]

[#] *Food Technology Division, School of Industrial Technology, Universiti Sains Malaysia, 11800, Penang, Malaysia*
E-mail: sapina@usm.my

* *Food Technology Research Centre, MARDI Headquarters, Serdang, P.O. Box 12301, 50774 Kuala Lumpur, Malaysia*
E-mail: aida@mardi.gov.my

* *Politeknik LP31 Medan, Medan Sumatera Utara, Indonesia*
E-mail: ruri.adit@gmail.com

***Abstract*— Two types of eggplants (Solanum melongena L.), Chinese Eggplant and Indian Eggplant were cooked at three different cooking methods including frying, grilling and superheated steam (SHS). The objective of this research was to discover the effect of different cooking methods on the quality attributes of eggplant in terms of the physico-chemical properties, antioxidant properties and overall acceptability. The conditions for frying and grilling were set at 170°C for 7 minutes meanwhile; two parameters were used in SHS including 170°C for 7 minutes and 220°C at 15 minutes as the optimum conditions. SHS gives highest results in terms of physicochemical properties and antioxidant properties but frying methods gain high scores for the overall acceptability. Based on the results it can be concluded that even though SHS gives healthier and better results of the eggplant, but, texture, taste and aroma will influence on the acceptability of the final food products.**

***Keywords*— Eggplant; cooking method; superheated steam; antioxidant activity; functional food**

I. Introduction

Eggplants (Solanum melongena L.) are most popular vegetable worldwide and one of an important market vegetable in Asian and Mediterranean countries [1,2]. Eggplants were categorized in an excellent source of antioxidants, and top ranking for the vegetables rich in phenolic compounds3. Purple pigmented eggplants appear to have high antioxidant anthocyanins however, the peel represents only less than 5% of the total fruit weight [4,5]. According to Nisha et al6 eggplants are versatile vegetables and could be process at different techniques and cooking methods. In Malaysia, eggplants normally serve as side dishes during major meals and usually, the eggplants will be boiled for a few seconds or deep fried before being served. However, those processing and heat-applied-cooking process (frying, boiling, steaming and roasting), has a significant effect on the changes of chemical compositions such as bioactive components, antioxidant activities and physical characteristics including color, texture, sensory and flavour [7,8].

Study by Xazela et al [9] observed that cooking methods have significant effect on the sensory scores in terms of aroma, juiciness and first bite acceptance. Furthermore, study on children's acceptance by Poelman et al8, proved that cooking time may influenced on the firmness and chewing resistance, as well as odor and flavor of the vegetables. Further investigation shows that the combination of flavor and texture attributes will determine the acceptance of vegetables rather than the texture attributes itself.

Additionally, antioxidant in fruits, vegetables and grains may decrease due to the food processing operations [10,11]. Food processing may alter the antioxidant activity in either positive or negative ways. Sun et al [12] has stated antioxidant activity is correlated with the occurrence of phytochemicals including phenolics, flavonoids, and anthocyanins in foods. Therefore, this study was aim to investigate the effect of fry, grill and superheated steam method on the quality attributes of eggplant in terms of physicochemical properties, antioxidant activity and overall acceptability. This would provide some insights on the attribute and property of end products with regards to the different cooking methods.

II. Materials and Methods

Two different types of eggplants; Chinese eggplant (long shape) and Indian eggplant (oval shape), were purchased from the market. High qualities with good morphology in terms of ripeness, freshness, color and size, were the most concerned criteria in eggplants selection. All the chemicals used for analysis were analytical grade.

A. Sample preparation

Eggplants were washed under running tap water for a few minutes to remove soil and foreign particles. Without peeling of the skin the eggplants were then sliced into thin slices. Samples were cooked at three different cooking methods, including frying, grilling and superheated steam.

B. Cooking methods

1) Frying Method: The eggplants were fried using frying pan at temperature 170 ºC for 7 minutes.

2) Grilling: Grill method was done using a double grill pan (Vantage, DF-DP03). The grill pan was coated with oil and heated up to 170°C before the eggplants were arranged on it. Samples were grilled for 7 minutes at ~170°C.

3) *Superheated steam method:* The superheated steam oven was set at supersteam convection (supersteam bake/roast) mode with two different parameters; optimum conditions, 220 ºC for 15 minutes and standard conditions, 170°C for 7 minutes.

C. Moisture and fat analysis

Moisture analyzer (Denver Instrument IR-30) was hired to analyze moisture content with setting temperature 105°C. Fat analysis was conducted follows Soxhlet Extraction Method [13].

D. Antioxidant analysis

Extraction sample was carried out by weighing 1 g of dried sample into a conical flask which wrapped with aluminium foil and 100 mL of 80% methanol was added into the flask. The mixture was shaken for 24 hours at 160 rpm, at 27 ºC with an orbital shaker (IKA incubator shaker KS 4000 ic control, China). The mixture was then centrifuged at 2500 rpm for 30 minutes (KUBOTA 5100 Centrifuge, Japan) in order to obtain a clear supernatant. Then the methanol was removed by using the Rotary Evaporator (EYELA N1000S-WD, Tokyo, Japan). Free radical scavenging activity of eggplant extract was estimated using a stable DPPH radical, DPPH (1,1-diphenyl-2-picrylhydrazyl) assay [14]. Approximately 800 µL of DPPH solution (100 µM) was mixed with 200 µL of the extracted samples. The mixture was left to stand in the dark at room temperature for 20 minutes. The absorbance was measured spectrophotometrically at 515 nm. Results were expressed as % radical scavenging activity:

$$\text{\% of DPPH free radical scavenging activity} = \frac{\text{ABS control} - \text{ABS sample}}{\text{ABS control}} \times 100$$

Where,
ABS control: Absorbance of blank/control
ABS sample: Absorbance of sample

E. Colour measurement

Colorimeter (Minolta spectrophotometer CM-3500d, Osaka, Japan) was used to determine the color of the cooked eggplant. Browning assessment was carried out according to Ruangchakpet & Sajjaanantakul [15] method with the calculating formula as follow:

Browning Index (BI) = ([(x - 0.31)/ 0.17] X 100) /(5.645L* + a* – 0.3012b*) , where x= a* + 1.75L*

F. Texture analyzer

Texture analysis was performed using texture analyzer (Stable MICRO System, TA.XT-Plus, Surrey, U.K). Texture measurements of the eggplants were done at room temperature (25°C) by a compressing test using a 65 mm compression plate, with load cell, 30 kg- 5kg load; return distance, 30 mm; return speed, 5 mm/s; contact force, 5 g; and strain 50%. Sample was placed over the support and system was run until the probe touch and compresses the sample. The hardness, gumminess, and springiness are measured.

G. Statistical Analysis

All the analysis was performed in duplicate. All the data were analyzed statistically by SPSS. Analysis of variance was performed and statistical significance was determined at 5% significant level using one way ANOVA. Duncan test at a level of significance of $p < 0.05$ was performed for post hoc comparisons to compare the treatment means. All the data were presented as mean ± standard deviation.

III. Result and Discussion

A. Moisture and fat analysis

Moisture content in Figure 1 shows raw samples and different types of cooked samples were significantly diferent ($P < 0.05$). Mositure content in raw eggplants shows 91.92 % and 90.42 % for RL and RR, respectively. Meanwhile, cooked eggplants show moisture in the range 21.49 % - 43.05 % for long eggplants and 37.51 % - 41.94 % for round eggplants with frying method shows lowest moisture content for both samples. A study by Ramírez-Anaya et al [16] shows low moisture and higher fat content were gained in the deep frying vegetables which were similar to results obtained. Water removal during cooking process causes reduction of moisture content in the samples. Generally, cooking will lead to reduce the moisture content whilst increasing in other nutrients [17], and fat content [18].

The variation in the moisture content of the vegetables affected the proportions of fat and dry matter in the food after the different cooking processes [19]. Figure 2 shows fat content of both samples in different cooking method. Refer to the result, it shows both controls, were significantly different ($p < 0.05$) with cooked samples except for GL. RL shows 1.54 % of fat content meanwhile, RR resulted 1.71 %. These results were in agreement to the study by Agoreyo19, raw eggplant has about 1.65 % of fat content. Base on the observation, frying method gained high fat content and was significantly different to other cooking methods of both samples. Fat content of frying method, FL and FR were noticeable high with 93.09 % and 72.20 % respectively compared to superheated steam 4.92 % - 5.72 % (AL & BL), 5.39 % - 5.60 % (AR & BR) as well as grill method 2.44 % (GL) and 7.06 % (GR). According to Chiou et al [20], frying is a dehydration process in which the evaporation of water in the surface layers provides spaces to oil fill in the foodstuff's pores.

TABLE I
ABBREVIATION FOR ALL SAMPLES USED

	Abbreviation
AL	Superheated steam under 170 ^{0}C for 7 minutes of long eggplant
AR	Superheated steam under 170 ^{0}C for 7 minutes of round eggplant
BL	Superheated steam under 220 ^{0}C for 15 minutes of long eggplant
BR	Superheated steam under 220 ^{0}C for 15 minutes of round eggplant
GL	Grill method of long eggplant under 170 ^{0}C for 7 minutes
GR	Grill method of round eggplant under 170 ^{0}C for 7 minutes
FL	Fry method of long eggplant under 170 ^{0}C for 7 minutes
FR	Fry method of round eggplant under 170 ^{0}C for 7 minutes
RL	Raw long eggplant
RR	Raw round eggplant

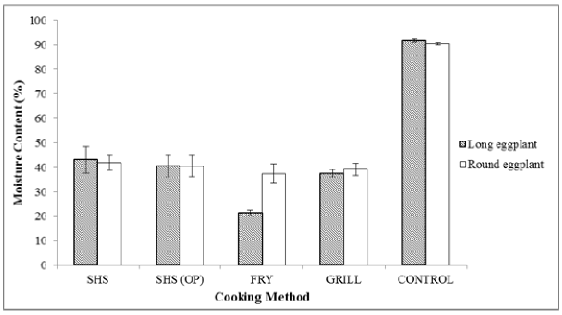

Fig. 1 Moisture Content of different types of cooked eggplant. Data are means ± SD (n=3)

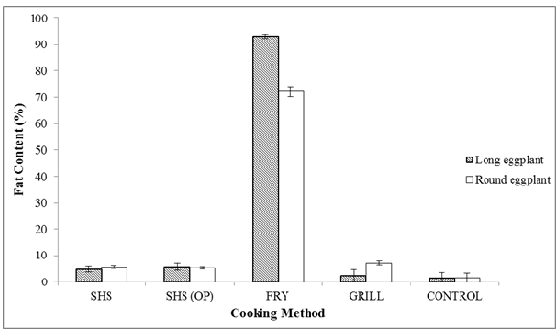

Fig. 2 Fat content of different cooking method of eggplant. Data are means ± SD (n=3)

B. *Antioxidant scavenging activity DPPH*

Ease and convenience method lead to the widely used of DPPH assay as a tool to determine the free radical scavenging activity. Table 2 show the radical scavenging activity of eggplants at different cooking method. The results show that DPPH were significantly increased from frying > grill > superheated steam method. Highest results gained by AL with 90.23 % and the lowest are FL with 22.29 %. Study by Chumyam et al [21] observed the DPPH radical scavenging assay in eggplant fruits were significantly ($p<0.05$) increased when heated with either by boiling, steaming, or microwaving compared with the raw fruits.

TABLE II
DPPH CONTENT IN EGGPLANTS FROM DIFFERENT COOKING METHOD

	DPPH Content
Long eggplant	
Superheated steam	90.2281 ± 1.23f
Superheated steam (optimum)	66.0905 ± 1.28d
Frying method	22.2922 ± 4.97a
Grill method	40.5123 ± 2.39b
Control	
Round eggplant	
Superheated steam	88.9525 ± 1.26f
Superheated steam (optimum)	82.8364 ± 1.83e
Frying method	22.9740 ± 3.32a
Grill method	48.7385 ± 3.90c
Control	

Data is expressed as mean ± standard deviation (n = 3). Means in column sharing the same superscript letter are not significantly different ($P<0.05$).

C. *Texture (Hardness)*

Texture significantly influence on the consumer's perception towards food products. In this study, texture analysis focus on the hardness which is represented the firmness of the eggplant. Refer to the Figure 3, RL and RR significantly show highest hardness results compared to the cooking eggplants with 20.46 g and 14.72 g respectively. Different cooking methods give no significant difference ($p > 0.5$), in the hardness of both eggplants. Superheated steam shows medium firm (soft texture) on the eggplant texture with 5.29 g for AL and 4.13 g for AR. Caixeta et al [22] observed softer texture of potato chips was obtained in superheated steam method.

In contrast, frying method samples were less hardness among other methods with FL, 1.31 g and FR, 1.53 g due to their texture was flaccid and oily. According to Eissa & Ramadan [23], eggplant is capable to absorb large amounts of frying oil, hence explained on the lowest hardness gained by FL and FR. Additionally, the cooking process can soften the vegetable tissue, facilitating the extraction of compound from the cellular matrix [24].

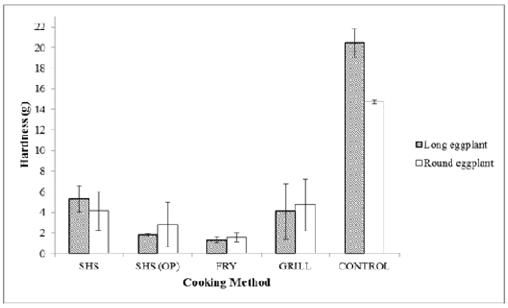

Fig. 2 Texture in terms of hardness of different cooking method of eggplant. Data are means ± SD (n=3)

D. Color

Browning reaction is the main reason for the color changes in food during thermal processing. Polyphenol is the principle compound in eggplants that may induce Mailard reaction; one of the browning reaction. Color measurement and Browning index (BI) results were shown in Table 3 with L* representing lightness. Both control eggplants show significantly different with all the cooked eggplants samples. L* value for the RL gives the highest value with 85.50 %, followed with BL, 74.65 %, AL, 67.90 %, GL, 57.05 % and FL, 41.49 %. Furthermore, L* value for RR have same pattern results with 84.39 % for lightness value, followed by SHS > grill > frying. In contrast, all the control a* and b* values have the lowest values compared to cook samples. It shows that the redness and yellowness values of the eggplants were increasing after cooked. Martins [25] stated that the rate of Maillard reactions rising with temperatures, hence, by raising the temperature caused an increase of the reactivity between the sugar and the amino group.

Browning index is the purity of brown color, and it could be calculated from all the interaction of L-value, a-value and the b-values. Refer to the result in table 3, different cooking methods give significant results on browning index. Results show RL and RR have lowest browning index with 20.64 ± 2.51 and 23.07 ± 0.70 respectively. Observation on the browning index for long eggplant indicate that FL gives highest result with 126.83 ± 25.29 meanwhile round eggplant shows GR were the highest with 73.01 ± 18.89 Numbers of study have proved the level of phenolics were correlate to the browning index [26,27].

TABLE III
COLOR AND BROWNING INDEX OF THE EGGPLANTS FROM DIFFERENT COOKING METHODS

	L value	**Browning Index**
Long eggplant		
Superheated steam	67.90 ± 4.39c	37.98 ± 2.73ab
Superheated steam (optimum)	74.65 ± 1.75d	29.13 ± 3.79a
Frying method	41.49 ± 1.11a	126.83 ± 25.29d
Grill method	57.05 ± 1.18b	81.47 ± 2.43c
Control	85.50 ± 0.36e	20.64 ± 2.51a
Round eggplant		
Superheated steam	71.19 ± 1.43cd	30.99 ± 0.92a
Superheated steam (optimum)	66.24 ± 7.00c	31.40 ± 3.20a
Frying method	54.20 ± 1.21b	52.29 ± 7.82b
Grill method	55.34 ± 2.65b	73.01 ± 18.89c
Control	84.39 ± 0.48e	23.07 ± 0.70a

Data is expressed as mean ± standard deviation (n = 3). Means in column sharing the same superscript letter are not significantly different (P<0.05).

IV. CONCLUSIONS

Several investigations were done in this study observed that superheated steam method gives highest results in terms of physicochemical properties and antioxidant properties but frying methods gain high scores for the overall acceptability. Superheated steam shows medium firm on the eggplant's texture compared to flaccid and the oily texture gained by frying method. L* value gives results in an arrangement of SHS > grill > frying meanwhile, for a* and b*, it shows that the redness and yellowness values of the eggplants were increased after cooked. For the antioxidant properties, superheated steam was significantly gaining highest DPPH result with AL 90.23 % and the lowest are frying method with 22.29 %. The most important characteristics of the superheated steam are the samples was heated or dried under non-oxygen environments, thus, low oxidation process was occurring in this method. Based on the results it can be concluded that even though superheated steam gives healthier and better results, texture, taste and aroma will influence on the acceptability of the final food products.

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