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Effect of Grinding Process on Physical Properties of Torch Ginger Puree

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Abstract

Torch ginger is a type of herb with pink inflorescence from family Zingiberaceae, the family of ginger. It is known to be rich in nutritional content and it has irreplaceable distinct aroma and flavour which is commonly used in culinary. However, it has a short shelf life which is about a week and the quality is often destroyed by the enzymatic browning reactions. A statistical model has been developed in this study to optimise the grinding process through the production of torch ginger puree from raw torch ginger puree for torch ginger preservation. The experiment was designed using response surface methodology (RSM) based on 22 face-centred central composite design (FCCCD) to evaluate and optimise the grinding process by studying interaction of the grinding time and amount of water added. The process was optimised to achieve ideal properties of puree in terms of total soluble solids, water activity, colour and browning index (BI). By using the predicted regression model equations, an optimum grinding operation was obtained at 405s of grinding time and addition of 257ml water with high composite desirability which was 0.983. In conclusion, the treated torch ginger puree with optimum grinding process has improvement on its colour in terms of 48% higher on L*, 40% lower on a* and 68% lower on BI with the commercial product.

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1. Introduction

Torch ginger is a popular perennial herb in New Guinea, Australia, and South East Asia especially Malaysia, Thailand and Indonesia, where it has young shoots, inflorescences and fruits that are commonly used in culinary and traditional medicine [1, 2, 3]. Its rich antioxidant, vitamin and phytochemicals properties, active in antibacterial and anticancer activities give benefit to human's health [2, 4].

Although torch ginger is available throughout the year in tropical and subtropical countries like Malaysia, it still has a narrow peak harvesting season which is between April and May every year [5]. The shelf life of the flower bud of torch ginger is relatively short which is around 5 to 7 days. The high productivity despite seasonal brings mass production to the market [5]. However, during non-peak season and festival season, the demand for torch ginger becomes high that directly causes the rising price of the torch ginger. The seasonal and unstable pricing has impacted the manufacturer every year.

Preparation of value-added torch ginger puree product is able to increase availabilities of the torch ginger throughout the year. Puree is the unfermented, semi-processed using blended edible parts and peeled flesh which has higher viscosity than juice. The production of torch ginger puree is useful and convenience and most importantly is to improve the availability of the torch ginger. The changing of the lifestyles and habit, the health promoting and easy-to-use or convenience products are produced to follow the trend of the consumer habit now [6] even the product is pricier than the fresh materials due to the processing and packaging added.

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Application of grinding as added values for the torch ginger puree will be ideal to produce quality improved product. Grinding process is a unit operation involving size reduction of food. This process is significant to produce the foods with ideal size distribution which suitable for the further processing and consumption. However, it has little or no preservative effect [7] and it is an inefficient processing where the energy inputs have to be utilised them efficiently [8]. According to Jeevani et al. [4], torch ginger has high dietary fibre content. This is which makes the grinding hard and inefficient, and greater loss on the quality of the torch ginger.

The efficiency of the grinding process needs to be further studied and optimised to improve the process in terms of the two important parameters; grinding time and moisture content. These factors can be studied by using response surface methodology (RSM) which is able to determine the impacts or roles of each of the grinding time and amount of water added and their interactions with the quality or dependent factors of the torch ginger puree [9]. The objective of this study is to investigate the physical quality of torch ginger puree with grinding conditions through optimisation approach and specifically optimise the grinding process with parameters of grinding time and the amount of water added with RSM approach.

2. Materials and Methods

20kg of fresh torch ginger (Etlingeraelati or) were purchased from a farm in BatuPahat, Johor, Malaysia. They were washed and cleaned to remove the soil and dirt prior to blanching. The fresh torch gingers were then chopped into big pieces and removed the stems. The adequacy of blanching process was studied with guaiacol and 0.08% H202 to check the peroxidise activity of the blanched torch ginger. A brick red colour indicates peroxidise activity while no change in colour indicates no peroxidise activity [10]. From the preliminary study, the effective blanching time at 100°C is 5 minutes. The fresh torch ginger inflorescences were chopped into half and removed the stems before blanched in water at 100°C for 5 minutes and cooled in iced water for 3 minutes.

The experiment was designed using RSM with face-centred central composite design (FCCCD) for a total of 13 runs. 13 runs were designed with 22 design which included 4 corner points and 5 centre points. The grinding time, X1 and amount of water, X2 combinations of the grinding processes were set in the range of 240-480 s and 100-600 ml, respectively, as in Table 1.

The quadratic polynomial equation (Eq. 1) represents the second order model used in the experiment to identify the curvature and to optimise the process:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_{12} X_1 X_2 + \beta_{11} {X_1}^2 + \beta_{22} {X_2}^2 + \varepsilon \quad (1)$$

250g of blanched torch gingers were used for each grinding treatments. They were grinded with specific water amounts using the food processor (HR7761/01, Philips, UK) at the speed 1900 rpm according to the operational manual with the time given in order to them into a homogenised puree.

The torch ginger puree from different treatments were analysed on their physical properties. Total soluble solids (TSS) were measured in °Brix by using a refract meter (PAL-BX/RI, Atago, Japan) [11]. Water activity of the torch ginger puree was measured using a water activity meter (AL1823, AquaLab, USA). The coordinates of the colour CIE- L* (lightness) and a* (redness) of samples were obtained with colour spectrophotometer (EZ 4500L, Hunter Lab, USA), whereas browning index (BI) was calculated from the following equations 2 and 3 [12].

$$\mathrm{BI} = \frac{100(X - 0.31)}{0.172} \quad (2)$$

$$\text{where, } X = \frac{a + 1.75L}{5.645L + a - 3.012b} \quad (3)$$

Table 1: Response values for TSS, water activity, colour and BI

Treatment	Independent variables		Responses				
	Grinding time (s), X_1	Water added (ml), X_2	TSS, Y_1	Water activity, Y_2	Colour		BI, Y_5
					L*, Y_3	a*, Y_4	
1	480	350	0.63±0.1	1.01±0.00	71.61±0.3	6.59±0.1	35.000
2	240	350	0.70±0.2	1.00±0.00	69.78±0.3	7.99±0.0	39.041
3	480	600	0.60±0.0	1.00±0.00	73.89±0.1	5.47±0.1	34.062
4	360	350	0.73±0.1	0.99±0.01	70.29±0.2	8.40±0.2	38.366
5	360	100	1.90±0.1	0.96±0.01	65.22±0.3	10.74±0.1	49.279
6	240	100	1.83±0.3	0.97±0.01	66.56±0.3	10.75±0.0	45.680
7	360	350	0.87±0.2	0.99±0.00	71.67±0.3	7.57±0.2	39.745
8	360	350	0.73±0.1	0.99±0.01	69.45±0.3	7.27±0.3	35.239
9	360	600	0.60±0.1	1.00±0.00	74.28±0.3	5.73±0.2	28.877
10	480	100	1.77±0.2	0.97±0.01	64.49±0.2	11.01±0.1	46.814
11	240	600	0.57±0.1	0.99±0.00	75.12±0.8	6.11±0.2	30.915
12	360	350	0.83±0.1	0.99±0.01	70.51±0.2	9.08±0.1	37.799
13	360	350	0.70±0.2	0.99±0.00	69.51±0.2	7.65±0.2	35.990

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After the experiments were performed, the interaction and relationship among the independent factors and responses were studied by statistical analysis of different models to evaluate the analysis of variance (ANOVA), regression and graphical analyses to optimise the process with Minitab® 17.1.0 (Minitab Inc. US). Both the independent and dependent variables were fitted into four models which were linear effect, linear square model, linear interaction and full quadratic model to compare the fitness of the data in each of the models and to determine the best model for the data prior to the optimisation and prediction for the variables. The predictions were studied using the response surface and contour plot. The optimisation was done after the optimum ranges for each response were set according to the raw and blanched puree which were the control, as well as the commercial product. After the optimum grinding operation conditions were obtained, another experiment to validate the outcome of the optimisation. The validity of the optimisation result was calculated with the percent errors.

3. Results and Discussion

The raw and blanched torch ginger which acted as controls for this study were characterised before the experiments. The data are shown in Table 2. The raw torch ginger puree has TSS value of 2.93 and water activity 0.87. In terms of colour, torch ginger puree gives a light pink or darker pink impression from the appearance depends on their maturity. Young torch ginger gave a light pink while matured torch ginger gave slightly darker pink impression from the appearance. From the spectrophotometer, L* and a* parameters have obtained for raw torch ginger puree which are 68.30, 11.52 and 18.28. It has BI of 42.53.

Table 2: Characterisation of raw and blanched torch ginger puree

Treatment	TSS (ºBrix)	Water Activity	Colour		BI
			L*	a*	
Raw	2.93±0.2	0.87±0.00	68.30±0.1	11.52±0.2	42.527
Blanched	2.23±0.2	0.90±0.02	70.34±0.1	11.34±0.2	40.506
Commercial	1.80±0.1	0.96±0.01	46.64±0.9	15.38±0.5	135.310

All the torch ginger that used in the experiment were treated with the blanching process. As the grinding process in the experiment has little preservative effect, hence the blanching process is significant to reduce the contamination and preserve the colour of the raw materials [12]. The effectiveness of the blanching process was proven by the guaiacol test for POD activity. The result of preliminary study is supported by the study of Tomás-Barberán and Espín [13] on blanching of fruits and vegetables. The POD activities were checked mainly because POD enzyme is the most thermally stable and the one responsible for the enzymatic browning reaction in the presence of hydrogen peroxide [12]. The inactivation of POD indicates that the other less heat-resistant enzymes are also destroyed [7].

Blanched torch ginger (control) had slightly lower BI, higher L* and lower a* value than raw puree. These indicated the browning reaction happened on the raw puree during the analysis process unlike the blanched puree that kept its colour after the blanching process which stopped the enzymatic activities. Due to the direct water blanching process, the torch gingers were softened and hence, improved their moisture with water. Hence, the TSS value was slightly lower, whereas water activity were slightly increased as compared to raw torch ginger.

Commercial torch ginger puree in another way had darker colour from the appearance and it had relatively the highest BI and a* as well as lowest L*. This was highly possible due to the minimised processed puree and led to browning reaction on the puree as storage period prolonged. It also had the lowest TSS as one of the ingredients is water as labelled and higher water activity due to the water added.

The experiments were carried out with the designed treatments for the independent variables on TSS, water activity, colour and BI. The experiment design and the experimental responses are listed in Table 1. The responses were varied with different treatment with different conditions on grinding time and amount of water added.

Amount of water directly affected the TSS and water activity of the puree. TSS is often linked with the viscosity of the puree as TSS is proportional to its viscosity [14]. Besides, organic acids in the samples might contribute to the reading of TSS [11]. Water activity of the puree samples increased with more amount of water added, which the range of the values were more than 0.90 as shown in Table 1.

Water activity measurement is included as one of the dependent variables as it is representing the biochemical and microbiological activities in the food system. Water activity is often used to describe the availability of water to react to the surrounding and to act as solvent [15]. It is usually directly link to the shelf life and stability of the food itself [16]. Measurement of water activity meter using water activity meter is among the simplest and rapid method. The range of the water activity of the torch ginger puree is above 0.90 which is considered as highly perishable [15] in general. The addition of moisture in the sample showed changes on their water activity, which the water activity increased with the increased water amount added. However, the quality of the torch ginger puree is assured by the effective blanching process before the grinding process which removes the contamination and halt the enzymatic activities of torch ginger puree.

The change in the visual colour properties or the BI can be taken as critical tools to assess the overall colour changes in the samples during any treatment applied [17]. Torch ginger puree that had been through longer grinding time, were having greater impact on their colour

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parameters and BI, where they had lower value of L*, higher a* and BI. These can be caused by the increased of oxidative deterioration which came along with the increased of surface area after extensive grinding process [7]. However, the impacts were reduced by the higher amount of water added according to the responses.

The responses were fitted into different models which were linear effect, linear square model, linear interaction and full quadratic model to compare the fitness of the data in each of the models and to determine the best model for the data. An ideal model has significant regression and insignificant lack of fit at 95% confidence level [18]. From Table 3, all of the predicted model had relatively lower S, statistically significant which P-values are lower than 0.05 at 95% confidence level, insignificant P-values for lack-of-fit are more than 0.05. S is the estimated standard deviation or values represent the standard distance that the data values fall from the regression line. The small S value indicates better the predictions from the equation. The residual error measures the variations from the responses that are unexplained by the model. The p-value of the lack-of-fit should be studied to understand the significant of the residuals at 95% confidence level. The residuals' variations are usually caused by measurements fluctuation or pure error which are not only the lack of fit but directly related to the quality of the model. The significant lack-of-fit usually caused by measurements fluctuation or pure error. R^2 describes the variation in the response values and fitness of the model with the response values, while adjusted R^2 is adjusted for the number of terms in the model. Higher R^2 and adjusted R^2 indicated the greater fitness of the data on the models. Predicted R^2 is the fitness of the model to predict the new response values [19] where a fair agreement is shown predicted R^2 with the other R^2 values. The fitness of the model cannot be decided by the R^2 alone. R^2 values increase with the addition of variables. Hence, even high R^2 with statistically insignificant responses or variables will give bad predictions or estimation during optimisation process [20].

Table 3: Chosen model summary statistics for TSS, water activity, pH, colour and BI

Dependent variables, Y	**Model**	**Standard Deviation, S**	**Model p-value**	**Regression, R^2 (%)**	**Adjusted R^2 (%)**	**Predicted R^2 (%)**	**Lack-of-Fit p-value**
TSS, Y_1	Linear Square	0.059	0.000	99.09	98.63	98.00	0.835
a_w, Y_2	Full Quadratic	0.0049	0.001	92.17	86.58	34.69	0.000
L*, Y_3	Linear Square	0.969	0.000	94.25	91.37	82.70	0.404
a*, Y_4	Linear Square	0.642	0.000	92.39	88.59	81.92	0.723
BI, Y_5	Linear Square	2.293	0.000	90.38	85.57	67.93	0.235

The regression equations 4 to 8 of the models chosen as in Table 3 where the response values are fitted into were obtained as following.

$$Y_1 = 1.918 + 0.00403X_1 - 0.008089X_2 - 0.000006X_1X_1 + 0.000008X_2X_2 \quad (4)$$

$$Y_2 = 1.0328 - 0.000456X_1 + 0.000143X_2 + 0.000001X_1X_1 \quad (5)$$

$$Y_3 = 66.61 - 0.019X_1 + 0.02477X_2 + 0.000024X_1X_1 - 0.00001X_2X_2 \quad (6)$$

$$Y_4 = 10.71 + 0.0133X_1 - 0.01719X_2 - 0.000022X_1X_1 + 0.00001X_2X_2 \quad (7)$$

$$Y_5 = 51.7 + 0.0039X_1 - 0.0542X_2 - 0.000005X_1X_1 + 0.000032X_2X_2 \quad (8)$$

The responses of every factors in the design are fitted into the equations and they are used predict new variables from the equations. The equations are made up of positive and negative signs. The term with positive sign shows that the terms are having synergetic effects and negative sign implies antagonistic effect [19].

The range of the optimum conditions on each response were defined as either maximum, minimum or targeted value in order to achieve minimum water activity, a* and BI, whereas maximum for TSS and L*. Then, the optimum ranges were set according to the control samples which are the raw and blanched torch ginger as well as the commercialised torch ginger product as reference. There are no specific standards specifically for torch ginger puree to be followed, hence, the optimum ranges were decided based on the control and commercialised product as they are accepted by the market.

The software looked for desired conditions for the factors and combined the desired optimum range for each response to optimise the grinding process simultaneously. With that, the optimum conditions for grinding time and amount of water added are 405s and 257ml, respectively. The predicted optimum conditions have considerably high composite desirability, 0.983 which is closed to 1.

Hence, another experiment was conducted to validate the outcome of the optimisation. In order to compare the predicted and experimental results, the percent error (%) were calculated to understand the accuracy and reliability of the FCCCD design optimisation process. From Table 4, only a_w, L*, a* and BI had percent error which were less than 10%, whereas the TSS is more 10% which relatively undesirable. The deviation of results from the predicted responses might be due to the quality of the torch ginger used in the experiment.

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Table 4: Predicted and experimental values of the responses

Response	Predicted	Experimental	Error (%)
TSS	1.052	1.167	10.93
a_w	0.983	0.978	0.51
L*	68.495	68.870	0.55
a*	8.762	9.277	5.88
BI	40.599	42.924	5.73

4. Conclusion

An optimum grinding operation conditions was obtained at 405s of grinding time and addition of 257ml water with composite desirability of 0.982 which is close to 1. The optimum grinding process was achieved to utilise the grinding energy efficiently and produced desirable qualities torch ginger puree as compared to raw and commercial one.

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