Optimization of Bread Enriched with *Garcinia mangostana* Pericarp Powder

U K Ibrahim, R Mohd Salleh, S N S Maqsood-ul-Hague, S Abd Hashib and S F Abd Karim

Faculty of Chemical Engineering, Universiti Teknologi Mara, 40450 Shah Alam, Selangor, Malaysia

ummi985@salam.uitm.edu.my

Abstract. The aim of present work is to optimize the formulation of bread enhanced with *Garcinia mangostana* pericarp powder with the combination of baking process conditions. The independent variables used were baking time (15 - 30 minutes), baking temperature (180 - 220°C) and pericarp powder concentration (0.5 - 2.0%). The physical and chemical properties of bread sample such as antioxidant activity, phenolic content, moisture analysis and colour parameters were studied. Bread dough without fortification of pericarp powder was used as control. Data obtained were analyzed by multiple regressions and the significant model such as linear and quadratic with variables interactions were used. As a conclusion, the optimum baking conditions were found at 213°C baking temperature with 23 minutes baking time and addition of 0.87% for *Garcinia mangostana* pericarp powder to the bread formulation.

1. Introduction

Recent revolutions in the world reflect extreme transformations in many aspects of human life especially in daily food consumption. Nowadays, people are looking food for the health protection that is easily accessible and nutritious. Unfortunately, present foods are mostly having minimum nutrients essential for the maintenance of human health [1]. Thus, it is necessary to develop enriched food with functional application. Interests in incorporating active ingredients such as dietary fiber and phenolic antioxidants into popular foods such as bread have grown rapidly, due to the increased consumer health awareness [2]. The main characteristic of an antioxidant is its ability to trap free radicals. Highly reactive free radicals and oxygen species are present in biological systems from a wide variety of sources. These free radicals may oxidize nucleic acids, proteins, lipids or DNA and can initiate degenerative disease. Antioxidant compounds like phenolic acids, polyphenols and flavonoids scavenge free radicals such as peroxide, hydroperoxide or lipid peroxyl and thus inhibit the oxidative mechanisms that lead to degenerative diseases.

Food byproduct, due to its phenomenal biodiversity, is a treasure house of many novel healthy food ingredients and biologically active compounds such as those found in *Garcinia mangostana* pericarp. Despite having so many health benefits, *Garcinia mangostana* pericarp has been underexploited for food purposes. Bakery products are widely used throughout the world and are the potential source of incorporating with functional ingredient. Bread was found to have advantages as the nutritional products for health through additional of functional ingredients. One of the latest enrichment has been the addition of seaweed to enhance the phytochemical content in breadsticks [3]. The authors revealed that fiber-rich seaweed bakery products are acceptable to consumers and have potential of increasing seaweed consumption among non-seaweed consumers. Thus, expanding the use of breads as medium for nutritious product could potentially be done in the near future.

Bread making is one of the most usual ways of processing cereals. The antioxidant activity and residual free phenolic acid content of flour were found decreased by mixing, fermentation and baking [4]. Due to that, addition of functional ingredient that contains high antioxidant in dough formulation hope will enhance the antioxidant activity in bread and may have potential health advantages for consumers. Therefore, the amount of phenolic acids and antioxidant activity in bread after baking process should be investigate and optimization of the process should be done. Several studies have been carried out to find potential sources of natural antioxidant in bread [5-12]. With respect to that, this study would like to take the opportunity to find out the potential of *Garcinia mangostana* pericarp powder as a functional ingredient in bread formulation.

2. Material and methods

2.1. Dough formulations

Commercial wheat flour, sugar, salt, yeast and bread improver was obtained from local market. *Garcinia mangostana* pericarp powder was purchased from Malaysia Herbal Shop. A standard white bread recipe was prepared. All dry ingredients were weighed and mixed in a laboratory mixer for 10 minutes at low speed. The produced dough was covered with food wrapper to prevent excessive moisture loss and left to rise at room temperature for 60 minutes. Then, the dough was punched and kneads again to release the air inside the dough. Each of dough was weighed in equal size and placed in four rectangular baking containers. The dough was allowed to rest for another 60 minutes before baking. The design of experiment is presented in Table 1.

Table 1. Design experiment of bread baking

Run	Temp (°C)	Time (min)	Pericarp powder (%)	Run	Temp (°C)	Time (min)	Pericarp powder (%)
1	220.00	30.00	2.00	11	200.00	22.50	1.25
2	200.00	22.50	1.25	12	200.00	22.50	0.50
3	200.00	22.50	1.25	13	180.00	15.00	0.50
4	200.00	22.50	1.25	14	200.00	22.50	2.00
5	180.00	15.00	2.00	15	180.00	30.00	0.50
6	220.00	15.00	2.00	16	200.00	22.50	1.25
7	220.00	15.00	0.50	17	180.00	30.00	2.00
8	180.00	20.00	1.25	18	200.00	30.00	1.25
9	220.00	20.00	1.25	19	220.00	30.00	0.50
10	200.00	22.50	1.25	20	200.00	15.00	1.25

2.2. Baking conditions

Bread dough was baked at different temperatures (180 to 220°C) and different times (15 to 30 minutes). Each of the dough with different baking condition was placed in the conventional baking oven to provide uniform heat distribution over the dough during baking process. The control bread sample was baked without addition of *Garcinia mangostana* pericarp powder with the same baking conditions.

2.3. Bread sample extraction

The bread sample extraction, phenolic acid measurement and antioxidant activity were determined using modified procedure established by Das et al. [13]. Bread samples were sliced (3 cm width and 1cm thickness) and dried in an oven at 40°C for 24 h. The dried material was ground in a grinder to obtain powdered bread. 10 g of powdered bread was extracted with 100 mL of 80% aqueous methanol for 2 h at 40°C. Samples were then centrifuged at 12,000×g for 15 min. The supernatant collected was used in the assay.

2.4. Determination of phenolic acid

1 mL of bread extract was added with 0.5 mL of the Folin-Ciocalteau reagent. After 5 minutes, 1 mL of 7.5% sodium carbonate was added and the contents mixed thoroughly. The final volume should be adjusted to 10 mL with distilled water and left to stand for 30 minutes at room temperature. A colour

developed and the absorbance was measured at 765 nm in spectrophotometer using gallic acid as a standard. Calibration curve for gallic acid equivalent was determined using modified procedure established by de Amorim et al. [14].

2.5. Determination of antioxidant activity

The DPPH radical solution was prepared by dissolving 10 mg of DPPH in 100 mL of 80% methanol. 1 mL of the bread extracts were then mixed with 1 mL of DPPH solution and 4 mL of 80% methanol. The mixtures were shaken vigorously and allowed to stand at room temperature for 30 minutes. The control consisted of 1 mL DPPH + 4 mL 80% methanol. The mixture was kept in dark for 30 minutes at room temperature. The decrease in absorbance of the resulting solution was measured spectrophotometrically at 517 nm. The percentage of inhibition or the percentage of discoloration was calculated as Equation 1:

$$\left[\frac{Absorbance(\text{control})_{517\text{nm}} - Absorbance(\text{sample})_{517\text{nm}}}{Absorbance(\text{control})_{517\text{nm}}}\right] \times 100\% \quad (1)$$

2.6. Colour measurement

The crust and the crumb color parameters of the bread samples were measured following the method described by Das *et al*. [14] with some modifications. The colour parameters was obtained from chromameter, CR-400, Konica Minolta, illumination of D_{65}, by standardizing with a white plate (L* = 89.8; a* = 0.3173; b* = 0.3343). For each treatment, 3 replications were taken. The results were expressed according to the CIELAB system of colour measurement in terms of L* (lightness/darkness) ranging from 100 (white) to 0 (dark), a* (redness/greenness) ranging from positive values (red) to negative values (green), and b* (yellowness/blueness) ranging from positive values (yellow) to negative values (blue).

2.7. Moisture content measurement

Bread crumb and crust was ground using laboratory grinder/blender. Moisture content was determined by taking about 2 g of the grinded bread crumb and crust, placed in a moisture analyzer plate and dried for 30 minutes at 130°C. Percentage of moisture in the bread crust and crumb were read from the moisture analyzer.

3. Results and Discussion

3.1. Analysis of variance (ANOVA)

The acceptability of the model was determined by the lack of fit, coefficient of determination (r^2) and the Fisher's test value (F-value) obtained from the analysis of variance (ANOVA) generated by the Design Expert software. ANOVA were performed to calculate the significance of the linear, quadratic and interaction effects of the factor variables on response variables. The model equations and coefficient of determination (r^2) for each response variable were given in Table 2. In order to get the best fit model, the minimum value for r^2 should be at least 80% [15]. The significance of the coefficients was determined by using p-values ($p \leq 0.05$). From the results showed, most of response variables can be considered as good fit model as their coefficient of determination were more than 80% except for moisture content in the bread crust and crumb.

Table 2. Regression equations for physical and chemical properties of bread with different dough formulations and baking conditions

Chemical properties	**Equation**	***p*-values ($p \leq 0.05$)**	**Lack of fit**	r^2
Phenolic content (bread crust)	$Y = 1.59 - 0.06\ X_1 + 0.06\ X_2 - 0.44\ X_3 * - 0.11\ X_1^2 + 0.56\ X_2^2 * + 0.14\ X_3^2 + 0.0065\ X_1X_2 + 0.056\ X_1X_3 - 0.024\ X_2X_3$	0.014	0.4215	0.8016
Phenolic content (bread	$Y = 1.57 - 0.036\ X_1 - 0.025\ X_2 - 0.090\ X_3 + 0.91\ X_1^2 * + 0.13\ X_2^2 - 0.24\ X_3^2 - 0.13\ X_1X_2 - 0.010\ X_1X_3 - 0.12\ X_2X_3$	0.0065	0.2234	0.8336

crumb)				
Antioxidant (bread crust)	$Y = 86.09 - 11.47\ X_1* - 0.51\ X_2 + 0.15\ X_3 - 8.94\ X_1^2* - 3.08\ X_2^2* + 0.84\ X_3^2 - 0.34\ X_1X_2 + 0.046\ X_1X_3 + 1.07\ X_2X_3$	<0.0001	0.4814	0.9801
Antioxidant (bread crumb)	$Y = 83.32 - 6.80X_1* + 0.24\ X_2 - 1.12\ X_3 – 0.20\ X_1^2 + 8.59\ X_2^2* - 9.97\ X_3^2* + 0.81\ X_1X_2 - 0.067\ X_1X_3 - 0.32\ X_2X_3$	0.0054	0.1120	0.8402
Physical properties				
Colour (bread crust)				
L*	$Y = 49.33 + 1.31\ X_1 - 4.84\ X_2* - 4.42\ X_3* - 0.45\ X_1X_2 - 6.36\ X_1X_3* - 0.71\ X_2X_3$	0.0005	0.4495	0.8103
a*	$Y = 12.49 + 0.70\ X_1* + 2.51\ X_2 - 0.77\ X_3 – 0.84\ X_1^2 - 3.49\ X_2^2* - 1.37\ X_3^2 + 0.29\ X_1X_2 – 0.029\ X_1X_3* - 1.50\ X_2X_3$	0.0001	0.1495	0.9792
b*	$Y = 25.95 - 1.76\ X_1 - 2.07\ X_2* - 1.22\ X_3 - 2.71\ X_1^2 - 2.92\ X_2^2 - 1.26\ X_3^2 - 0.40\ X_1X_2 + 4.90\ X_1X_3* - 0.50\ X_2X_3$	0.0017	0.1533	0.8770
Colour (bread crumb)				
L*	$Y = 56.61 – 0.85\ X_1 - 0.41\ X_2 – 2.39\ X_3* + 0.33\ X_1^2 – 0.97\ X_2^2 – 2.40\ X_3^2 + 0.37\ X_1X_2 + 1.59\ X_1X_3* + 0.62\ X_2X_3$	0.0143	0.5693	0.8006
a*	$Y = 1.49 - 0.16\ X_1 + 0.66\ X_2 + 2.20\ X_3* - 0.49\ X_1^2 + 0.58\ X_2^2 + 1.13\ X_3^2 – 0.79X_1X_2 – 0.17X_1X_3 + 0.79\ X_2X_3*$	0.0018	0.1250	0.8747
b*	$Y = 15.93 + 0.19\ X_1 + 0.43\ X_2 + 1.56\ X_3* - 1.33\ X_1^2 + 1.02\ X_2^2 – 0.83\ X_3^2 – 0.23\ X_1X_2 – 0.30\ X_1X_3 + 0.27\ X_2X_3$	0.0129	0.0795	0.8054
Moisture content (bread crust)	$Y = 26.96 + 0.99\ X_1 + 0.16\ X_2 + 2.47\ X_3* - 2.75\ X_1^2 + 2.48\ X_2^2 – 3.18\ X_3^2 + 0.63\ X_1X_2 + 0.17\ X_1X_3 - 0.62\ X_2X_3$	0.0320	0.1694	0.7588
Moisture content (bread crumb)	$Y = 45.36 - 0.037\ X_1 - 1.79\ X_2* + 0.90\ X_3$	0.0092	0.8275	0.5037

X_1 is baking temperature, X_2 is baking time and X_3 is concentration of *Garcinia mangostana* pericarp
*The term is significant at $p \leq 0.05$, lack of fit ≥ 0.05 and $r^2 \geq 0.8$

3.2. Optimization process

The criteria of optimization were selected on the basis of accepted bread quality. Therefore, the aim of this study was to maximize the responses of phenolic content and antioxidant activity as well as to get the desired colour and moisture content. As a result, the optimum levels of X_1 is 213°C, X_2 is 23 minutes and X_3 is 0.87%. The predicted responses at the optimum levels can be listed as 1.75 and 1.92 mg/g phenolic content and 74.68 and 77.02% of antioxidant activity in bread crust and crumb, respectively. For colour parameters, the value of lightness (L*) is 54.04 for bread crust and 56.22 for bread crumb. While, the redness value (a*) for both crust and crumb were 12.92 and 1.35 and finally for yellowness parameter (b*) indicates 22.10 and 14.61 for bread crust and crumb, respectively. All the colour parameters showed the acceptability for bread colour quality. Additionally, the predicted values for moisture content are 24.45 and 42.38% for both crust and crumb.

Table 3 shows the values of physical and chemical properties of bread sample and control. Bread enhanced with *Garcinia mangostana* pericarp powder was found to have significant effect especially on phenolic content and antioxidant activity. From the table, it demonstrated that enhanced bread contains higher antioxidant and phenolic content than normal bread. Other properties present almost comparable in quality by showing slightly difference between enhanced and normal bread. However, bread crumb lightness (L*) value was discovered much different between the sample and control due to the dark colour of pericarp powder but in the acceptable range. In conclusion, enhancement of *Garcinia mangostana* pericarp powder into bread formulation will produce functional bread with high phenolic content and antioxidant activity without affecting the quality of the bread such as colour and

moisture content. All breads containing pericarp powder showed significantly higher phenolic compounds and antioxidant activities when compared with the control.

Table 3. Comparison between Predicted, Experimental and Control Values of Bread Sample Properties under Optimal Conditions

BREAD	Phenolic Content (mg/g)		Antioxidant Activity (%)		Colour		Moisture Content (%)	
	Crust	Crumb	Crust	Crumb	Crust	Crumb	Crust	Crumb
Predicted Values	1.75	1.92	74.68	77.02	L* = 54.04 a* = 12.92 b* = 22.10	L* = 56.22 a* = 1.35 b* = 14.61	24.45	42.38
Actual Values	1.81	1.97	74.83	77.10	L* = 54.96 a* = 12.22 b* = 23.8	L* = 55.42 a* = 1.38 b* = 13.69	25.14	42.55
Values Without Pericarp Powder (Control)	0.03	0.14	54.80	49.76	L* = 56.99 a* = 10.40 b* = 29.44	L* = 73.08 a* = 1.81 b* = 11.88	33.17	44.91
% Error Between Actual and Predicted Values	3.3%	2.5%	0.2%	0.1%	L* (1.7%) a* (5.7%) b* (7.1%)	L* (1.4%) a* (2.2%) b* (6.7%)	2.7%	0.4%

Optimal Conditions: Baking temperature, X_1 = 213°C, baking time, X_2 = 23 minutes and concentration of pericarp powder, X_3 = 0.87 wt%
Percentage error acceptable range ≈ ±10%

4. Conclusion

The objective of this study is achieved by performed the optimization of bread enhancement with *Garcinia mangostana* pericarp powder. The results of this study gave useful information antioxidant activity, phenolic content, bread surface colour and moisture content since magnitude of baking conditions and dough enhancement with *Garcinia mangostana* pericarp powder was adjusted according to the optimum conditions given. It was found that baking temperature, baking time and pericarp powder content give significant effect on phenolic content, antioxidant activity, bread crust and crumb surface colour and moisture content. The optimum levels were found 213°C for baking temperature, 23 minutes for baking time and 0.87% for *Garcinia mangostana* pericarp powder percentage added to the bread formulation. Since the study produce good experimental results, it should be recommended to produce high quality functional bread using *Garcinia mangostana* pericarp powder as functional ingredient in bread dough formulation. Further research will be carried out to investigate the feasibility of a functional bread model containing *Garcinia mangostana* pericarp powder, the health beneficial effects of the product, and possible side effects to encourage their application in improving human health.

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