Extraction of Virgin Coconut Oil from Dehydrated Coconut Meat using Mechanical Screw Press

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DOI: 10.29322/IJSRP.12.07.2022.p12732
http://dx.doi.org/10.29322/IJSRP.12.07.2022.p12732

Paper Received Date: 18th June 2022
Paper Acceptance Date: 3th July 2022
Paper Publication Date: 12th July 2022

Abstract- Virgin coconut oil is becoming more widely known and used as a beneficial food oil. VCO is the purest form of coconut oil which is water like white in color. It is high in antioxidants (vitamin E) which help to prevents the peroxidation reaction. Mechanical screw press methods are used to extract virgin coconut oil in this study because the mechanical extraction is a greener and healthier way of manufacturing oil due to there are no solvent (chemical) residues in the oil. Small quantities of oil were required for analysis in the laboratory, hence it is desirable that a screw press that can be efficiently handle small amount of oil-seed/nut was provided. The VCO was obtained by pressing the best dehydrated coconut meat using a mechanical screw press at different temperatures (75°C, 85°C, 95°C, 105°C, 115°C) and different duration (15 min, 30 min, 45 min, 60 min, 75 min). Response surface methodology (Design Expert Version 12) was used to optimize the extraction conditions at five-level, two-variable using central composite rotatable design (CCRD). Maximum oil yield and antioxidant activity of VCO were obtained at 95ºC for 75 min of extraction conditions.

Index Terms- Virgin coconut oil, Mechanical screw press, Dehydrated coconut meat, Response surface methodology, CCRD, Oil yield, Antioxidant activity. Sustainability.

I. INTRODUCTION

Coconut (*Cocos nucifera L.*) is the familiar fruit or superfood for human (Sangamithra et al., 2013). Coconut fruit with the age of 11-12 months is suitable for harvesting because of the highest oil content (Balleza and Sierra, 1976). VCO is a high demand for value added products of coconut great culinary, medicinal, cosmetic and industrial application. Promoting the value-added products through national and global level develop new products can increase the income (Asghar et al., 2020).

Oil that is extracted from fresh or dried meat (mature kernel) of coconut by mechanical or natural means, with or without the use of heat and without refining process is known as virgin coconut oil (VCO) or natural organic coconut oil. VCO has natural fresh aroma and taste of coconut, absence of high temperature and chemical treatment makes it tasty and healthy (Yunus, 2014). Virgin coconut oil (VCO) is growing in popularity as functional food oil and the public awareness of it is increasing. Virgin coconut oil can be consumed in its natural state without the need for further processing (Rajagopal and Rajeev, 2017).

VCO is effective in preventing the peroxidation of lipid and increase the level of antioxidant enzymes (Nevin and Rajamohan, 2010). VCO serves as a nutritional food supplement, unique, abundant antimicrobial properties (Villariba, 2004). The benefits of VCO is to maintain blood sugar level, to control cholesterol level, to reduce the risk of chronic disease, to accelerate metabolism, to helps balance hormones, to prevent cardiovascular and Alzheimer's disease (Shijina et al., 2016).

There are edible and inedible applications in VCO. It serves as an important source of energy in diet (Bawalan and Chapman, 2006). It can be taken by mixing with warm food or drink. It can be used as substitute for butter and margarine, cooking and frying oil to enhance the flavor of food (Gerard et al., 2016). It can also be used as a skin and hair conditioner (Bawalan, 2011), an aromatherapy and massage oils (Songkro et al., 2010).

VCO can be extracted from various methods like solvent extraction method, dry method and wet methods (Marina et al., 2009). The use of solvents for oil recovery has several drawbacks such as high safety hazard, high-energy input, low quality oil, environmental risk and low quality meal (Bhosle and Subramanian, 2005). In wet method, oil is extracted through coconut milk by heating and non-heating processes (Ravindra and Bosco, 2017). In dry methods, the kernel is dried to remove moisture in it preventing scorching and microbial invasion (Raghavendra, 2010).

Among then, mechanical method was a preferred method to extract virgin coconut oil. Mechanical extraction involves the application of pressure (using hydraulic or screw presses) to force oil out of an oil-bearing material (Arisanu, 2013). The screw press method involves the removal of the kernel test, by roasting in air over fire, and conveying the decorticated material through a small opening by the screw mechanisms. As the material is being conveyed, it is milled; the small opening at the exit presses the meal, releasing the cake while oil drains off. The oil and meal will be obtained by this method are of high quality, fit for both human and animal consumption (Ademola et al., 2004). The advantages of mechanical oil extraction include simple use, rapid realization of the process and that leads to the short duration of the process, use of small quantities of raw materials, application of different oilseeds and low cost. Also as a by-product protein rich press cake is obtained (Singh and Bargale, 2000).

Response surface methodology is a collection of mathematical and statistical techniques that are useful for modeling and analyzing of problems in which a response of interest is influenced by several variables and the objective is to optimize this response (Montgomery, 1997; Noordin et al., 2004). RSM is commonly used in food process engineering domain due to its advantages of relatively easy to be established, clear on parameter sensitivity (Jin, Chen, & Simpson, 2001).

Temperature plays a crucial role when the screw press is used for nut oil extraction (Adrián et al., 2018). The higher temperature accelerates the reaction rates of oxidation and the more trans-fat is generated (Song et al., 2015). Seneviratne et al., 2008 also concluded that the possibility of slight heat employed in other processing methods may enhance antioxidant activity, but excess heat will lead to reduction in antioxidant activity as observed by oil sample. The retention of antioxidant compounds may provide mechanical screw press oil with acceptable oxidative stability and better health properties (Parry,2006). Yield is generally one of the prime parameters in VCO extraction. Both yield and quality of VCO could be affected by several factors, both intrinsic and extrinsic ones (Umesh patil et al., 2016).

II. MATERIALS AND METHODS

2.1 Experimental Site and Periods

The experiment was conducted at the laboratory of Department of Postharvest Technology, ACARE, Yezin Agricultural University, Nay Pyi Taw from December 2021 to March 2022.

2.2 Sources of Raw Materials

The dehydrated coconut meat which optimum drying conditions (70°C and 6 h) was used to extract virgin coconut oil. 350 g of dehydrated coconut sample were used for each treatment.

2.3 Statistical Analysis

Response surface methodology (Design Expert Version 12) was used to optimize the processing conditions at five-level, two-variable using central composite rotatable design (CCRD) (DC Montgomery,2005). These treatments were carried out with thirteen experiments of CCRD design. The treatment combination of different pressing temperature (75℃, 85℃, 95℃, 105℃, 115℃) and pressing duration (15 min,30 min,45 min,60 min,75 min) were operated by using mechanical screw press to optimize the virgin coconut oil.

2.4 Experimental Design

The variables were used to pressing temperature (ºC, X_1), pressing duration (min, X_2) and oil yield (%), antioxidant activity (%), oil recovery (%), residual fat (%) were selected as the responses. The adequacy of each model was determined by evaluating the lack of fit and the coefficient of determination (R^2). The significance of each coefficient was determined by using F-test obtained from the analysis of variance (ANOVA) that was generated. Regression coefficients were then used to generate response surfaces. 3D response surface graph for predicted value and variable was plotted using the Design Expert 12 software. Thirteen experiments were performed which consisted of two factorial points, two extra points (star points) and five replicates for the center point in Table 2.1. The five replicates for the center point were used to estimate the experimental error.

2.5 Analytical Methods

Oil yield was determined by (AOAC, 2007) method. (350) g of coconut slices was used in each run of different pressing temperature and duration using mechanical screw press machine. Before pressing, this machine was needed to warm for preheat about 8 minutes or more temperature was controlled by using SET Key. After the motor was starting, the dehydrated coconut slices were added in the hopper for pressing. While the pressing was continued, the pressing chamber out of the oil has been dropped.

$$\textbf{Oil Yield}\ (\%) = \frac{\textbf{Mass of Oil}}{\textbf{Mass of Sample Used}}\ \textbf{x 100}$$

Antioxidant activity was measured by (Genwali et al., 2013) method. 0.1 mM DPPH solution was prepared by dissolving 3.9 mg of DPPH with 100 ml ethanol in amber volumetric flask and stirred with 700 rpm for 30 min at room temperature. A control solution was prepared by mixing 4 ml methanol and 1 ml 0.1 mM DPPH solution. The control solution was shaken well and kept in the dark place for 30 min at room temperature. For sample analysis, 1 ml of the extracted sample was mixed with 4 ml of methanol. Then, 1 ml of 0.1 mM of DPPH solution was added to the solution and the mixture was shaken vigorously. The mixture was maintained in the dark place for 30 minutes at room temperature. The absorbance was measured at 517 nm using UV spectrophotometer (Shimadzu Inc., Kyoto, Japan).

$$\%\mathbf{RSA} = \frac{\mathbf{A\ control\ - A\ vco}}{\mathbf{A\ control}} \mathbf{x100}$$

Residual fat content was determined by solvent extraction method (AOAC, 2003) and using Randall apparatus (VELP SCIENTIFICA SER 158 solvent auto extractor). 7 g of coconut sample was weighed and then placed in thimble. Cotton was blocked at the top of the thimble. 100 ml of n-hexane was added in each glass cap. They were placed in fat extractor stand for 2.45 h. These fat sample were evaporated at ambient temperature until 24 hr. Then, these were placed in hot air oven at 105º C for 1 hr and cooled in desiccator for 1 hr. Extraction time was completely finished until reach to constant weight.

$$\mathbf{Fat\ Content}\ (\%) = \frac{\mathbf{Weight\ of\ fat\ Cap - \ Weight\ of\ Empty\ Cap}}{\mathbf{Weight\ of\ sample}} \mathbf{x100}$$

Oil recovery was determined by using mechanical screw press after finishing the extraction of oil yield and fat content determination.

$$\mathbf{Oil\ Recovery}\ (\%) = \frac{\mathbf{Weight\ of\ meal\ x\ meal\ oil\ content}}{\mathbf{Weight\ of\ sample\ x\ oil\ content\ in\ sample}} \mathbf{x100}$$ (Zheng, 2003)

Table 2.1 Experimental design with coded and actual levels for optimization of extraction conditions of virgin coconut oil

Run	Coded Value		Actual Value	
	Factor A (Temp)	Factor B (Time)	Pressing Temperature (°C)	Pressing duration (min)
1	0	0	95	45
2	-1.41421	0	75	45
3	0	0	95	45
4	0	0	95	45
5	0	1.41421	95	75
6	1	-1	105	30
7	0	0	95	45
8	0	-1.41421	95	15
9	0	0	95	45
10	-1	-1	85	30
11	1.41421	0	115	45
12	1	1	105	60
13	-1	1	85	60

III. RESULTS AND DISCUSSION

3.1 Effect of pressing conditions of temperature and duration on the responses of virgin coconut oil

The different pressing temperature and pressing duration conditions were affected on the responses of virgin coconut oil. In Table 2.3, the results showed that the oil yield, residual fat content, oil recovery and antioxidant activity of VCO ranged from 40 to 67%, 15 to 25.04%, 4.1 to 6.2% and 30 to 76% respectively. In Figure A, the oil yield plotted at 3D surface. Maximum oil yield 67% was obtained at temperature 95°C and 75 min, followed by 60% at temperature 95°C and 15 min according to Table 2.3 and Figure A. And then, the second maximum oil yield 54% was obtained when the temperature and duration was increased at 105°C and 60 min. Other different pressing temperature and duration for oil yield were slightly decreased to around 40% respectively in Table 2.3. The optimum oil yield was obtained 67% at pressing temperature 95°C and pressing duration at 75 min. Oil yield was increased with medium temperature and long duration. Therefore, the pressing temperature and duration were important for oil yield.

Oil yield increases with the increasing duration for pressing duration of 75 min and at temperature of 95°C. Afterward, further increase in duration and higher temperature (above 95°C) caused decreasing the oil yield. Increasing in temperature reduces the viscosity of oil and improves the oil flow. At excess temperature, more water is lost and dehydrated samples will get hard. So, the resistance to pressure during pressing increased and decreased the oil yield (Huang et al., 2019).

Erna subroto et al., (2014) mentioned that increasing the temperature coagulates the protein, softening the solid structure and decreases the oil viscosity. Ajala et al., (2019) were investigated that the processing of shea butter, to optimize the oil yield of 37% from 150 g sample of shea kernel at 90ºC and 20 min. Fakayode and Ajav (2016) studied the relationship between the yield and the process parameters of mechanical pressing and finally obtained the maximum yield by optimizing the mechanical oil extraction process from Moringa oleifera seeds using RSM. Mariano et al., (2017) studied a mechanical screw press process, an optimum oil yield of 73.38% at 70 ºC and 32 rpm.

According to Table 2.3, the minimum value of residual fat content was 15% at 95ºC and 15 min and maximum value was 25.04% at 115ºC and 45 min. In Figure B, residual fat content was plotted at 3D surface. The highest residual fat content was 25.04% at 115°C, 45 min and the lowest residual fat content was 17% at both 75ºC, 30 min and 95ºC, 45 min. The higher temperature accelerates the reaction rates of oxidation and the more trans-fat is generated (Song et al., 2015). VCO contains many types of fatty acids in the medium chain triglyceride (MCT) group so that it has high oxidative stability. This oxidative stability is supported by the value of the active oxygen method (AOM) on MCT greater than other oils (Sahin, 2019).

The minimum residual oil recovery in cake was obtained 4.1% at 95ºC and 75 min, beyond then 4.2% at 85ºC and 60 min in Table (2.3). The maximum residual oil recovery in cake was obtained 6.2% at 115ºC and 45 min, followed by 5.5% at 105°C and 60 min. In figure (C), oil recovery was plotted at 3D surface. The minimum oil recovery was obtained 4.1% at 95ºC and 75 min in Table (2.3) and figure (C). Oil yield and oil recovery were inversely proportional affect, because of the highest oil yield result was obtained at 95ºC and 75 min. At pressing temperature 115°C and duration 45 min, the maximum oil recovery was 6.2. Similarity, Arslan M. (2010) was finding studied by using treated seeds/nut, an approximately 7% of the oil remains in the seed/nut. Singh et al., 2012 examined that the effect of pre-treatment on the extraction efficiency of linseed oil, these results showed that the pretreatments had a significant effect on oil yield and no significant effect on oil recovery.

In Table 2.3, the antioxidant activity was obtained the maximum value of 76 % at 95°C and 75 min and followed by 67% at 105°C and 60 min. The minimum value of antioxidant activity was 30% at 75°C and 45 min. In figure D, the antioxidant activity plotted at 3D surface was maximum result of 76% at 95°C and 75 min. After that, the second maximum antioxidant activity was 67% at 105ºC and 60 min, minimized was 30% at 75°C and 45 min in Table 2.3 and figure D. Similarity as above Oil yield, Antioxidant activity was increased with medium temperature and long duration. In this results, pressing temperature and pressing duration was important for antioxidant activity. Yashi, (2016) investigated that the antioxidant activity ranged from 65 to 70% in VCO. The maximum, oil yield and antioxidant activity of VCO was found under the experimental conditions of pressing temperature 95°C and duration 75 min.

3.2 Analysis of variance(ANOVA) and regression coefficient of the model

According to ANOVA table results in Table 2.4, the developed model was found highly significant at F value ($p<0.001$) with non – significant lack of fit at p value ($p>0.05$). Significance of different terms of each coefficient was determined using the F-value and p-value. The coefficient of determination (R^2) and variation (CV%) on the oil yield (OY) were 0.99 and 1.84, residual fat (RF) content were 0.94 and 5.19, oil recovery (OR) were 0.93 and 4.10 and antioxidant activity (AO) were 0.94 and 7.83 respectively. Therefore, the developed quadratic model was suitable for prediction of the effect of process parameters on product responses (OY, RF, OR and AO value) with high accuracy within experimental range. According to Yolmeh et al., (2014) reported that a large F-value and a small p - value would imply a more significant effect on the corresponding response variable. Lee et al., 2010 suggested that for a good fit of a model, R^2 should be at least 0.80. The R^2 for these response variables was higher than 0.80, indicating that the regression models explained the mechanism well.

3.3 Regression coefficient of the Second - order polynomial

In table 2.4, showed the second order polynomial regression model designed for OY, RF, OR, AO value in terms of coded factors were as follows. Regression coefficient model showed oil yield was positively highly significant ($p<0.001$) influenced on pressing duration as linear effect, pressing temperature and pressing duration as interaction effect and pressing duration as quadratic effect. Residual fat content was highly significant ($p<0.001$) influenced on pressing duration as linear effect, negatively slightly significant influenced as interaction effect and positively highly significant influenced on pressing temperature as quadratic effect. Oil recovery was positively highly significant ($p<0.001$) influenced on pressing temperature as linear effect. No significant influenced on pressing duration as linear effect and quadratic effect. Positively slightly significant influenced as interaction effect and highly significant influenced on quadratic effect as pressing temperature. Regression coefficient model showed antioxidant activity was positively highly significant ($p<0.001$) influenced on pressing temperature and pressing duration as linear effect and slightly significant as interaction effect. The actual quadratic equation of the oil yield, residual fat content, oil recovery and antioxidant activity of VCO responses were given in equations (1) (2), (3) and (4) respectively.

3.4 Model fitting

Empirical models were developed to describe the relationship between pressing conditions and virgin coconut oil quality. From the empirical data obtained, standardized equations for predicting the effects of pressing temperature and duration on oil yield, residual fat content, oil recovery and antioxidant activity of the oil generated are respectively modeled and presented as Equations 1 to 4.

Oil yield $= 42.14 + 0.45\ X_1 + 2.63\ X_2 + 6.87\ X_{12} - 0.49\ X_1^2 + 10.76\ X_2^2$…………………(1)
Residual fat content $=18.95 + 0.39\ X_1 + 3.40\ X_2 -2.82\ X_{12} + 2.95\ X_1^2 + 0.50\ X_2^2$…………..(2)
Oil recovery $=4.57 + 0.54\ X_1 – 0.19\ X_2 + 0.60\ X_{12} + 0.46\ X_1^2 - 0.04\ X_2^2$…………….(3)
Antioxidant activity $=52.77 +13.02\ X_1 +12.06\ X_2 + 9.59\ X_{12} – 3.59\ X_1^2 - 2.40\ X_2^2$…………(4)

3.5 Numerical optimization and point predication

In table 2.6 showed that goal and importance factor of response variables for determining optimum value in extraction conditions. In all treatments, RSM was selected the optimization conditions of 95°C and 75 min. Because of these treatments have highest oil yield, maximum antioxidant activity, medium residual fat and lowest oil recovery in cake. The comparison of predicted and observed value for response variables at optimum conditions of 95ºC and 75 min were shown in table 2.7. Both value of % variation are 0.01% for oil yield, 0.00 % for residual fat content, 0.02 % for oil recovery and 0.01 % for antioxidant activity. These test showed that there is not a significant difference between the predicted and actual values since the variation value (V) (0.02) is much smaller than the cut - off value of (V) for 95% confidence level as similarity reported by Mooney and Swift,1999.

Table 2.2 Effect of pressing conditions and responses of virgin coconut oil condition according to central composite rotatable design (CCRD)

Std Run	Temp (T)	Time(t)	Oil yield (%)	Residual fat (%)	Oil recovery (%) in cake	Antioxidant activity (%)
1	75	45	40	24.00	4.6	30
2	85	30	49	17.00	5	38
3	115	45	41	25.04	6.2	61
4	95	45	42	18.02	4.5	49
5	105	60	54	22.81	5.5	67
6	95	45	42	19.17	4.5	53
7	85	60	46	25.00	4.2	43
8	95	75	**67**	24.26	4.1	76
9	95	45	41	19.45	4.8	53
10	105	30	43	20.46	5.1	52
11	95	45	42	19.80	4.3	50
12	95	45	41	17.00	4.4	59
13	95	15	60	15.00	4.7	39

Table 2.3 Analysis of variance(ANOVA) and regression coefficient of the model for the relation between extraction variables and product responses

Product Response	Regression Model (F-value)	Lack of Fit (p-value)	T	t	T * t	T^2	t^2	R^2	CV%

Oil Yield (%)	223.83***	0.09 ns	1.61	55.75***	63.47***	1.86	892.82***	0.99	1.84
Residual Fat Content (%)	22.64***	0.62 ns	0.82	61.01***	7.01*	43.74***	1.27	0.94	5.19
Oil Recovery (%)	16.01***	0.29 ns	37.89***	4.58	7.74*	25.89***	0.21	0.92	4.53
Antioxidant Activity (%)	25.43***	0.36 ns	60.76***	52.13***	5.49*	4.40	1.97	0.94	7.83

*** Significant at P < 0.001, ** Significant at P < 0.01 *Significant at P < 0.05

Table 2.4 Regression coefficient of the Second - order polynomial for the relationship between extraction conditions and changes in VCO conditions

Parameter	β_0	X_1	X_2	X_{12}	X_{11}	X_{22}
Oil Yield (%)	42.14	0.45	2.63***	6.87***	-0.49	10.76***
Residual Fat Content (%)	18.95	0.39	3.40***	-2.82*	2.95***	0.50
Oil Recovery (%)	4.57	0.54***	-0.19	0.60*	0.46***	-0.04
Antioxidant Activity (%)	52.77	13.02***	12.06***	9.59*	-3.59	2.40

*** Significant at P < 0.001, ** Significant at P < 0.01 *Significant at P < 0.05 ns = Non Significant

Table 2.5 Goal and Important factor and response variables for determining optimum extraction conditions

Factor/response	Goal	Importance	Lower Limit	Upper Limit	Optimum Value
Factor					
Temperature (°C)	In range	+++	75	115	95
Time (min)	In range	+++	15	75	75
Response					
Oil Yield (%)	Maximum	+++	15.00	25.04	68.31
Residual Fat Content (%)	In range	+++	40.3	67	24.41
Oil Recovery (%)	In range	+++	4.1	6.2	4.43
Antioxidant Activity (%)	Maximum	+++	30	77	77.27

Table 2.6 Comparison of predicted and observed values for response variables

Independent Variables (Process Parameter)	Optimum Conditions		
Temperature (°C)	95		
Time (min)	75		
	Predicted Value (P)	**Observed Value (O)**	**% Variation (V)**

Oil yield (%)	68.31	67.44	0.01%
Residual fat content (%)	24.41	24.35	0.00%
Oil recovery (%)	4.37	4.27	0.02%
Antioxidant activity (%)	77.26	76.57	0.01%

$$V = \mathcal{E}\,\frac{(O-P)2}{p} = 0.02$$

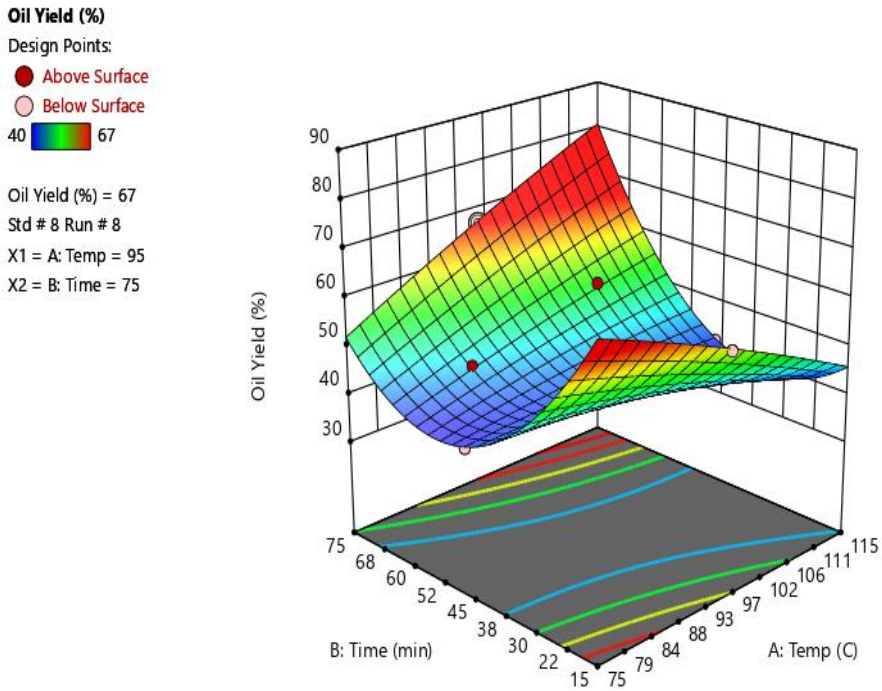

Figure (A): 3D surface plot showing the effect of pressing temperature and pressing duration on oil yield content (%)

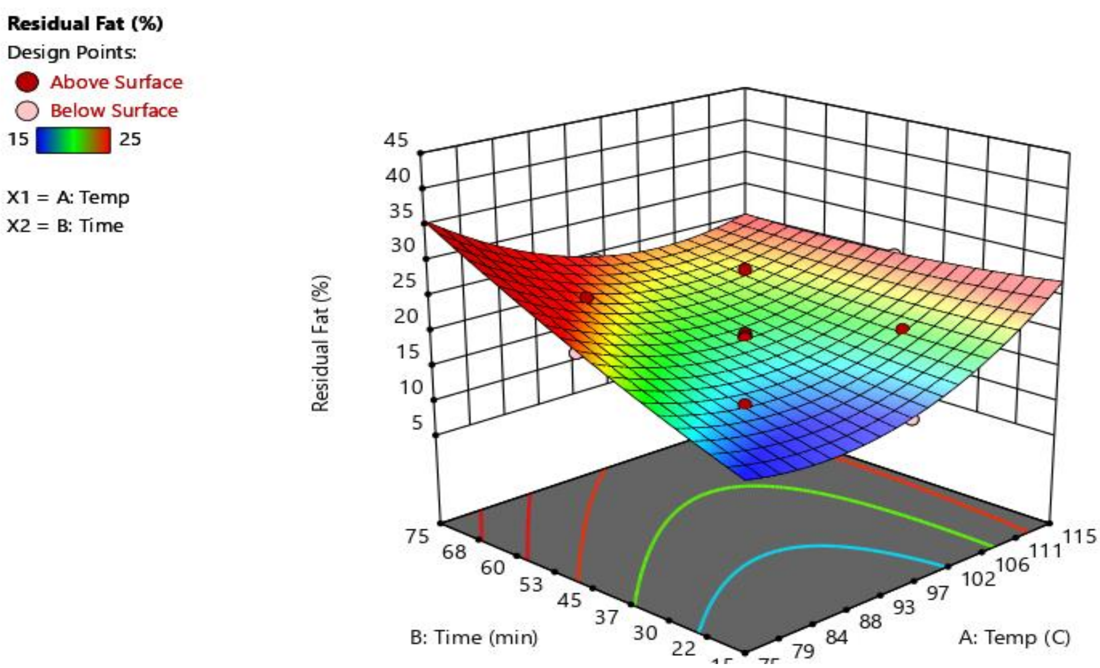

Figure (B): 3D Surface plot showing the effect of pressing temperature and pressing duration on residual fat content (%)

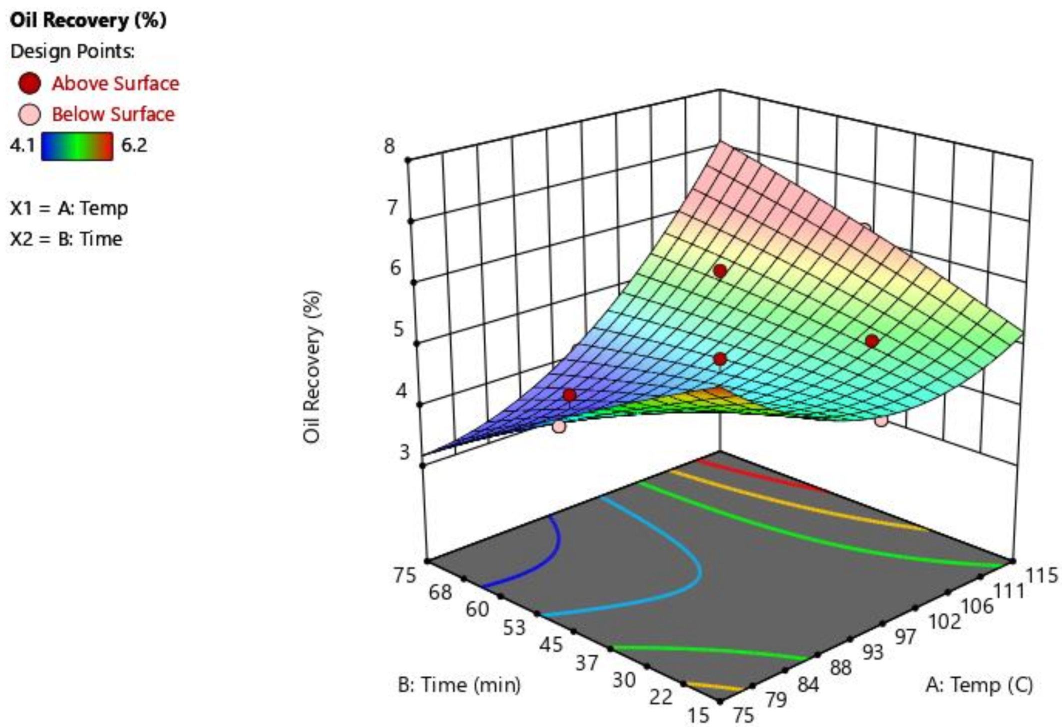

Figure (C): 3D Surface plot showing the effect of pressing temperature and pressing duration on oil recovery (%)

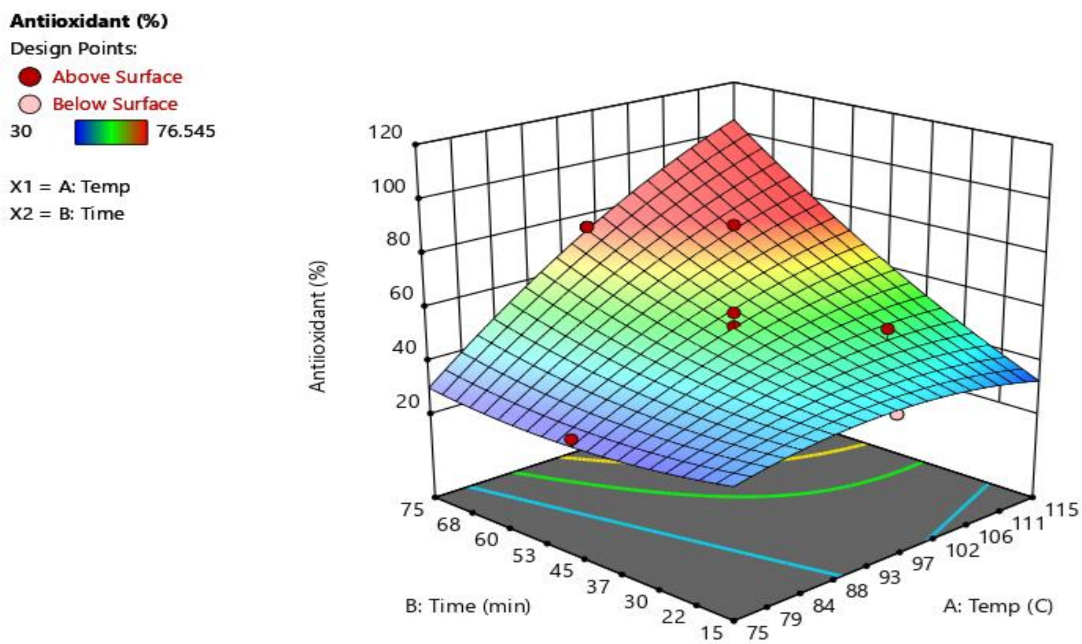

Figure (D): 3D Surface plot showing the effect of pressing temperature and pressing duration on antioxidant activity (%)

IV. Conclusion

In this study, virgin coconut oil was established that applied temperature, applied duration are significantly influenced on affecting the oil yield, antioxidant activity, residual fat and oil recovery in cake. The best conditions of pressing temperature and duration at 95 ºC for 75 min, which gave maximum oil yield (67.44%), maximum antioxidant activity (76.57%), residual fat content (24.35%) and minimum oil recovery in cake (4.27%). The screw press method can be used commercially as it is environmental friendly, cheaper and easy-applicable. Virgin coconut oil is not processed or chemically altered, unlike other edible oils, so it keeps all of its beneficial plant-based nutrients.

Acknowledgment

The authors gratefully acknowledged to Dr.Myat lin (Professor and Head, Department of Postharvest Technology, ACARE) and India-Myanmar Friendship Project, Dr. Saw Hto Lwe Htoo (Professor, Department of Horticulture) and Dr.Kyi Moe(Associate Professor, Department of Agronomy) for the knowledge support until the finishing of this research.

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