

# Degradation Study of Bromelain-extracted Virgin Coconut Oil Based on Peroxide and Fatty Acid Formation Under the Elevated Temperatures

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**Abstract.** This research seeks to ascertain the kinetic parameters of VCO degradation based on the formation of peroxide and free fatty acids and to evaluate the shelf life of bromelain-extracted VCO at various temperatures. The kinetic parameters and shelf life of VCO were determined by measuring the value of peroxides and free fatty acids (FFA) concentration at temperatures of 50 °C to 200 °C. The heating was performed in a 1 L conical flask immersed in the paraffin bath. Samples were collected for each temperature at 0 to 60 minutes. The rate constant of peroxide and FFA formation was determined by regression analysis using Microsoft Excel, based on the plot of sampling time and value of peroxide and FFA concentration. The rate constant of peroxide formation escalated from 0.0114 to 0.1419 mEq Kg<sup>-1</sup> min<sup>-1</sup> when the VCO was heated at 50 °C to 200 °C. Meanwhile, the rate constant of FFA formation rose from 0.0188 to 0.0393 % min<sup>-1</sup> when subjected to heating at 50 °C to 200 °C. Based on the shelf-life prediction established by Indonesian National Standards or the Asian and Pacific Coconut Community, the shelf-life of bromelain-extracted VCO varies from 10 to 3 hours at temperatures ranging from 2 °C to 50 °C. It was determined that elevating the temperature reduced the shelf-life of bromelain-extracted VCO. These findings suggest that temperature is crucial for the stability of bromelain-extracted VCO.

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## 1 Introduction

Indonesia possesses extensive agricultural and plantation areas. The coconut (*Cocos nucifera L.*) plantation subsector serves as an export commodity and is a significant source of the national economy. Almost all coastal areas of Indonesia are covered with coconut trees as they can grow in regions with a tropical climate, including Indonesia [1]. Accordingly, it triggers community innovation in managing and processing coconut trees due to the possible utilization of all parts of the plant. The trunks can serve as building frames; leaves can function as decorations; coconut sticks and fibers can be utilized for brooms; coconut water can be transformed into nata de coco; and coconut meat can produce copra, coconut cream, coconut milk, and virgin coconut oil (VCO), familiar to the public because of its rich benefits [2].

VCO is an oil derived from processed fresh coconut meat, produced by several methods, including physical methods (gradual heating and centrifugation), chemical methods (pancaking and acidification or salting), and enzymatic [3]. The oil derived from processed coconut meat surpasses ordinary cooking oil. It has an economic value of higher selling prices, where the resulting VCO has notable color characteristics, distinctive aroma of coconut oil, low water content, and free fatty acids, resulting in a long shelf life of more than 12 months [4].

The production of VCO by enzymatic methods offers advantages over physical and chemical methods since it yields a greater amount of VCO and preserves its physicochemical properties due to the relatively tiny heat and mechanical energy required [5]. Enzymes utilized in VCO production include bromelain enzymes, which can be obtained from pineapple plants (*Ananas comosus L.*). The required bromelain enzyme comes from extracts of stems, leaves, skin, or meat of pineapple fruit, with different enzyme activities [6]. Bromelain enzyme is a class of proteolytic or protease, having the capability to break peptide bonds in coconut milk emulsions by damaging fat emulators to separate oil from water [7].

VCO is classified as an oil predominantly composed of saturated fatty acids, amounting to 92%, with its saturated fatty acid composition including lauric acid (48.74%), myristic acid (16.31%), caprylic acid (10.91%), capric acid (8.10%), and caproic acid (1.25%), which encompass medium-chain fatty acids (MCFA). The unsaturated fatty acids of 8% consist of oleic and linoleic acids [8]. The content of MCFA can help overcome degenerative diseases such as diabetes, heart disease, and obesity and prevent free radicals because they are directly digested in the digestive tract and transported to the liver for metabolic conversion into energy. At the same time, no excess accumulation occurs [9], [10].

Oxidation can cause damage to VCO. Hydrolysis and microbial contamination can be identified by changes in the chemical properties of VCO, such as peroxide value and free fatty acid concentration [11]. Therefore, this study aims to determine the kinetic parameters of peroxide and free fatty acid formation for predicting the self-life of VCO produced using bromelain enzyme from pineapple extract. The shelf-life determination of VCO utilized the Arrhenius equation approach.

## 2 2. Materials and Methods

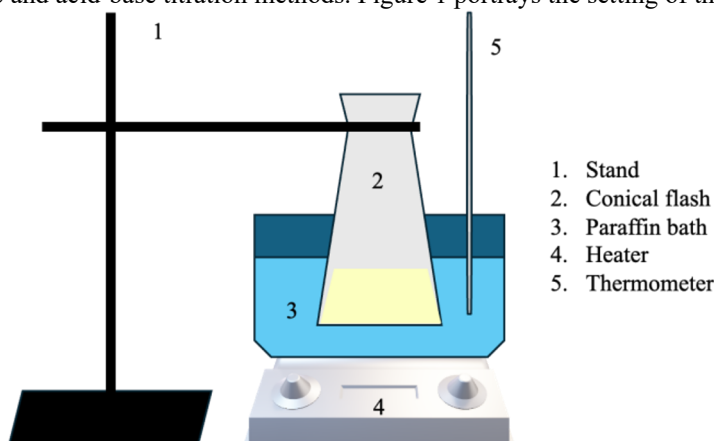
### 2.1 Materials

Bromelain-extracted VCO was prepared following [12]. Several chemicals were employed, encompassing analytic grade glacial acetic acid (Merck), chloroform (Merck), potassium

iodide (Merck), starch (Bratachem), NaOH (Bratachem), oxalic acid (Merck), potassium dichromate (Merck), 95% alcohol (Bratachem), and phenolphthalein (Merck). All chemicals were directly utilized without additional treatment.

## 2.2 Experiment

Data were obtained by heating 550 g of VCO samples in a 1 L Erlenmeyer at 50 °C, 100 °C, 150 °C, and 200 °C for 60 minutes using a paraffin bath. An electric stove was deployed as the heating device. Samples of 5 g were taken at 0, 10, 20, 40, and 60 minutes. The formed peroxides and free fatty acids were analyzed on each sample for two replications using iodometric and acid-base titration methods. Figure 1 portrays the setting of this experiment.



**Fig. 1.** Setting of experiment

## 2.3 Analysis

### 2.3.1 Peroxide Value

A 5 g sample of VCO was put into an Erlenmeyer iodine flask, and 1 g of potassium iodide and 30 mL of glacial acetic acid-chloroform mixture in a 3:2 ratio were added and then homogenized. After mixing the solution, it was immediately covered with aluminum foil and allowed to stand for 30 minutes. Subsequently, 50 mL of distilled water and 1 mL of starch indicator were added and titrated using 0.01 N sodium thiosulphate until the color changed from blue to colorless [13],[14]. The titration was carried out for two repetitions. According to [15], peroxide value could be calculated using formula (1), where  $a$  denotes the volume of sodium thiosulphate used to titrate the blank,  $b$  implies the volume of sodium thiosulphate used to titrate the sample,  $N$  represents the normality of sodium thiosulphate, and  $W$  signifies the weight of the sample.

$$\text{Peroxide value} = \frac{(b-a) \times N \times 1000}{W} \quad (1)$$

### 2.3.2 Free Fatty Acid (FFA)

A 5 g VCO sample was put into an Erlenmeyer, and 50 mL of neutral alcohol was added. Then, three drops of phenolphthalein indicator were added and titrated using 0.1 N NaOH until the color changed from colorless to pink in exactly 30 seconds [13],[16]. The titration was carried out for two repetitions. According to [15], the free fatty acid concentration could be calculated using formula (2), where  $V$  denotes the volume of NaOH,  $N$  represents the normality of NaOH, 200 signifies the molecular weight of lauric acid, and  $m$  refers to the weight of the sample.

$$FFA (\%) = \frac{V \times N \times 200}{m \times 1000} \times 100\% \quad (2)$$

## 3 Results and Discussion

### 3.1 Peroxide Value

Peroxide value analysis determines the degree of oil rancidity caused by an oxidation reaction characterized by the presence of rancid taste and aroma. This rancid aroma and flavor arise from unsaturated fatty acids that can bind to oxygen in their double bonds. This oxidation reaction can occur due to continuous exposure to the sun or high-temperature heating; the higher the heating, the greater the peroxide value formed [17].

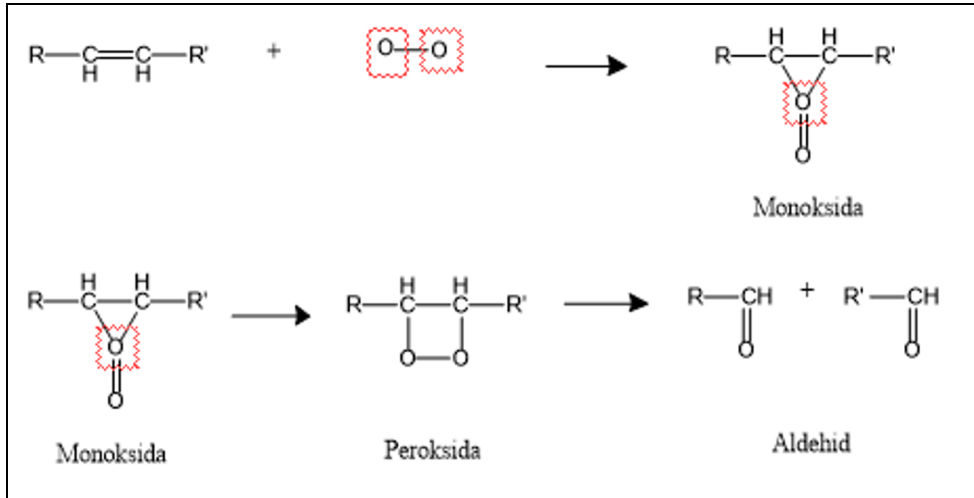
The peroxide value describes the amount of peroxide formed in oil, expressed in milligram equivalents per 1,000 g of the oil sample. The value of peroxides could be determined using the iodometric titration method, with a maximum limit of 2 mEq/kg as specified in [18]. However, it is slightly different from [19]. The maximum limit of peroxide value that complies with the standard is 3 mEq/kg. Table 1 lists the peroxide values of VCO produced using the enzymatic method.

**Table 1.** Peroxide values (mEq Kg<sup>-1</sup>)

Temperature (°C)	Time (Minute)				
	0	10	20	40	60
50	0.191	0.573	0.860	0.955	0.955
100	0.191	0.764	0.860	1.433	2.674
150	0.191	2.101	3.629	4.680	5.730
200	0.191	4.680	6.112	7.258	10.123

Following Table 1, the peroxide values in VCO produced using the enzymatic method, using young pineapple pulp, escalated with rising temperatures and longer heating times. The peroxide values meet the quality requirements of VCO determined by [18], with heating at 50 °C for 60 minutes and at 100 °C for 40 minutes.

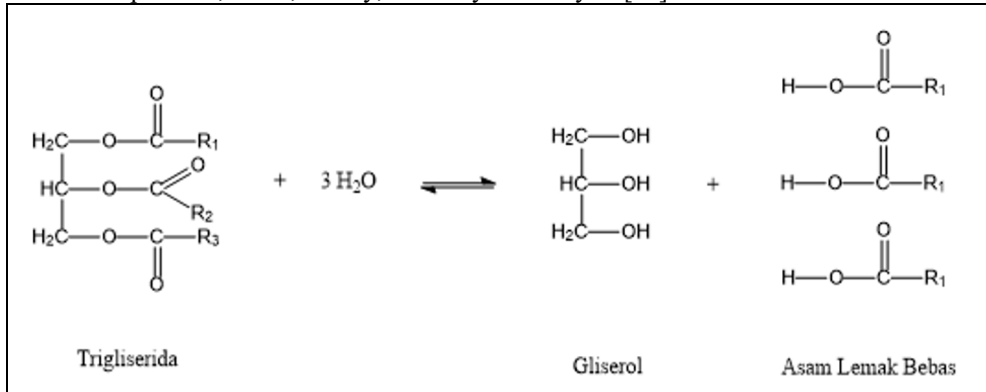
The high peroxide values are caused by oxidation reactions between unsaturated fatty acids that bind to oxygen to form peroxides, aldehydes, ketones, and other short-chain fatty acids, thus changing the physicochemical properties contained in VCO [20]. As exhibited in Figure 2, the reaction of peroxide formation has followed [20].



**Fig. 2.** Peroxide formation reaction [20]

### 3.2. Free Fatty Acid Concentration

Free fatty acids concentration refers to the amount of free fatty acids contained in oil or fat due to the hydrolysis reaction. Hence, analyzing the free fatty acids concentration is critical for assessing oil deterioration. Hydrolysis reactions in oil can occur quickly due to factors such as temperature, water, acidity, and enzyme catalysts [20].



**Fig. 3.** Triglyceride hydrolysis reaction [21]

Figure 3 exhibits the hydrolysis reaction of triglyceride to produce free fatty acids. Enzymes capable of breaking bonds or catalyzing triglyceride compounds belong to the hydrolase group, including lipase and proteolytic enzymes: bromelain and papain enzymes [22], [23].

Free fatty acids are triglyceride compounds decomposing into glycerol and free fatty acids caused by hydrolysis reactions. The reaction of free fatty acid formation refers to [21]. The concentration of free fatty acids in VCO could be determined by the number of milligrams of base (KOH/NaOH) required to neutralize the free fatty acids in 1 g of oil using the acid-base titration method [24]. Table 2 displays the concentrations of free fatty acids in VCO produced by the enzymatic method.

Table 2 discloses that the free fatty acid concentrations in VCO produced using the enzymatic method, with the addition of young pineapple pulp, escalated with elevated temperatures and prolonged heating times. The concentrations of free fatty acids have

fulfilled the quality requirements of VCO according to [19], with heating at 50 °C for the initial ten minutes due to the maximum limit of 0.5%. However, it differs from the free fatty acid concentrations according to [18], setting the maximum free fatty acid concentration at 0.2%. Hence, none of the samples analyzed met the VCO standards.

**Table 2.** Free fatty acid concentrations (% FFA)

Temperature (°C)	Time (Minute)				
	0	10	20	40	60
50	0.259	0.299	0.539	1.018	1.297
100	0.259	1.178	1.517	1.796	1.996
150	0.259	1.088	1.537	2.036	2.455
200	0.259	1.597	1.856	2.056	3.114

### 3.3. Reaction Kinetics

The reaction kinetic model could help predict the shelf life of a food product using the accelerated storage studies (ASS) method. The ASS method involves modifying the environmental conditions to be abnormal to accelerate the deterioration of food product quality. The observations involve analyzing the empirical approach using the Arrhenius equation, which often adheres to zero-order or first-order kinetics in the analysis of the shelf life of a food product [25].

The model of food quality change and the reaction order of change could be investigated using the integration method, followed by an analysis of the estimation function. The accuracy of the estimation function model was assessed by comparing the coefficient of determination ( $R^2$ ) value closest to 1 from the relationship between concentration and time for zero order, natural logarithmic concentration and time for first order, and one per concentration and time for second order [26]. The higher the resulting  $R^2$  value, the greater the linearity, signifying that the mathematical model can accurately predict the actual quality value [27]. Furthermore, in the kinetic analysis, the formation of peroxides and free fatty acids followed the zero-order because they have coefficients of determination ( $R^2$ ) values closest to 1. Table 3 demonstrates the coefficient of determination ( $R^2$ ) at zero, first, and second orders for peroxide values and free fatty acid concentrations.

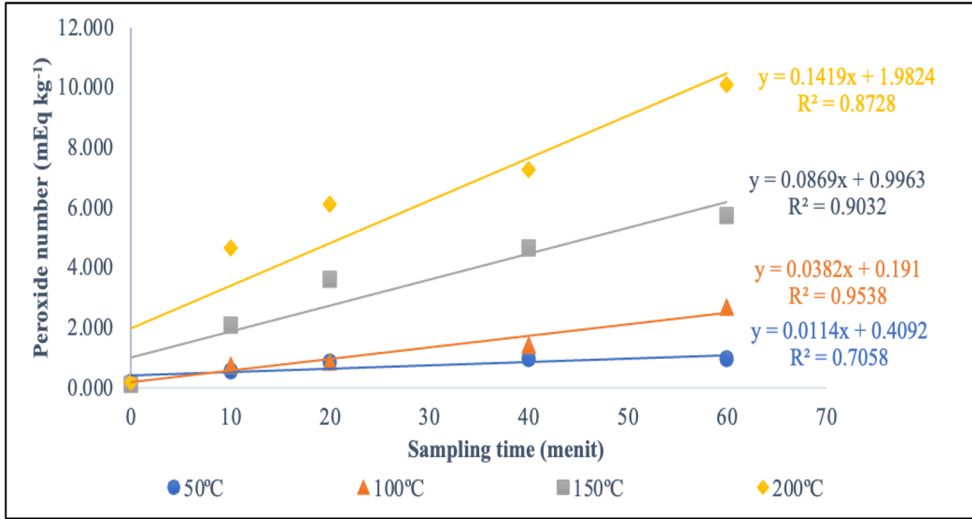
**Table 3.** Coefficient of determination ( $R^2$ ) of peroxide and free fatty acid values

Temperature (°C)	Peroxide value			Free fatty acid value		
	Order			Order		
	Zero	First	Second	Zero	First	Second
50	0.7058	0.5908	0.4822	0.9786	0.9495	0.8749
100	0.9538	0.8477	0.5506	0.7866	0.5871	0.4467
150	0.9066	0.6103	0.4083	0.9161	0.6901	0.4857
200	0.8728	0.533	0.3814	0.8526	0.6098	0.4346

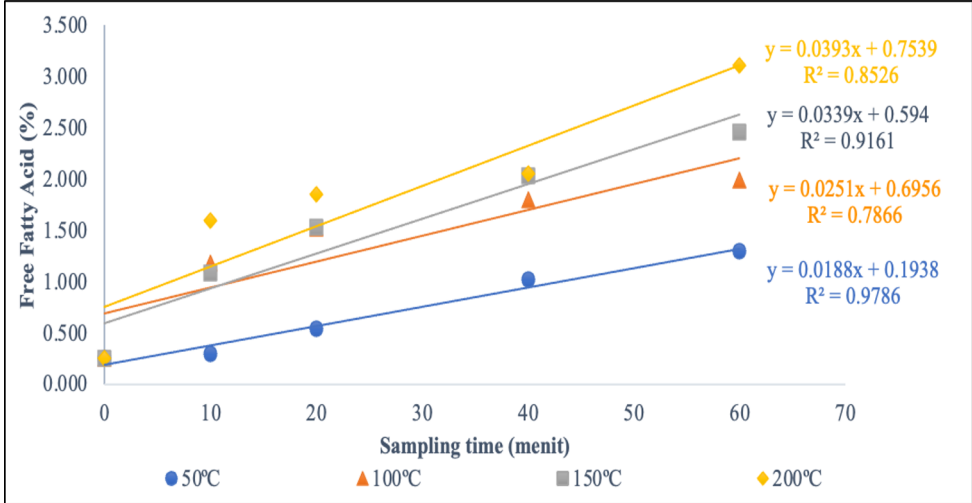
Following the opinion expressed by [26], the zero-reaction order could help identify the deterioration of food quality, such as rancidity due to oxidation, hydrolysis, and microbial processes. Table 3 illustrates the kinetics of the zero-reaction order obtained from the analysis of the coefficient of determination closest to 1. Meanwhile, Figures 4 and 5 depict the linearity graphs of peroxide and free fatty acid formation.

*The reaction kinetic orders in Figures 4 and 5 disclosed that the rate constants of peroxide and free fatty acid formation could be determined as the slope of the equation generated*

from regression analysis, as provided in Table 4. Utilizing the data in Table 4, a plot of the constant peroxide formation rate and free fatty acid formation constant against the reciprocal of temperature (K) could ascertain the shelf life of VCO [26]. Figures 6 and 7 portray the plotting results, showcasing an activation energy of 5146.73 KJ mol<sup>-1</sup> K<sup>-1</sup> for peroxide formation and 1531.44 KJ mol<sup>-1</sup> K<sup>-1</sup> for free fatty acid formation.



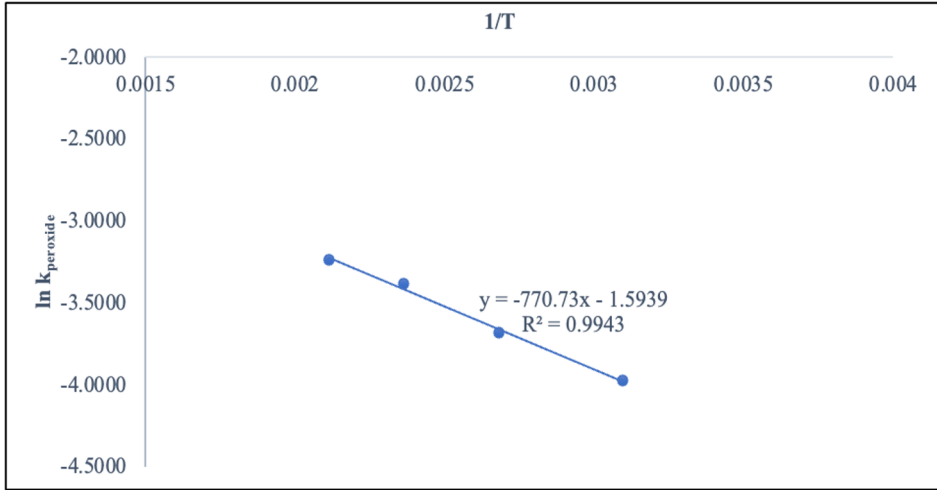
**Fig.4.** Zero-order peroxide formation



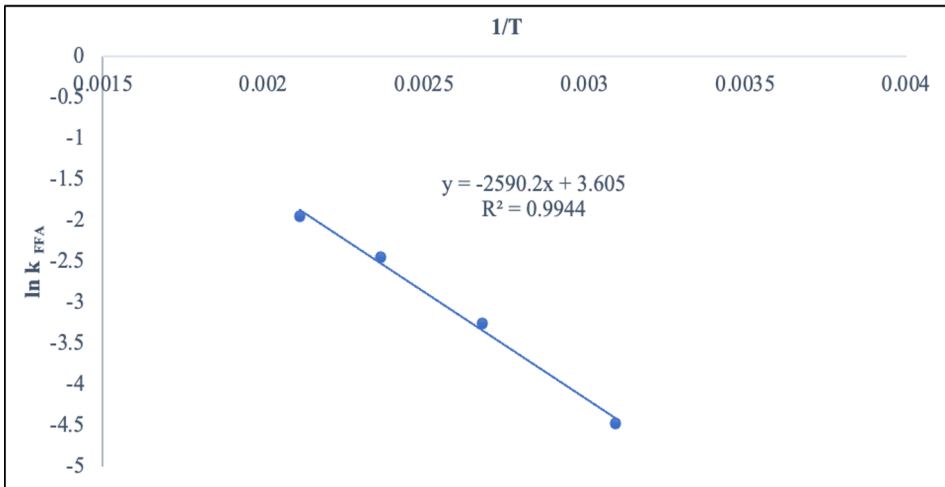
**Fig. 5.** Zero-order FFA formation

**Table 4.** Peroxide and free fatty acid formation rate constants

Temperature (°C)	Peroxide constant (mEq kg <sup>-1</sup> min <sup>-1</sup> )	Free fatty acid constant (%FFA min <sup>-1</sup> )
50	0.0114	0.0188
100	0.0382	0.0251
150	0.0862	0.0339
200	0.1419	0.0393



**Fig. 6.** Plot of the natural logarithmic rate constant of peroxide formation ( $\ln k_{\text{peroxide}}$ ) vs.  $1/T$



**Fig. 7.** Plot of the natural logarithmic rate constant of FFA formation ( $\ln k_{\text{FFA}}$ ) vs.  $1/T$

**Table 5.** Predicted shelf life of VCO

Temperature (°C)	Peroxide (Hour)	Free fatty acids (Hour)
2	10.050	0.327
15	6.554	0.287
25	4.863	0.263
50	2.645	0.214
100	0.789	0.160
150	0.350	0.118
200	0.212	0.102

Table 5 displays the prediction of VCO self-life following the Arrhenius equation when VCO was stored at modified temperatures. The VCO depicted a too short shelf life. Extending the shelf life could be performed through purification using zeolite, activated charcoal, and rice husk ash [28]. Additionally, the results disclosed VCO as an extremely

temperature-sensitive material. Hence, the storage and transportation must be placed in a temperature-conditioning room. Therefore, preservatives, such as antioxidants, should be added during the formulation of any food or pharmaceutical preparation.

## 4 Conclusions

The analysis unveiled that heating reduced the quality of VCO produced with bromelain enzyme. The peroxide and FFA values rose with elevating temperature. The reaction of peroxide formation and free fatty acid followed the zero order. The rate constants of peroxides and FFA formation escalated with rising temperatures. The Arrhenius equation could determine the shelf life of VCO.

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## Conflict of interest

The authors declare that they have no conflict of interest.

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## Ethics approval

There is nothing to declare.

## References

- [1] K. Pertanian, “Statistik Perkebunan Indonesia Komoditas Cengkeh,” *Statistik Perkebunan Indonesia 2018-2020*, pp. 1–100, 2019.
- [2] S. Sangadji, A. S. Mahulete, and D. A. Marasabessy, “Studi Produktifitas Tanaman Kelapa (*Cocos Nucifera* L.) di Negeri Tial Kecamatan Salahutu Kabupaten Maluku Tengah,” *Jurnal Agrohut*, vol. 13, no. 2, pp. 87–96, 2022, doi: [10.51135/agh.v13i2.176](https://doi.org/10.51135/agh.v13i2.176).
- [3] N. Suharcaryo and Yuwidianoro, *Proses Aktivasi Dalam Peningkatan Kualitas Vicoil Bopanprog Desa Bojong, Kecamatan Panjatan, Kabupaten Kulonprogo*. 2020.
- [4] D. O. Rachmawati, I. Suswandi, and L. P. B. Yasmini, “Pendampingan Uji Kadar Air Kualitas Vco Berdasarkan Standar Nasional Indonesia Produksi Kwt Tunas Amerta,” *Jurnal Widya Laksana*, vol. 11, no. 1, p. 158, 2022, doi: [10.23887/jwl.v11i1.39205](https://doi.org/10.23887/jwl.v11i1.39205).
- [5] N. Asiah, R. M. Astuti, L. Cempaka, and R. Setiani, “Physical and Chemical Characteristic of Virgin Coconut Oil under Mix Culture Fermentation Technique,” *Technlogy Journal of Physics: Conference Series*, vol. 1364, p. 12009, 2018, doi: [10.1088/1742-6596/1364/1/012009](https://doi.org/10.1088/1742-6596/1364/1/012009).
- [6] C. Varilla, M. Marcone, L. Paiva, and J. Baptista, “Bromelain, a Group of Pineapple Proteolytic Complex Enzymes (*Ananas comosus*) and Their Possible Therapeutic and Clinical Effects. A Summary,” *Foods*, vol. 10, no. 10, Oct. 2021, doi: [10.3390/FOODS10102249](https://doi.org/10.3390/FOODS10102249).

- [7] S. C. Palilingan and M. Pungus, "Produksi enzimatis Virgin Coconut Oil (VCO) dengan enzim bromelin serta pemurniannya menggunakan adsorben zeolit," *Fullerene Journal of Chemistry*, vol. 3, no. 2, p. 70, 2018, doi: [10.37033/fjc.v3i2.41](https://doi.org/10.37033/fjc.v3i2.41).
- [8] J. Silalahi, L. K. Karo, S. Morin Sinaga, Y. Cinthya, and E. Silalahi, "Composition of Fatty Acid and Identification of Lauric Acid Position in Coconut and Palm Kernel Oils," *Indonesian Journal of Pharmaceutical and Clinical Research*, vol. 1, no. 2, pp. 1–8, Dec. 2018, doi: [10.32734/IDJPCR.V1I2.605](https://doi.org/10.32734/IDJPCR.V1I2.605).
- [9] A. S. Pereyra, K. L. McLaughlin, K. A. Buddo, and J. M. Ellis, "Medium-chain fatty acid oxidation is independent of l-carnitine in liver and kidney but not in heart and skeletal muscle," *Am J Physiol Gastrointest Liver Physiol*, vol. 325, no. 4, p. G287, Oct. 2023, doi: [10.1152/AJPGI.00105.2023](https://doi.org/10.1152/AJPGI.00105.2023).
- [10] S. M. Houten, S. Violante, F. V. Ventura, and R. J. A. Wanders, "The Biochemistry and Physiology of Mitochondrial Fatty Acid  $\beta$ -Oxidation and Its Genetic Disorders," *Annu Rev Physiol*, vol. 78, pp. 23–44, Feb. 2016, doi: [10.1146/ANNUREV-PHYSIOL-021115-105045](https://doi.org/10.1146/ANNUREV-PHYSIOL-021115-105045).
- [11] N. A. A. Ghani, A. A. Channip, P. Chok Hwee Hwa, F. Ja'afar, H. M. Yasin, and A. Usman, "Physicochemical properties, antioxidant capacities, and metal contents of virgin coconut oil produced by wet and dry processes," *Food Sci Nutr*, vol. 6, no. 5, pp. 1298–1306, Jul. 2018, doi: [10.1002/FSN3.671](https://doi.org/10.1002/FSN3.671).
- [12] S. Harimurti, R. M. Rumagesan, and Susanawati, "Environmentally friendly production method of virgin coconut oil using enzymatic reaction," *IOP Conf Ser Mater Sci Eng*, vol. 874, no. 1, p. 012004, Jun. 2020, doi: [10.1088/1757-899X/874/1/012004](https://doi.org/10.1088/1757-899X/874/1/012004).
- [13] V. M. Ati, R. S. Mauboy, and M. S. R. A. Keneng, "Pengujian Kadar Bilangan Peroksida dan Asam Lemak Bebas Minyak Kelapa (*Cocos nucifera* L.) Kelentik," *Jurnal Biotropikal Sains*, vol. 17, no. 2, pp. 24–30, 2020.
- [14] A. H. Burhan, "Penetapan Angka Peroksida Minyak Goreng Curah Sawit Pada Penggorengan Berulang Ikan Lele," *Jurnal Pendidikan Sains (Jps)*, vol. 6, no. 2, p. 48, 2018, doi: [10.26714/jps.6.2.2018.48-53](https://doi.org/10.26714/jps.6.2.2018.48-53).
- [15] A. Febliza, O. Okatariyani, and A. M. Putri, "Kualitas Minyak Blend Kelapa Kopro dan Minyak Kelapa Sawit ditinjau dari Kadar Air, Kadar Asam Lemak Bebas dan Bilangan Peroksida," *Jurnal Riset Kimia*, vol. 11, no. 1, pp. 1–8, 2020, doi: [10.25077/jrk.v11i1.347](https://doi.org/10.25077/jrk.v11i1.347).
- [16] D. Fitriani, E. Widiyati, and D. A. Triawan, "APLIKASI PENGGUNAAN EKSTRAK NANAS DAN RAGI ROTI SEBAGAI BOKATALISATOR PEMBUATAN VCO (Virgin Coconut Oil) SERTA PEMURNIANNYA DENGAN MENGGUNAKAN ZEOLIT ALAM BENGKULU DAN ABU SEKAM PADI," *Dalton : Jurnal Pendidikan Kimia dan Ilmu Kimia*, vol. 4, no. 1, pp. 8–19, 2021, doi: [10.31602/dl.v4i1.4872](https://doi.org/10.31602/dl.v4i1.4872).
- [17] Yeniza and A. P. Asmara, "Penentuan Bilangan Peroksida Minyak Rbd (Refined Bleached Deodorized) Olein Pt. Phpo Dengan Metode Titrasi Iodometri," *Amina*, vol. 1, no. 2, pp. 79–83, 2020, doi: [10.22373/amina.v1i2.39](https://doi.org/10.22373/amina.v1i2.39).
- [18] SNI 7381:2008, "Syarat Mutu Minyak Kelapa," 2008.
- [19] APCC, "APCC Quality Standard RBD COCONUT OIL," *International Coconut Community*, no. August, pp. 5–6, 2009.
- [20] D. A. I. Pramitha and D. Juliadi, "PENGARUH SUHU TERHADAP BILANGAN PEROKSIDA DAN ASAM LEMAK BEBAS PADA VCO ( Virgin Coconut Oil ) HASIL FERMENTASI," *Indonesian E-Journal of Applied Chemistry*, vol. 7, pp. 149–154, 2019.
- [21] B. Untari, Miksusanti, and A. Ainna, "Penentuan Kadar Asam Lemak Bebas dan Kandungan Jenis Asam Lemak dalam Minyak yang Dipanaskan dengan Metode

- Titration Asam Basa dan Kromatografi Gas,” *Jurnal Ilmiah Bakti farmasi.*, vol. 1, no. 1, pp. 1–10, 2020.
- [22] E. Fatimah, “Review Artikel: Karakteristik Dan Peranan Enzim Lipase Pada Produksi Diacylglycerol (Dag) Dari Virgin Coconut Oil (Vco),” *Unesa Journal of Chemistry*, vol. 10, no. 3, pp. 246–256, 2021, doi: [10.26740/ujc.v10n3.p246-256](https://doi.org/10.26740/ujc.v10n3.p246-256).
- [23] R.- Anggraini and E.- -, “PEMANFAATAN DAUN PEPAYA SEBAGAI ENZIM PAPAİN SECARA EKSTRAKSI DENGAN PENAMBAHAN Na-Bisulfit UNTUK MENINGKATKAN MUTU MINYAK KELAPA (VCO),” *Jurnal Distilasi*, vol. 4, no. 1, p. 17, 2020, doi: [10.32502/jd.v4i1.2214](https://doi.org/10.32502/jd.v4i1.2214).
- [24] J. Radu, “PEMBUATAN MINYAK KELAPA Edisi Pertama ISBN Penulis : Editor :,” pp. 1–59, 2015.
- [25] H. Herawati, “Penentuan umur simpan pada produk pangan,” *Jurnal Litbang Pertanian*, vol. 27, no. 4, pp. 124–130, 2008.
- [26] T. Haryati, Estiasih, F. Heppy, and K. Ahmadi, “Pendugaan Umur Simpan Menggunakan Metode Accelerated Shelf-Life Testing ( ASLT ) dengan Pendekatan Arrhenius pada Produk Tape Ketan Hitam Khas Mojokerto Hasil Sterilisasi,” *Jurnal Pangan dan Agroindustri*, vol. 3, no. 1, pp. 156–165, 2015.
- [27] Z. L. Sarungallo, B. Santoso, M. M. Lisangan, S. N. P. Paiki, R. U. Situngkir, and E. A. Asokawaty, “Kinetika Perubahan Mutu Minyak Buah Merah (Pandanus conoideus) Hasil Degumming Selama Penyimpanan,” *Jurnal Aplikasi Teknologi Pangan*, vol. 7, no. 4, pp. 156–162, 2019, doi: [10.17728/jatp.2947](https://doi.org/10.17728/jatp.2947).
- [28] F. Fatimah and M. E. C. Sangi, “Kualitas Pemurnian Virgin Coconut Oil (VCO) Menggunakan Beberapa Adsorben,” *Chemistry Progress*, vol. 3, no. 2, pp. 65–69, 2010.