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RESEARCH ARTICLE — OPEN ACCESS

# Physicochemical qualities of low-lipase oil palm (*Elaeis guineensis* Jacq.) during fruit ripening on tree☆

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**Abstract** – Physicochemical qualities of crude palm oil (CPO)—including low free fatty acid (FFA) content, high carotenoid concentration, and a high deterioration of bleachability index (DOBI) value, are crucial parameters that influence oil quality and human health. This study aimed to evaluate some genotypes suspected to be elite oil palm types carrying low-lipase traits. An FFA analysis was carried out using titration, and carotene and DOBI were quantified through spectrophotometry. SL81, one of the 11 genotypes evaluated, had an extremely low FFA level averaging 2.23% ± 1.88%, significantly lower than that of the other genotypes (8.34% ± 2.51% to 17.70% ± 3.60%). The DOBI values for all genotypes met the standard (>2.3), and the carotene content of all genotypes except for SL45 and SL60 reached the standard (>581 ± 45.5 ppm). The SL81 genotype was suggested as elite low-lipase line fitted to Indonesian and Malaysian standards, and the bunches can be harvested anytime within 0–21 days after fruit ripening without compromising other quality parameters.

**Keywords:** oil palm / low-lipase / free fatty acid / carotene / physicochemical

**Résumé – Caractéristiques physico-chimiques du palmier à huile à faible activité lipasique (Elaeis guineensis Jacq.) pendant la maturation des fruits sur l'arbre.** Les qualités physico-chimiques de l'huile de palme brute (CPO), notamment une faible teneur en acides gras libres (AGL), une concentration élevée en caroténoïdes et une valeur élevée de l'indice de détérioration à la décoloration (DOBI), sont des paramètres cruciaux qui influencent la qualité de l'huile et la santé humaine. Cette étude visait à évaluer certains génotypes soupçonnés d'être des palmiers à huile d'élite présentant des caractéristiques de faible activité lipasique. L'analyse des AGL a été réalisée par titration, tandis que les caroténoïdes et l'indice DOBI ont été quantifiés par spectrophotométrie. Le génotype SL81, l'un des 11 génotypes évalués, présentait une teneur en AGL exceptionnellement faible, avec une moyenne de 2,23 % ± 1,88 %, nettement inférieure à celle des autres génotypes (8,34 % ± 2,51 % à 17,70 % ± 3,60 %). Les valeurs de DOBI pour tous les génotypes respectaient la norme (>2,3), et la teneur en caroténoïdes de tous les génotypes, à l'exception de SL45 et SL60, atteignait la norme (>581 ± 45,5 ppm). Le génotype SL81 est proposé comme une lignée élite à faible lipase répondant aux normes indonésiennes et malaisiennes, avec la possibilité de récolter les régimes entre 0 et 21 jours après la maturation des fruits sans compromettre les autres paramètres de qualité.

**Mots-clés :** palmier à huile / faible activité lipasique / acides gras libres / carotène / physico-chimique

☆ Contribution to the Topical Issue: "Palm and palm oil / Palmier et huile de palme".
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# 1 Introduction

**Highlights**

- SL81 is an elite low-lipase oil palm genotype with free fatty acid (FFA) levels below 3%;
- This genotype maintains high carotenoid content and DOBI values; ensuring superior oil quality
- SL81 bunches can be harvested up to 21 days after ripening without compromising key physicochemical properties.

Indonesia is the world's leading exporter and producer of palm oil (*Elaeis guineensis* Jacq., Arecaceae). Oil palm has three fruit types: tenera (thin shell), pisifera (no shell), and dura (thick shell; Arifiyanto *et al.*, 2017). The tenera type is the backbone of commercial production in Indonesia and most countries (Wening *et al.*, 2012). Crude palm oil (CPO) is extracted from the oil palm fruit mesocarp, which comprises up to 90% of the dry weight and contains the highest oil content among plant tissues (Bourgis *et al.*, 2011). The key physicochemical qualities that determine CPO quality include low free fatty acid (FFA) content, which minimises oil degradation (Morcillo *et al.*, 2013); high carotenoid content, which provides antioxidant benefits and enhances nutritional value (Fattore and Fanelli, 2013); and a high deterioration of bleachability index (DOBI) value, which ensures better oil clarity and refining efficiency (Julianti *et al.*, 2021). These qualities are essential to meet industry standards and improve the suitability of palm oil for consumption and industrial applications.

Oil quality is a concern in the oil palm industry. Furthermore, these quality measures have significant implications for human health. Owing to lipase activities in the mesocarp, triglycerides in ripe fruit quickly degrade after abscission and bruising (Sambanthamurthi et al., 1995; Abigor *et al.*, 1985). Lipase activity releases free fatty acids (FFAs) that promote palm oil acidification and reduce fruit quality. Some factors that affect FFA content include harvesting delay, factory processing, and storage duration (Henderson and Osborne 1991; Escallón-Barrios *et al.*, 2022.; Basyuni *et al.*, 2017). In addition, acidified palm oil with high saturated fatty acids is unfit for human consumption, since it could increase the risk of cardiovascular problems in the human body (Fattore and Fanelli 2013), due to oxidative stress (de Souza *et al.*, 2015). Moreover, the carotenoid concentration is proposed to possess antioxidant properties and is abundant in oil palm (Absalome *et al.*, 2020). These characteristics, including FFA and carotene content, need to be maintained by proper refining methods, which are indicated by the DOBI value (Gibon *et al.*, 2009). The higher DOBI value indicates the lower oxidation to the CPO, ensuring better oil stability and reducing harmful secondary oxidation products, which have been linked to inflammatory responses in humans (Gibon *et al.*, 2009). Thus, maintaining optimal levels of these physicochemical parameters is crucial for both oil quality and human well-being.

The FFA content in CPO can be removed by expensive refining methods requiring high energy (Gibon, 2012). However, using the oil palm plants with low lipase activity, would be a more cost-effective solution to the problem than using refinery processes. Meanwhile, studies correlating the selection of oil palm genotypes still focus on production (Daza *et al.*, 2021; Romero *et al.*, 2021), disease resistance (Tisné *et al.*, 2017; Basyuni *et al.*, 2019), and tissue culture propagation (Morcillo *et al.*, 2006). The present study suggests good results in oil quality rather than quantity. A CPO's qualities are essential for improving germplasm characteristics (Cadena *et al.*, 2013), and some genotypes of palm oil exhibit varying levels of lipase activity (Morcillo *et al.*, 2013; Domonhedo *et al.*, 2018).

In the current study, we demonstrate that some elite low-lipase palms can be selected from our large germplasm collections. Selection is based on the lowest FFA content, the highest DOBI and carotene level. The correlations between overripe bunches and days of harvesting were examined. Futhermore, using the oil palm with low lipase charactheristics, the oil palm plantations and smallholders can select convenient harvesting days for cost-effectiveness without risking any qualities.

# 2 Material and methods

## 2.1 Study Site

The study area was conducted at the Aek Loba Estate of PT Socfin Indonesia, in the district of Asahan, North Sumatra Province, Indonesia. The Aek Loba Estate is located at 02° 35′ 1.25″ and 02° 40′ 23.2″ N and 99° 32′ 34.52″ and 99° 43′ 30.87″ E. This estate has existed since the 1930s, now hosts third- and fourth-generation oil palm plantings. To date, plantations and surrounding areas in the estate are suffering from *Ganoderma boninense* attack (Mercière *et al.*, 2015). Physicochemical characteristics were analysed in the analytical laboratories of PT Socfin Indonesia, which was accredited by ISO 17025:2018.

## 2.2 Instrumentation

Agilent Cary 60 spectrophotometer (Crawford Scientific Ltd), BRAND digital burette (BRAND GMBH + CO KG, Germany), Precisa analytical balance XB-220 (Dietikon), Thermo Scientific micropipette (1000 μL), Hiclave HVE-50 autoclave (Hirayama), Liebherr freezer (Liebherr, Switzerland), and Memmert UNB400 oven (Memmert GmbH + Co. KG, Germany) were used.

## 2.3 Samples

The samples in this study were collected from the extensive germplasm collection owned by PT Socfin Indonesia, Indonesia, and consisted of 11 oil palm genotypes originating from Dabou, Lame, and Pobe. These genotypes were selected according to the origins of the families' ancestors. The first group (genotypes SL82, SL57, SL10, and SL45) was suspected to have high lipase activity and comprised genotypes from the families DA3D, DA5D, and LM718T. The second group (genotypes SL81, SL33, SL60, and SL66) was supposed to have low lipase activity and comprised genotypes from the families LM2T and DA115D. The DA3D, DA5D, DA115D, and LM2T families constituted the third group, which had normal-to-high lipase activity (genotypes SL13, SL93, and SL37).

### 2.4 Field Sampling

Ripe fruit samples were collected from 10-year-old oil palm trees with an average height of 5–7 m. A bunch was classified as ripe when one to five loose fruits were observed on the ground. The overripe bunch was left on the trees for subsequent sampling, 21 days after fruit ripening (AFR). Moreover, 15–20 pieces of fallen, ripe, overripe fruit in the bunch from random spikelets were harvested using clean knives and brought to the laboratory on the same day for further processing.

### 2.5 Oil Extraction

In the laboratory, the best-ripened fruits with no defects or fungal contamination were selected and cleaned. The mesocarp of the fruit was cut into thin slices with a blade and immediately dried in an oven at 103°C ± 2°C for 1 h. Oil was extracted from the hot sliced mesocarp with the press machine. CPO was stored in a small glass bottle and frozen at −20°C before analysis.

### 2.6 Free Fatty Acid (FFA) Content

The FFA content of the CPO samples was analysed using the titration method previously described (Ali *et al*., 2015). Frozen samples were thawed by heating to 50°C and weighed. Each sample was 2 g. The aliquots of ethanol were used to dissolve the samples, which were then titrated with 0.1 N NaOH and phenolphthalein indicator. When a persistent pink colour appeared, the FFA concentration calculated using the following formula:

$$\%FFA = \frac{256 \times V \times N}{10 \times W} \times 100\%, \quad (1)$$

where the molecular mass of palmitic acid is 256, $N$ is the normality of NaOH, $W$ is the CPO weight (g), and $V$ is NaOH volume titration.

### 2.7 Determination of Total Carotene

The total carotene concentration was determined using the UV-Vis spectrophotometer at 446 nm wavelength and a 1cm quartz cuvette according to the method described by Nokkaew *et al*. (2019), and expressed in parts per million (ppm). The samples were homogenised, and 0.1g ± 0.0001g of each sample was placed in a 25 mL volumetric flask. *n*-Hexane was used to dilute the samples before measurement, and the total carotene concentration was computed using the following formula:

$$Carotene(ppm) = \frac{A_{446} \times 383 \times V}{100 \times W}, \quad (2)$$

where $W$ is the CPO weight, $A_{446}$ is 446 nm absorbance, specific extinction coefficient is 383, $V$ is the volume (mL).

### 2.8 Determination of Deterioration of Bleachability Index (DOBI)

DOBI in CPO was measured as described by Nokkaew R. *et al*. (2019). Approximately 0.1g of CPO extract was weighed and placed in a 25 mL volumetric flask, and *n*-hexane was used to dissolve the samples. The samples were measured at 269 and 446 nm with the UV-Vis spectrophotometer and quartz cuvette (1 cm). DOBI was calculated using the following formula:

$$\%DOBI = \frac{A_{446}}{A_{269}}, \quad (3)$$

where $A_{269}$ is absorbance at 269 nm and $A_{446}$ is absorbance at 446 nm.

### 2.9 Overripening CPO

To assess the impact of overripening on CPO quality, fruit bunches were left on the trees for an extended period beyond the initial ripening stage. The fruits were then collected at different intervals (0, 7, 14, and 21 days after ripening) to evaluate the changes in FFA, carotenoid content, and DOBI values. This method allowed for an accurate assessment of how extended ripening influences oil quality.

### 2.10 Statistical Analysis

Data analysis was carried out by performing one-way analysis of variance followed by Duncan's multiple range test. $P < 0.05$, and IBM SPSS Statistic Version 29 was used. The effect of the harvesting days and genotype on FFA, DOBI, and total carotene content of the CPO was examined, and correlations among these parameters and the effects of one trait on others were evaluated.

## 3 Results

### 3.1 Physicochemical Properties of Low-Lipase Oil Palm Genotypes

To assess the performance of major physicochemical qualities among the 11 genotypes, we analysed FFA, carotene, and DOBI content. The SL81 genotype had the lowest FFA content (2.23% ± 1.88%), whereas SL37 had the highest (17.70% ± 3.60%). The DOBI values of SL33, SL93, SL10, and SL81 were exceptionally high (above 3.6), whereas the other genotypes had lower values (2.8–3.4). Furthermore, SL66, SL93, SL33, and SL81 had very high carotene content (above 800ppm), whereas SL60 and SL45 had the lowest content (under 600 ppm). The other genotypes had average content (700–800 p-pm; Fig. 1). The standard deviation of FFA was high, except in the SL60 genotype (Fig. 1a).

### 3.2 Development of Physicochemical Qualities during Ripening and Overripening

We further focused on the major cause of oil acidity in palm oil: delayed bunch harvesting because of the lack of labor and remoteness of an area. Bunches from 11 genotypes were left on the trees for up to 21 days after ripening, and the development

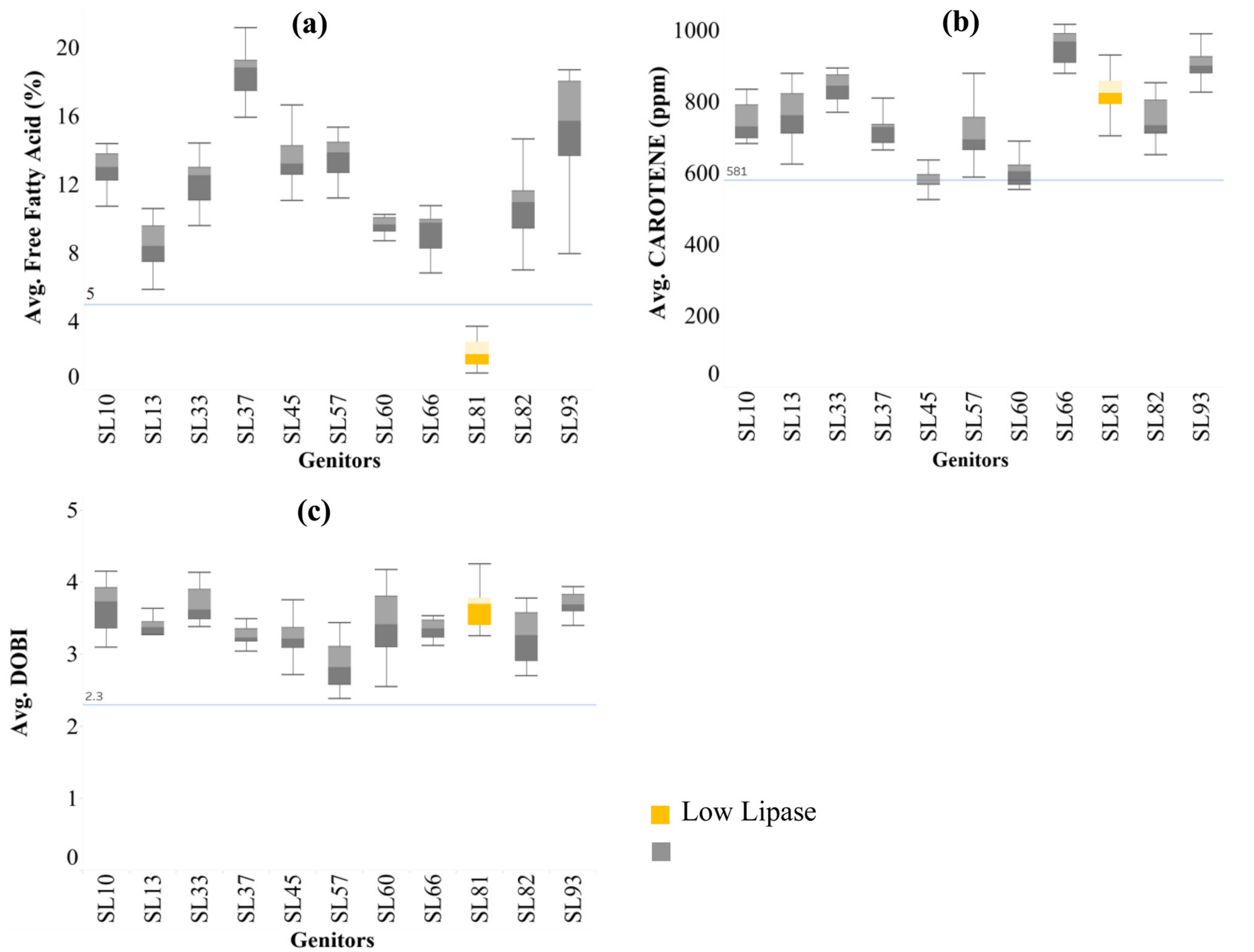


**Fig. 1.** Boxplot showing free fatty acid (a), carotene (b), and DOBI (c) levels**.** Data are presented as mean ± SD (n = 10). Blue line indicates Malaysian maximum/minimum standard (MS 814, 2007).

of FFA and carotenoid content and DOBI in the overripe fruit (0–21 days) fruit was observed.

To prevent environmental factors from affecting fruit quality, oil extraction was conducted in the laboratory within four hours after harvesting. This approach ensured that external conditions did not alter the physicochemical properties of the oil, allowing for accurate assessment of FFA, carotenoid content, and DOBI values. In general, FFA content increased from 0 to 21 days AFR (Fig. 2a). The FFA content in SL81 remained below 3% 21 days AFR. By contrast, carotenoid content decreased (Fig. 2b), and the DOBI was more stable from the first harvesting day (day 0) to day 21 AFR (Fig. 2c).

## 4 Discussion

### 4.1 CPO Qualities in Genotypes

The strict quality requirements for edible vegetable oils have increased in the past decades, particularly for CPO. Requirements for FFA, DOBI, and carotene, which affect human health, have been implemented. At room temperature, CPO from low-lipase genotypes was solid and homogeneous, indicating that the saturated fat levels were higher than those of unsaturated fats (de Souza *et al.*, 2015). However, the high-lipase CPO was still liquid and contained some crystals. This effect has been described by Corley and Tinker (2016), who noted that crystallisation in CPO is caused by diglycerides and can be removed by an energy-costly refining process (Simarani *et al.*, 2009).

The acceptable FFA content of CPO is under 5%. Thus, a value exceeding this limit is considered unfit for human consumption (Morcillo *et al.*, 2013). According to the Indonesian (TAMSI-DMSI, 2010) and Malaysian standards (MS 814, 2007), SL81 is the only genotype that fulfils the FFA content requirements (Fig. 1a). The average FFA content at ripening was 2.23% (1.00%–3.70%), which was statistically significant compared with the FFA content of the other genotypes. Moreover, the carotene content and DOBI of SL81 was excellent 20 days AFR. Meanwhile, SL37 had the highest FFA content (average of 17.70%, ranging from 6.17% to 24.83%) and significantly different from the FFA content of the other genotypes. That is, the the SL37 genotype did not meet the requirements of either standard.

A DOBI of >3.0 indicates a good CPO product, whereas a value under 2.0 indicates poor CPO quality. DOBI is the ratio of the total carotenoid to the secondary oxidation products

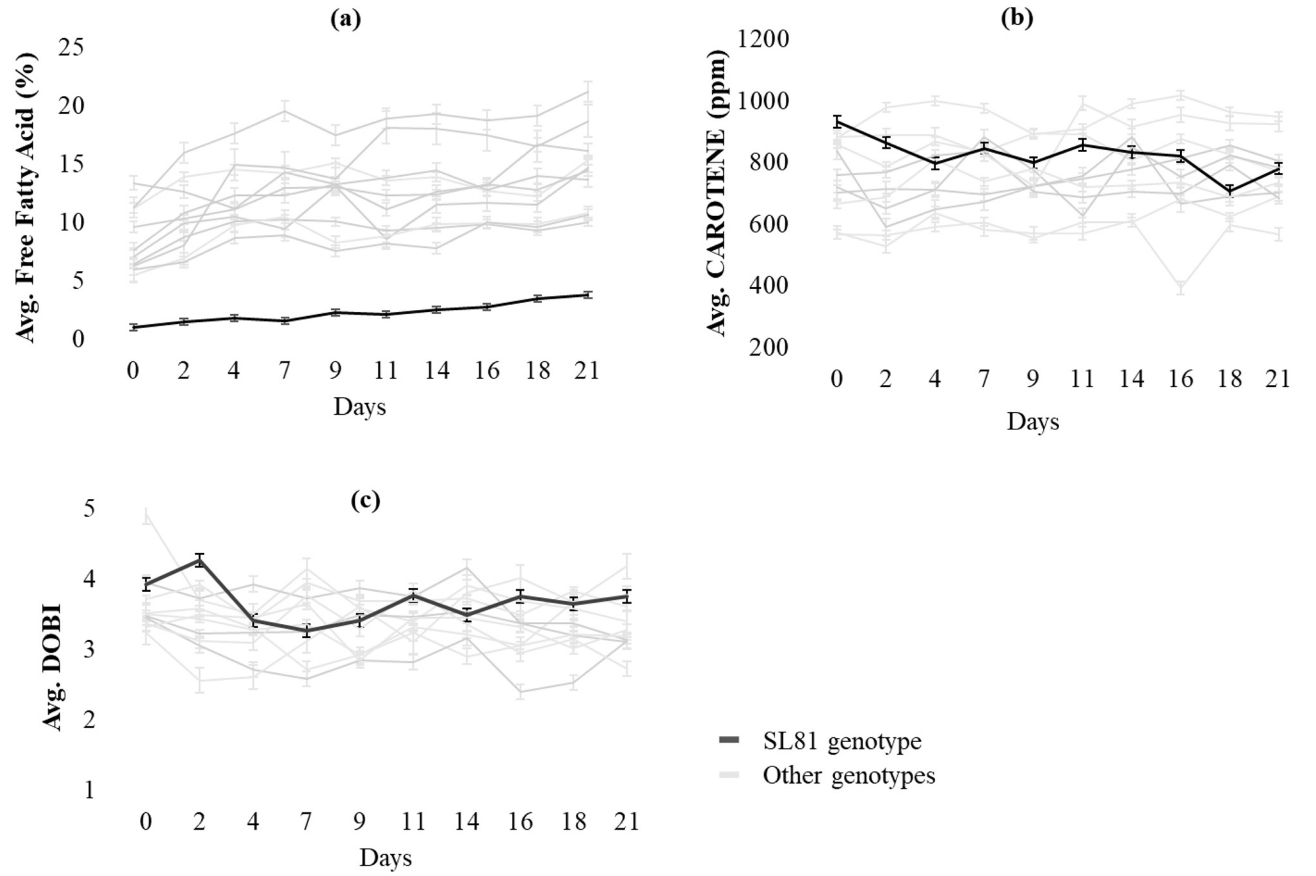


**Fig. 2.** Physicochemical development of fruit during ripening and AFR: FFA **(a)**, carotene **(b),** and DOBI **(c)**. Data are presented as mean ± SE (n = 6).

(Julianti *et al.*, 2021). If the DOBI ratio does not reach the minimum standard, it would impede the refinery process in a mill (Gibon, 2012) and increase the cost of oil production. The carotene content of SL45 and SL60 did not meet the Malaysian standard (581 ± 45.5 ppm). By contrast, the other genotypes met the requirement (Fig. 1b). Fortunately, the DOBI values of the CPOs exceeded the standard (>2.3; Fig. 1c).

Our result shows that the FFA deviation standard of the genotypes was high (Fig. 1a), indicating that some palm trees within the same genotype had high FFA content. This result indicates that the low-acidity trait was inherited after Mendelian segregation and confirmed as a monogenic trait (Morcillo *et al.*, 2013).

## 4.2 Effect of Overripening on CPO Quality

In general, the quality and stability of CPO, including FFA and carotene content and DOBI, decreases after a few days of storage (Baharin *et al.*, 2001; Basyuni *et al.*, 2017). These issues can be mitigated through sterilisation procedures for post-harvest fruit in mills on the same day. Unfortunately, these procedures may be difficult to implement in plantations with limited labour and infrastructure. This problem can be offset by using the SL81 genotype, which has an extremely low FFA content (<5%) during ripening or overripening until 21 days (Fig. 2). Naturally, the FFA content in the bunch increased up to two to three times during the overripe period, compared with the first harvesting day. However, when other genotypes showed an insufficient amount of FFA, the SL81 still showed the minimum amount and met the Indonesian and Malaysian standards.

The carotenoid concentration in SL81 consistently decreased from day 1, reaching approximately 800ppm by day 21. This concentration is considered high under Malaysian and Indonesian standards. Nevertheless, some genotypes exhibited stability from ripening (day 1) to overripening (day 21). This result differed from that obtained by Basyuni *et al.* (2017), who reported that carotenoids degraded by up to 50% during storage on day 28. The carotenoid content of the fruit that was not harvested was influenced by biosynthesis in the tree and was stable until the fruit was overripe, unlike the carotenoid content in the harvested bunches, which had no connection to plant biosynthesis and were then influenced by the environment (Morcillo *et al.*, 2013).

Similar to carotenoid content, the DOBI values for all genotypes, including the SL81, from day 1 to day 21 exceeded 2.3, whereas the carotenoid content and DOBI of this genotype were positively correlated (Supplementary Table 1B). That is, the DOBI decreased when the carotenoid content was lowered and vice versa. This result indicates that the carotenoid content was one of the key factors influencing the quality of oil and affects the stability and quality of nutrition (Baharin *et al.*, 2001). The results indicate that oil palm plantations and smallholders may extend harvest intervals from the standard 7-day rotation to 8–21 days AFR without losing the quality of CPO by using SL81.

## 5 Conclusions

Only SL81 exhibited an extremely low FFA content. The increase in FFA content during ripening and overripening is a predictable physiological process. Even though the FFA content, carotenoid levels, and DOBI in SL81 at 21 days AFR still met both Indonesian and Malaysian standards, four trees with the SL81 genotype had a high FFA content (Supplementary Table 2). This indicates that some individuals within the SL81 genotype may still carry the high-lipase trait. Nonetheless, SL81 is confirmed as an elite low-lipase line, with bunches that can be harvested flexibly up to 21 days AFR.

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### Conflicts of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

### Author contribution statement

Each author (D.A., M.B., R.I.M.D., and R.) contributed equally by conducting experiments and analyses, writing the initial draft, and finalizing the draft. R.P.A., D.A., and I.S. reviewed and completed the manuscript. All authors have read and approved the published version of the manuscript.

### Supplementary materials

**Table 1.** Correlation matrix of CPO qualities on each genotype.
**Table 2.** %FFA content on genotype SL81.

The Supplementary Material is available at https://www.ocl-journal.org/10.1051/ocl/2025011/olm.

### References

Absalome MA, Massara CC, Alexandre AA, *et al.* 2020. Biochemical properties, nutritional values, health benefits and sustainability of palm oil. *Biochimie* 178: 81–95.

Abigor DR, Opoku RA, Opute FI, Osagie AU. 1985. Partial purification and some properties of the lipase present in oil palm (*Elaeis guineensis*) mesocarp. *J Sci Food Agric* 36: 599–606.

Ali FS, Shamsudin R, Yunus R. 2015. The effect of storage time of chopped oil palm fruit bunches on the palm oil quality. *Agric Agric Sci Procedia* 2: 165–172.

Arifiyanto D, Basyuni M, Sumardi, Putri LAP, Siregar ES, Risnasari, Syahputra I. 2017. Occurrence and cluster analysis of palm oil (*Elaeis guineensis*) fruit type using two-dimensional thin-layer chromatography. *Biodiversitas* **18**: 1487–1492. https://doi.org/10.13057/biodiv/d180427

Baharin BS, Latip RA, Che Man YB, Abdul Rahman R. 2001.The effect of carotene extraction system on crude palm oil quality, carotene composition, and carotene stability during storage, J Am Oil Chem Soc 8 (8): 851–855. https://doi.org/10.1007/s11746-001-0354-4

Basyuni M, Amri N, Putri LAP, Syahputra I, Arifiyanto D. 2017. Characteristics of fresh fruit bunch yield and the physicochemical qualities of palm oil during storage in North Sumatra, Indonesia. *Indones J Chem* **17** (2): 182–190. https://doi.org/10.22146/ijc.24910

Basyuni M, Afandi D, Hayati R, Bimantara Y, Arifiyanto D, Syahputra I. 2019. Microsatellite analysis on oil palm (Elaeis guineensis) tolerance to Ganoderma boninense. In: *IOP Conf Ser Earth Environ Sci* 305: 012037.

Bourgis F, Kilaru A, Cao X, *et al.* 2011. Comparative transcriptome and metabolite analysis of oil palm and date palm mesocarp differ dramatically in carbon partitioning. *Proc Natl Acad Sci U S A* 108: 12527–12532.

Nokkaew R, Punsuvon V, Inagaki T, Tsuchikawa S. 2019. Determination of carotenoids and DOBI content in crude palm oil by spectroscopy techniques: Comparison of Raman and FT-NIR spectroscopy. *GEOMATE J* 16 (55): 92–98.

Cadena T, Prada F, Perea A, Romero HM. 2013. Lipase activity, mesocarp oil content, and iodine value in oil palm fruits of *Elaeis guineensis*, *Elaeis oleifera*, and the interspecific hybrid O × G (*E. oleifera* × *E. guineensis*). *J Sci Food Agric* 93 (3): 674–680.

Corley RHV, Tinker PB. 2016. *The oil palm*, 5th ed. Oxford: John Wiley & Sons Ltd.

Daza E, Ayala-Díaz I, Ruiz-Romero R, Romero HM. 2021. Effect of the application of plant hormones on the formation of parthenocarpic fruits and oil production in oil palm interspecific hybrids (*Elaeis oleifera* × *Elaeis guineensis* Jacq.). *Plant Prod Sci* 24 (3): 354–362.

Domonhedo H, Cuéllar T, Espeout S, *et al.* 2018. Genomic structure, QTL mapping, and molecular markers of lipase genes responsible for palm oil acidity in the oil palm (*Elaeis guineensis* Jacq.). *Tree Genet Genomes* **14**: 69. https://doi.org/10.1007/s11295-018-1284-7

de Souza RJ, Mente A, Maroleanu A, *et al.* 2015. Intake of saturated and trans unsaturated fatty acids and risk of all-cause mortality, cardiovascular disease, and type 2 diabetes: systematic review and meta-analysis of observational studies. *BMJ* 351: h3978. https://doi.org/10.1136/bmj.h3978

Escallón-Barrios M, Castillo-Gomez D, Leal J. 2022. Improving harvesting operations in an oil palm plantation. *Ann Oper Res* **314**: 411–449. https://doi.org/10.1007/s10479-020-03686-6

Fattore E, Fanelli R. 2013. Palm oil and palmitic acid: a review on cardiovascular effects and carcinogenicity. *Int J Food Sci Nutr* 64 (5): 648–659. https://doi.org/10.3109/09637486.2013.768213

Gibon V, Ayala JV, Dijckmans P, Maes J, De Greyt W. 2009. Future prospects for palm oil refining and modifications. *OCL* 16 (4-6): 193–200.

Gibon V. 2012. Palm oil and palm kernel oil refining and fractionation technology. In: *Palm oil*, AOCS Press, pp. 329–375. https://doi.org/10.1016/b978-0-9818936-9-3.50015-0

Henderson J, Osborne DJ. 1991. Lipase activity in ripening and mature fruit of the oil palm: stability *in vivo* and *in vitro*. *Phytochemistry* 30 (4): 1073–1078.

Julianti E, Ginting S, Sinaga H, Lubis Z, Sinaga PP. 2021. Palm oil stripping through cellulolytic microorganism fermentation. *IOP Conf Ser Earth Environ Sci* 733: 012104.

Morcillo F, Cros D, Billotte N, *et al.* 2013. Improving palm oil quality through identification and mapping of the lipase gene causing oil deterioration. *Nat Commun* 4: 2160. https://doi.org/10.1038/ncomms3160

Morcillo F, Gagneur C, Adam H, *et al.* 2006. Somaclonal variation in micropropagated oil palm: characterisation of two novel genes with enhanced expression in epigenetically abnormal cell lines and in response to auxin. *Tree Physiol* 26 (5): 585–594.

Malaysian Standard MS 814. 2007. *Specification for crude palm oil*. Standards Research Institute of Malaysia, Kuala Lumpur, 30 p.

Mercière M, Laybats A, Lacombe CC, *et al.* 2015. Identification and development of new polymorphic microsatellite markers using genome assembly for *Ganoderma boninense*, causal agent of oil palm basal stem rot disease. *Mycol Prog* **14**: 103. https://doi.org/10.1007/s11557-015-1123-2

Romero HM, Daza E, Ayala-Díaz I, Ruiz-Romero R. 2021. High-oleic palm oil (HOPO) production from parthenocarpic fruits in oil palm interspecific hybrids using naphthalene acetic acid. *Agronomy* 11 (2): 290.

Sambanthamurthi R, Oo KC, Parman SH. 1995. Factors affecting lipase activity in *Elaeis guineensis* mesocarp. *Plant Physiol Biochem* 33: 353–359.

Simarani K, Hassan MA, Abd-Aziz S, Wakisaka M, Shirai Y. 2009. Effect of palm oil mill sterilisation process on the physicochemical characteristics and enzymatic hydrolysis of empty fruit bunch. *Asian J Biotechnol* 1 (2): 57–66.

TAMSI-DMSI. 2010. *Facts of Indonesian Oil Palm*. *Indonesian Palm Oil Advocacy Team-Indonesian Palm Oil Board, Jakarta*, 35 p.

Tisné S, Pomiès V, Riou V, Syahputra I, Cochard B, Denis M. 2017. Identification of *Ganoderma* disease resistance loci using natural field infection of an oil palm multiparental population. *G3 Genes Genomes Genet* 7 (6): 1683–1692.

Tranbarger TJ, Dussert S, Joe T. 2011. Regulatory mechanisms underlying oil palm fruit mesocarp maturation, ripening, and functional specialization in lipid and carotenoid metabolism. *Plant Physiol* **156**: 564–584. https://doi.org/10.1104/pp.111.175141

Wening S, Croxford AE, Ford CS, *et al.* 2012. Ranking the value of germplasm: new oil palm (*Elaeis guineensis*) breeding stocks as a case study. *Ann Appl Biol* 160 (2): 145–156.

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