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Short Communication

Real-World Quality Assessment of a Medium- and Long-Chain Triglyceride Oil for Deep Fried Japanese Rice Cakes (Agemochi)

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Abstract

Background: Edible oil consisting of medium-chain triglycerides (MCTs) has potential health benefits; however, the low smoking temperature of this oil prevents its use in deep-frying. Therefore, this study aimed to evaluate the thermal stability of a synthetic medium- and long-chain triglyceride (MLCT) oil, as well as its acceptability for cooking traditional Japanese deep-fried rice cakes (Agemochi). **Methods**: The content of total polar materials (TPMs) was measured after continuously heating the MLCT and control (non-MCT) cooking oils at 160 °C or 180 °C for 8 h, or after a frying cycle of 1 h performed twice daily for 4 consecutive days. The TPM content was also measured after deep-frying Agemochi without breading or butter (twice daily for 1 h over 4 days). **Results**: The TPM of the MLCT oil remained below the rejection threshold (25%) under all conditions, whereas that of the control oil increased with temperature and heating time. The TPM content during deep-frying of Agemochi did not reach the rejection limit with either oil type. However, the TPM values after the fourth cooking day were significantly lower in the MLCT oil than in the control, with no apparent differences in sensory evaluation scores. **Conclusion**: The MLCT oil demonstrated improved thermal stability for deep-frying compared to the non-MLCT oil, as evidenced by the cooking of the Japanese rice cake, Agemochi. Additional studies are required with other foods; however, the results of this study illustrate that an MLCT oil could be a viable option for cooking oil in domestic deep-fat frying.

Keywords: deep-frying; edible oil; medium- and long-chain triglycerides; total polar materials; quality assessment; traditional food

1. Introduction

Mochi is a popular traditional Japanese rice cake made from the short-grain Japonica rice cultivar. Due to the low-calorie, low-fat, and high protein content of Japonica rice flour, mochi is eaten alone, as a major component of main meals and/or snacks, and as an ingredient in other prepared foods [1]. Agemochi is a popular fried snack food made from the leftovers of dried, cut rice cake (Kiri-mochi). It is deep-fried in edible oil without breading or butter (in Japanese, "Age" and "Kiri" mean deep-fry and cut, respectively) (Fig. 1). The crunchy and crispy tastes of Agemochi are enjoyed by Japanese children and adults alike as a common homemade snack.

Recent concerns regarding the edible oils used in home cooking have focused on the relationship between the nutritional habits and overall health of consumers. Medium-chain triglycerides (MCT) consist of mixed fatty acids containing predominantly free caprylic acid (C8) and capric acid (C10) extracted from natural products such as coconut oil and palm kernel oil. Growing evidence suggests that edible oils containing MCT have beneficial health effects, including enhancement of muscle mass, suppression of body and visceral fat, and improved cognition in older adults [2–6]. However, MCT oils are unsuitable for deep-frying because of adverse physicochemical characteristics during cooking at high temperatures (160–180 °C), including a lower smoking point (approximately 140 °C) and their tendency to foam [7].

In the setting of home-cooking, it is important to assess the quality of frying oils due to their absorption into fried food and hence our diet, particularly at high temperatures. An edible oil containing MCT (medium- and long-chain triglycerides, MLCT) has been manufactured through the process of lipase-catalyzed enzymatic transesterification. MCLT has an improved smoking point (approximately 200 °C) and foaming properties that are comparable to standard cooking oils consisting of long-chain triglycerides (LCT) [7,8]. This product was released in March 2023 and is now available in stores.

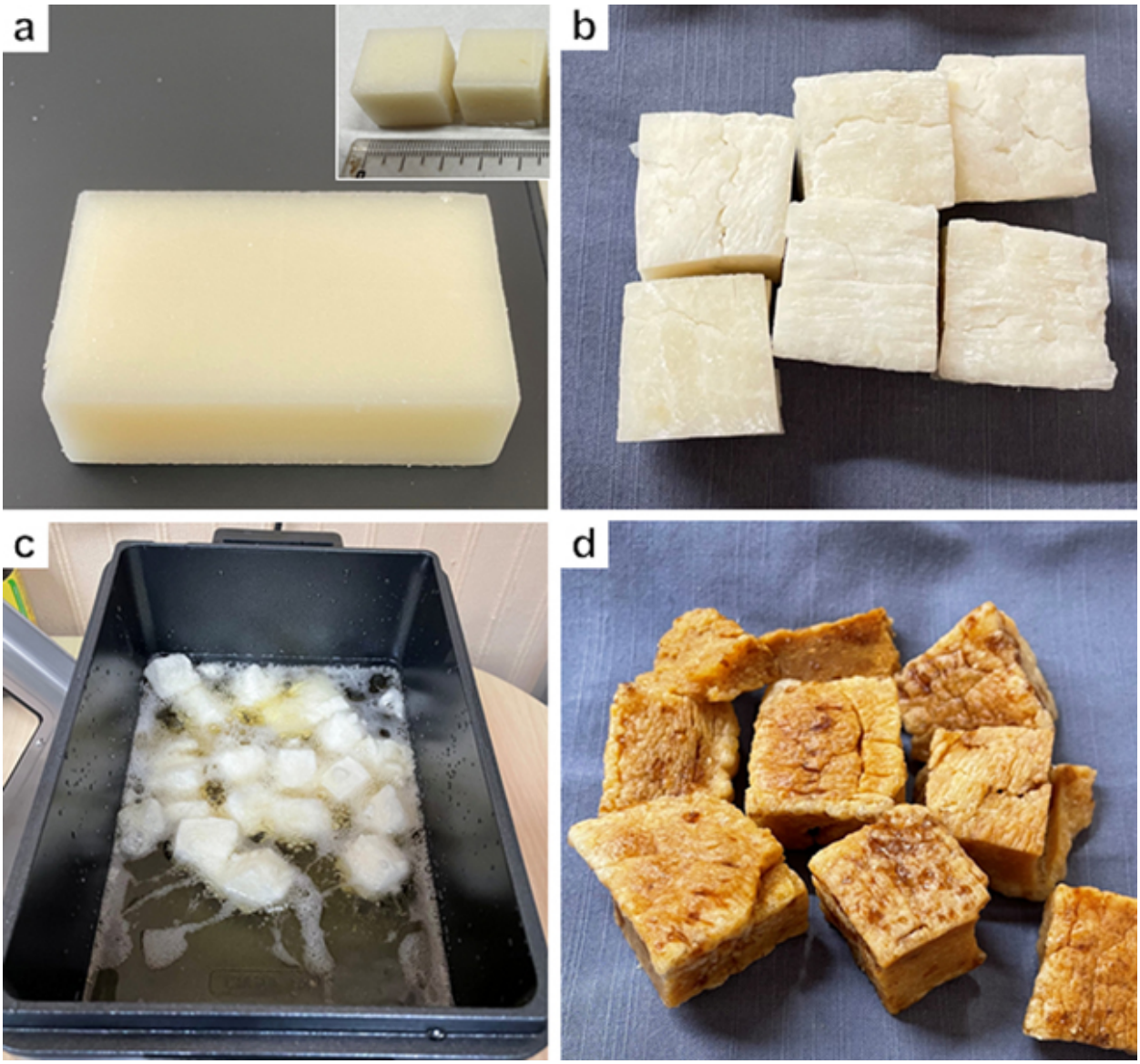

Fig. 1. Photographs of Kirimochi cut into approximately 1.5 cm cubes (*Inset*) (a), sun-dried Kirimochi pieces (b), Agemochi during deep frying (c), and the final product (d).

Considering its thermal tolerance and MCT-based health and medical benefits, MLCT oil appears to be an ideal choice for home cooking, including deep-frying. However, only a few studies have focused on the value and safety of MLCT oil and its product in real-world settings. The purpose of this study was to assess the quality of MLCT oil during domestic use for deep-frying of the most popular Japanese traditional snack food, Agemochi, compared to standard cooking oil. Non-volatile substances, collectively known as total polar material (TPM), were analyzed because they affect the quality of fried food, reduce the oil quality, and are also damaging to human health if consumed over a long period. Since the percentage of TPM in edible oil is almost identical to that present in oil absorbed by food [9], we evaluated TPM in frying oil as a measure of the TPM content in fried food.

2. Materials and Methods

2.1 Sample Preparation, Oils and Equipment

Commercially available Kirimochi (Sato Foods Co., Ltd., Niigata, Japan) was cut into 1.5 cm cubes (Fig. 1a) and dried in the sun for 1–2 weeks to become hard and dehydrated for long-term storage (Fig. 1b). A 50 g slice contains approximately 118 calories, 2.0 g of protein, 0.3 g of fat, and 26.8 g of carbohydrates.

MLCT (MCT Risetta) and control cooking (salad oil) oils were purchased from Nissin Oillio Group Co., Ltd. (Kanagawa, Japan). The fatty acid composition of each oil has been described elsewhere [10]. MLCT is comprised of inter-esterified triglycerides containing 1.6 g of medium-chain fatty acids (MCFAs) in 14 g (1 tbsp). In contrast, the control oil is made from soybean and rapeseed and does

not contain MCFAs (**Supplementary Table 1**). A polar fraction tester (Testo 270 BT, Testo SE & Co., KGaA, Germany) was used to evaluate TPM and temperature readings in hot oil (40 °C to 200 °C) in as little as 20 seconds after the oil has reached a stable temperature. Before the start of each experiment, calibration and adjustment of the oil tester were performed using reference oil (Testo 0554 2650 reference oil for Testo 270, Testo SE & Co., KGaA, Celsiusstr, Titisee-Neustadt, Germany).

2.2 Protocols

The thermal stability of oil samples at different temperatures was tested during continuous and intermittent heating or frying cycles. We initially tested the thermal stability of each fresh oil (without food heating) at two different temperatures commonly used for deep-frying (160 °C and 180 °C), as well as continuously for 8 h, and after a 1-h heating cycle performed twice daily for 4 consecutive days. A laboratory ceramic hot plate (PC-420D, Corning Inc., Corning, NY, USA) was used for this heating. Next, deep-frying of Agemochi was conducted for 1 h twice per day for 4 consecutive days and without supplementation with fresh oil. This was performed using a temperature-controlled YAG-L100 electric deep fryer (Yamazen Co., Ltd., Tokyo, Japan) filled with 500 mL of each cooking oil (Fig. 1c). After the temperature was raised to approximately 160 °C for the first 20 min, 150 g of Kirimochi were deep-fried without breading or butter until lightly browned. The temperature was adjusted to 160 or 180 °C as needed (Fig. 1d), and the TPM was determined in triplicate after frying.

Home-cooking procedures were performed by four types of people (young and adult, male and female) to avoid inter-examiner variability in cooking procedures. Differences in net weight were calculated before and after each deep-frying cycle to estimate the percentage of oil absorption by the finished product. For sensory evaluation, an untrained panel consisting of 10 students evaluated the characteristics of Agemochi samples made at different times. The different samples were all tasted at the same time, and within 24 h after each frying cycle. A 7-point hedonic grading scale was used, ranging from 1 = dislike very much, to 7 = like very much. Each panelist assessed sample attributes (color, odor, texture, and aftertaste) by filling out the score sheet (1 to 7 hedonic scale) based on their preferences [11,12].

2.3 Statistical Analysis

Data are presented as the mean ± standard deviation. Two-way repeated-measures analysis of variance (ANOVA) was used to assess differences in TPM values at different time points. The two time points were treated as within-subject factors (effect over time), and differences between the MLCT and LCT groups were treated as between-subject factors. When the repeated-measures ANOVA indicated a significant group × time interaction, tests of simple main effects were performed to determine which group(s) differed significantly across the intervention period using *post-hoc* analyses adjusted for Bonferroni correction, where appropriate. Statistical significance was set at $p < 0.05$. All analyses were performed using Bell Curve for Excel (SSRI, Tokyo, Japan) and Prism 9 (GraphPad Software, La Jolla, CA, USA).

3. Results

Changes in TPM values after heating MLCT and control oils are shown in **Supplementary Table 2**. In all samples, MLCT showed higher initial TPM values than the control oil ($p < 0.001$).

Continuous and intermittent heating of the control oil increased the TPM (Fig. 2a) value in relation to the exposure time ($p < 0.001$, within-subject time effect). This value almost reached the limit for rejection (25%) after intermittent heating at 180 °C and 8 h of total frying time (Fig. 2b). In contrast, MLCT tended to maintain the baseline value of TPM ($p = 0.062$, within-subject factor), with none of the conditions exceeding the TPM limit for rejection, irrespective of the heating method.

Changes in the TPM values of each oil after deep-frying Agemochi are shown in **Supplementary Table 3**. Although the limit of rejection was not reached with either oil type, the TPM values for MLCT were significantly lower than those of control oil after the fourth day of cooking ($p < 0.001$) (Fig. 3a). The mean absorption rate was 5.24 ± 0.70% for MLCT oil, and 5.22 ± 0.45% for test oil ($p = 0.96$). Regarding sensory evaluation of the final product, the score for aftertaste tended to decline in both groups after the sixth frying cycle (**Supplementary Table 4**). However, all samples showed high scores overall, as well as for the other attributes. No significant differences were observed between MLCT and control oils (Fig. 3b and **Supplementary Fig. 1**).

4. Discussion

The main finding of this study was that MLCT oil displayed better frying stability for home cooking of deep-fried Agemochi than non-MCT vegetable oil during repeated frying operations (up to two daily 1 h sessions for 8 cycles). To the best of our knowledge, this is the first study to evaluate the performance of MLCT in healthy Japanese traditional food.

The measurement of polar components is recognized as one of the most reliable assessments of thermo-oxidative degradation of frying oils, since most non-volatile by-products accumulate during the major reactions that occur during frying. The formation of polar compounds has been shown to increase with the degree of oil unsaturation, both during heating and repeated frying of oils [13]. While column chromatography is the standard method for analysis of TPM, the Testo 270 device offers a practical alternative for

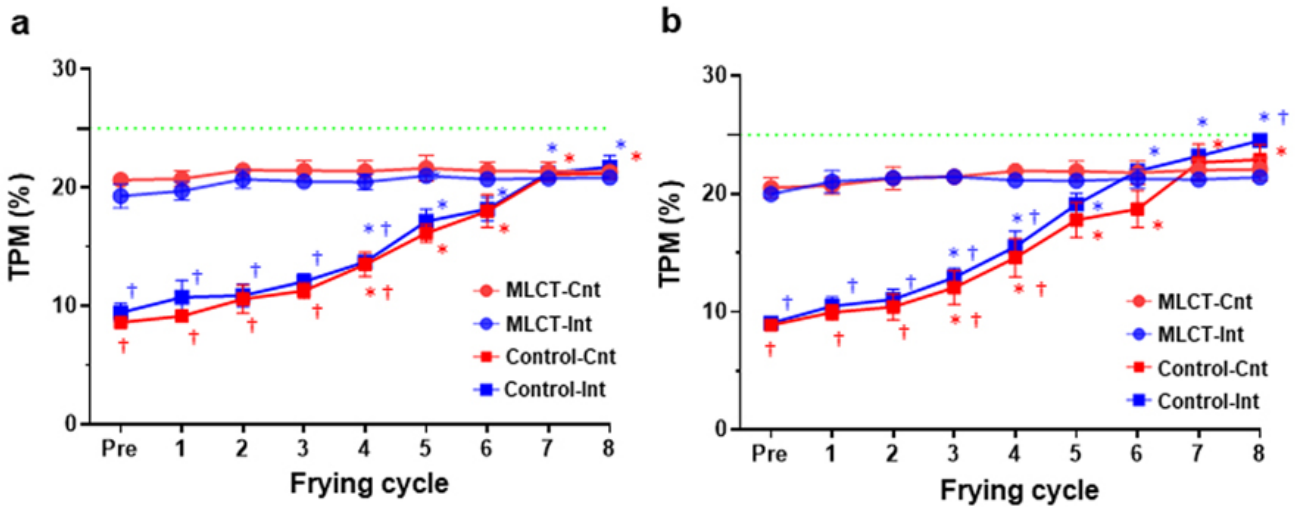

Fig. 2. Changes in total polar material (TPM) values during continuous (Cnt) or intermittent (Int) frying with medium- and long-chain triglyceride (MLCT) or control oils heated at 160 °C (a) or 180 °C (b). The dotted line indicates the regulatory limit (25%) for discard. $^{*}p < 0.05$ *vs.* initial values (Pre); $^{\dagger}p < 0.05$ *vs.* MLCT.

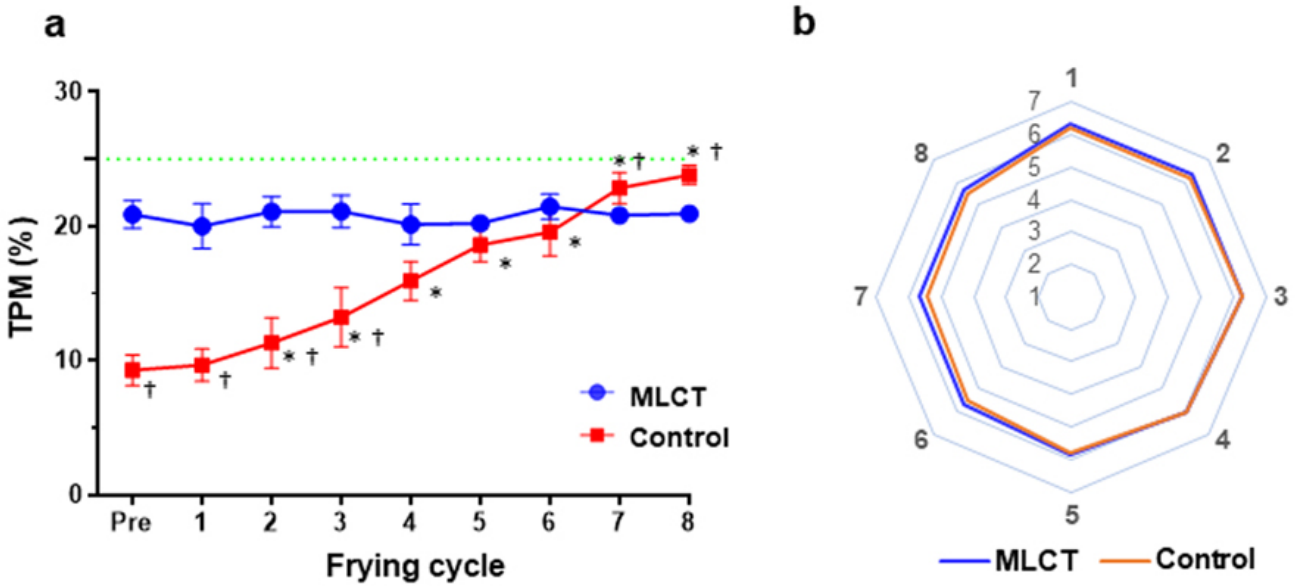

Fig. 3. Changes in TPM values for each frying cycle (a), and overall sensory scores for Agemochi (b) at different time points using MLCT and control oils. The dotted line indicates the rejection limit (25%). $^{*}p < 0.05$ *vs.* initial values (Pre); $^{\dagger}p < 0.05$ *vs.* MLCT.

rapid, on-site monitoring of oil quality by sensing the dielectric constant of the oil solution. The results from this method correlate well with the more time-consuming chromatography technique [14,15]. In the present study, higher initial values of TPM were detected in MLCT oil throughout the assessment period, possibly due to the higher diglyceride content and polar structure of medium-chain fatty acids (MCFAs) [16,17]. Coconut oil consists of >65% MCFAs and is more polar than oils containing long-chain fatty acids, which account for >35% of TPM [18], thus supporting the current observations.

In general, the TPM levels in deep-fried oils and oils extracted from fried food are similar, regardless of the type of oil. Depending on the type of frying medium and food, the uptake of absorbed oil in deep-fried food ranges from 4 to 14% of the total weight [19]. In addition, the frying process involves dehydration and moisture loss from the food products, which could also play a role in promoting oil absorption [20]. However, to provide crispness, dried rice cake for Agemochi already has less water content than other types of rice cake. The effect of moisture loss on the total product weight used to estimate oil absorption may therefore be minimal. Given the oil content of Agemochi in the present study was found to be approximately 5%, the estimated quantity of ingested MLCT oil (15 g per day) is close to the amount of dietary supplementation reported to en-

hance the suppression of body fat accumulation in healthy participants [21]. Such health benefits of MLCT oil may be attributable to the different kinetics of low-level MCFA components in the degradation of ingested fatty acids by activating β-oxidation in liver mitochondria of overweight individuals with a body mass index between 25 and 30 [10].

Our results suggest that MLCT and vegetable salad oils have acceptable thermal and sensory stabilities for repeated deep-frying of Agemochi, as demonstrated by a sustained level of polar compounds below the regulatory limit for rejection of 25% required in most countries [22]. Notably, MLCT oil showed smaller increases in the TPM percentage, irrespective of the cooking cycle (intermittent or continuous), whereas intermittent heating of the control oil resulted in the TPM rising close to the discard level. This could be advantageous for MLCT oil in the deep-frying of Japanese Agemochi, since intermittent frying may cause a greater degradation of quality than continuous frying [13]. Although MLCT and control oils showed similar results for the final product, only a limited number of reports have been published on the sensory properties of deep-fried Agemochi. Further studies on this topic should provide more accurate and reliable information on the thermal degradation of MLCT oil. In addition to measuring TPM in the oil used as the frying medium and analyzing the polar component composition of the breakdown products (e.g., oxidized triacylglycerols, diacylglycerols, and free fatty acids) [23,24], it would also be useful to extract the oil adsorbed by the cake to evaluate any hydrolysis and oxidation products. Indeed, the sensory properties of frying oils, such as flavor and aroma, are significantly influenced by the types and amounts of these polar compounds [25].

5. Conclusion

The present data confirm the superior thermal stability of MLCT oil compared to control oil for domestic deep-fried cooking, as represented by the Japanese low-calorie, low-fat rice cake, Agemochi. We anticipate that similar studies on other foods will confirm MLCT as a more attractive choice of cooking oil for domestic deep-fat cooking.

Availability of Data and Materials

The datasets generated and analyzed during the present study are available on reasonable request. The data are not publicly available due to privacy and ethical restrictions.

Author Contributions

YM designed and performed the research study. KS and RT provided help and advice throughout the study. YM analyzed the data. YTat and TM performed data curation. YM prepared and wrote original draft of the manuscript. YTak and HT supervised the research and contributed to critical revision of the manuscript. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

This study was approved by the Ethics Committee for Agricultural Food-Related Research of the Sendai Animal Care and Research Center (approval number: SACRC25-01). All participants or their families/legal guardians were informed about the study's purpose and their right to participate voluntarily, from all study participants verbal informed consent was obtained with ethical approval.

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Conflict of Interest

The authors declare no conflict of interest.

Supplementary Material

Supplementary material associated with this article can be found, in the online version, at https://doi.org/10.31083/JFSFQ44132.

References

[1] Honda Y, Saito Y, Katsumi N, Nishikawa M, Takagi H. Physicochemical properties of starch in rice flour with different hardening rates of glutinous rice cake (mochi). Journal of Cereal Science. 2023; 112: 103687. https://doi.org/10.1016/j.jcs.2023.103687.

[2] Takeishi J, Tatewaki Y, Nakase T, Takano Y, Tomita N, Yamamoto S, *et al*. Alzheimer's Disease and Type 2 Diabetes Mellitus: The Use of MCT Oil and a Ketogenic Diet. International Journal of Molecular Sciences. 2021; 22: 12310. https://doi.org/10.3390/ijms222212310.

[3] Ezaki O, Abe S. Medium-chain triglycerides (8:0 and 10:0) increase muscle mass and function in frail older adults: a combined data analysis of clinical trials. Frontiers in Nutrition. 2023; 10: 1284497. https://doi.org/10.3389/fnut.2023.1284497.

[4] Ishikawa H, Kojima K, Watanabe S, Nosaka N, Mutoh T. Effect of medium-chain triglycerides supplements and walking on health-related quality of life in sedentary, healthy middle-aged, and older adults with low BMIs: a randomized, double-blind, placebo-controlled, parallel-group trial. Frontiers in Nutrition. 2023; 10: 1296896. https://doi.org/10.3389/fnut.2023.1296896.

[5] Kojima K, Ishikawa H, Watanabe S, Nosaka N, Mutoh T. A Randomized, Double-Blind, Controlled Trial Assessing If Medium-Chain Triglycerides in Combination with Moderate-Intensity Exercise Increase Muscle Strength in Healthy Middle-Aged and Older Adults. Nutrients. 2023; 15: 3275. https://doi.org/10.3390/nu15143275.

[6] Mutoh T, Kunitoki K, Tatewaki Y, Yamamoto S, Thyreau

B, Matsudaira I, *et al*. Impact of medium-chain triglycerides on gait performance and brain metabolic network in healthy older adults: a double-blind, randomized controlled study. GeroScience. 2022; 44: 1325–1338. https://doi.org/10.1007/s11357-022-00553-z.

[7] Takeuchi H, Sekine S, Kojima K, Aoyama T. The application of medium-chain fatty acids: edible oil with a suppressing effect on body fat accumulation. Asia Pacific Journal of Clinical Nutrition. 2008; 17: 320–323.

[8] Negishi S, Shirasawa S, Arai Y, Suzuki J, Mukataka S. Activation of Powdered Lipase by Cluster Water and the Use of Lipase Powders for Commercial Esterification of Food Oils. Enzyme and Microbial Technology. 2003; 32: 66–70. https://doi.org/10.1016/S0141-0229(02)00269-7.

[9] Nayak PK, Dash U, Rayaguru K, Krishnan KR. Physio-Chemical Changes During Repeated Frying of Cooked Oil: A Review. Journal of Food Biochemistry. 2015; 40: 371–390. https://doi.org/10.1111/jfbc.12215.

[10] Nosaka N, Tsujino S, Sadamitsu S, Ando N, Kato K. Ingestion of triglycerides containing medium- and long-chain fatty acids can increase metabolism of ingested long-chain triglycerides in overweight persons. Frontiers in Nutrition. 2023; 10: 1260506. https://doi.org/10.3389/fnut.2023.1260506.

[11] Abdullah Zawawi NF, Ramli NA, Yusoff NNE, Tang JYH, Abd Ghani A. Effects of Salting Pretreatment on Quality and Safety of Shrimp (Parapenaeopsis Spp.) Powder. Journal of Applied Food Technology. 2023; 10: 63–69. https://doi.org/10.17728/jaft.20814.

[12] Warner K. Analyses of Fats, Oils, and Lipoproteins (pp. 344–386). In Perkins EG (ed.) AOCS Press: Champaign, IL. 1991.

[13] Das AK, Babylatha R, Pavithra AS, Khatoon S. Thermal degradation of groundnut oil during continuous and intermittent frying. Journal of Food Science and Technology. 2013; 50: 1186–1192. https://doi.org/10.1007/s13197-011-0452-7.

[14] Zhu S, Song L. Application of TESTO Rapid Testing Method on the Quality Monitoring of Repeated Usage of Frying Oil. Journal of the Chinese Cereals and Oils Association. 2017; 32: 163–170.

[15] Song J, Kim MJ, Kim YJ, Lee J. Monitoring changes in acid value, total polar material, and antioxidant capacity of oils used for frying chicken. Food Chemistry. 2017; 220: 306–312. https://doi.org/10.1016/j.foodchem.2016.09.174.

[16] Dayrit FM, Buenafe OEM, Chainani ET, de Vera IMS. Analysis of monoglycerides, diglycerides, sterols, and free fatty acids in coconut (Cocos nucifera L.) oil by 31P NMR spectroscopy. Journal of Agricultural and Food Chemistry. 2008; 56: 5765–5769. https://doi.org/10.1021/jf8005432.

[17] Marina AM, Man YC, Amin I. Virgin coconut oil: emerging functional food oil. Trends in Food Science & Technology. 2009; 20: 481–487. https://doi.org/10.1016/j.tifs.2009.06.003.

[18] Koh SP, Long K. Oxidative stability study of virgin coconut oil during deep frying. Journal of Tropical Agriculture and Food Science. 2012; 40: 35–44.

[19] Andrikopoulos NK, Boskou G, Dedoussis GVZ, Chiou A, Tzamtzis VA, Papathanasiou A. Quality assessment of frying oils and fats from 63 restaurants in Athens, Greece. Food Service Technology. 2003; 3: 49–59. https://doi.org/10.1046/j.1471-5740.2003.00064.x.

[20] Kishimoto N, Takano N. Enhanced moisture loss and oil absorption of deep-fried food by blending extra virgin olive oil in rapeseed oil. Food Science and Technology Research. 2021; 27: 63–68. https://doi.org/10.3136/fstr.27.63.

[21] Takeuchi H, Kasai M, Taguchi N, Tsuji H, Suzuki M. Effect of triacylglycerols containing medium- and long-chain fatty acids on serum triacylglycerol levels and body fat in college athletes. Journal of Nutritional Science and Vitaminology. 2002; 48: 109–114. https://doi.org/10.3177/jnsv.48.109.

[22] Stier RF. Ensuring the health and safety of fried foods. European Journal of Lipid Science and Technology. 2013; 115: 956–964. https://doi.org/10.1002/ejlt.201300180.

[23] Li X, Li J, Wang Y, Cao P, Liu Y. Effects of frying oils' fatty acids profile on the formation of polar lipids components and their retention in French fries over deep-frying process. Food Chemistry. 2017; 237: 98–105. https://doi.org/10.1016/j.foodchem.2017.05.100.

[24] Aladedunye F, Przybylski R. Performance of palm olein and modified rapeseed, sunflower, and soybean oils in intermittent deep-frying. European Journal of Lipid Science and Technology. 2014; 116: 144–152. https://doi.org/10.1002/ejlt.201300284.

[25] Dangal A, Tahergorabi R, Acharya DR, Timsina P, Rai K, Dahal S, *et al*. Review on deep-fat fried foods: physical and chemical attributes, and consequences of high consumption. European Food Research and Technology. 2024; 250: 1537–1550. https://doi.org/10.1007/s00217-024-04482-3.