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Research Article

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Assessment of potentials of *Moringa oleifera* seed oil in enhancing the frying quality of soybean oil

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Abstract: This study investigated the effects of mixing *Moringa oleifera* seed oil with soybean (*Glycine max*) seed oil in enhancing the physical and chemical properties of soybean oil during repetitive frying. Different blends (100:0, 50:50, and 70:30) of soybean and *M. oleifera* seed oils were formulated, while soybean oil served as control. All these oil samples were used for frying potato (*Ipomoea batatas*) slices. The quality of the fried oil samples was evaluated by determining the smoke point, refractive index (RI), viscosity, colour, peroxide value, iodine value, and free fatty acid (FFA). The range of values obtained were smoke point (158.7–172.3°C), RI (1.46–1.49°C), colour (6.0–9.42), viscosity (0.41–2.13 mm^2/s), peroxide value (0.93–5.16 meq/kg), iodine value (87.16–64.71 mg/100 g), and FFA (0.3–1.95%), for different blends of soybean and *M. oleifera* seed oils and control. In terms of changes in the chemical and physical properties, during frying, soybean/*M. oleifera* seed oil mix of 70:30 had the lowest reduction in iodine value (87.56–68.73 mg/100 g), lowest increase in peroxide value (0.93–1.86 meq/kg) and FFA value (0.3–0.65%), while no changes in RI (1.47°C) was observed. The study revealed that mixing of soybean seed oil with *M. oleifera* seed oil at a ratio of 70:30 enhanced the physical and chemical properties of the soybean oil after two repetitive frying.

Keywords: frying, *Moringa oleifera*, soybean, potato, blending, oxidation

1 Introduction

Frying is an essential unit operation, which has been widely used in food industry [1]. It is among the oldest method and still very relevant in the processing of foods [2]. Traditionally, frying includes dipping of foods in frying oil compartments, largely at temperatures beyond the water boiling point bringing about a counter-flow of water bubbles and oil on the surface of the product. Different kinds of cooking oils are employed in frying, such as plant oils from coconut, palm kernel, groundnut, sunflower, corn oil, soybean, cottonseed, peanut, olive oils to tallow and lard which are fats from animal. It is broadly used in household cooking and commercial catering. Fried foods are highly preferred due to their palatability, flavour, and colour [3].

During frying, diverse chemical reactions occur at raised temperatures such as oxidation, hydrolysis, polymerisation, and fission [4]. Due to these reactions, components such as free fatty acid (FFA) level, peroxide value, total polar compounds, iodine value, and saponification value increase and they are harmful to human health. At the preliminary stage of frying, fats and oils are constantly exposed to air at high temperature and moisture, which accelerates oxidation of the oil [5]. Degradation of oil occurs at high frying temperature which forms unstable and stable products [6].

The composition of fatty acid in oil is one of the foremost element influencing the stability and flavour of fried foods. A good pointer of frying oil quality is unified with

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low level of polyunsaturated fatty acid and significant level of oleic acid [7]. The quality of fried food products also depends on the nutritive value of the oil used in frying. The changes in chemical properties of frying oil eventually bring about changes in the value of fried food; use of frying oil repeatedly generates unwanted components such as conjugated diene, triene, FFAs, peroxides, cyclic compounds, ketones, aldehydes, and alcohols which may result in production of carcinogenic or toxic compound [8,9] and consequent health risk. This can reduce the sensory, functional, and nutritive value of oils [10].

Partial hydrogenation and synthetic antioxidants have been used to improve the stability of edible oils. But there are reports that partial hydrogenation leads to production of trans-fats which have been associated with risks of heart disease in humans, while the use of synthetic antioxidants has also been reported to have negative effects. There is a growing trend that the use of synthetic antioxidants should be minimised or avoided in enhancing oil stability. This has led to high research interest in the use of natural materials or unrefined extracts with higher level of antioxidant from spices and herbs.

Soybean oil is one of the well-accepted vegetable oils and its usage has been shown to reduce risk of breast and prostate cancer [11]. However, it has less oxidative stability than *Moringa oleifera* oil when stored at room temperature as well as when used for frying and cooking at high temperature [11]. *M. oleifera* is native to Himalaya and widely grown in many Asian and African countries with seed oil content ranging from 35–40% [12]. It is widely cultivated for a range of purposes including human consumption, as livestock feed, and for use in cosmetics, despite being listed as a weed in many countries [13]. *M. oleifera* plants flower at least four times a year starting from January and produces long, triangular, slender pods about 30–50 cm long, first harvest can take place 6–8 months after planting. A good tree can yield 1,000 or more pods, the seeds are embedded in the pods, the yield per hectare can become as high as 8–10 tonnes (8,000–10,000 kg) per hectare, while 250 L/ha of oil yield can be obtained from the seeds [14,15]. *M. oleifera* oil is high in antioxidative properties and has been reported in improvement of oil stability [11]. The composition of fatty acid in *M. oleifera* oil is comparable to olive oil, it has (75–77%) oleic acid [12].

Studies have indicated that blending of oils with higher and progressively unsaturated oils gives an increasingly steady and clear blend which stays stable when stored [16]. Numerous researchers have reported that mixing of plant oils can transform the fatty acid content and surge up the natural antioxidants of oil. For example, addition of ethanol concentrate of rosemary to palm oil, the mix of soybean and sunflower oil in equal amounts, and also mixed palm olein and sesame oil during frying process could protect from oxidation [17,18].

Soybean oil is a polyunsaturated oil, highly susceptible to oxidation when used in frying, and *M. oleifera* seed oil is high in antioxidative properties and has been reported in improvement of oil quality [11]. The composition of fatty acid in *M. oleifera* oil is comparable to olive oil with about 75–77% oleic acid [12]. *M. oleifera* seed oil contains high amount of monounsaturated fatty acid and natural antioxidants which have potentials to enhance stability when mixed with soybean seed oil. The aim of the present study is to investigate the effect of mixing soybean seed oil with *M. oleifera* seed oil on the physical and chemical properties of frying oil quality in repetitive frying.

2 Materials and methods

2.1 Materials

Soybean (*Glycine max*) grains (TGX 1448-2E) and matured sweet potato (*Ipomoea batatas*) tubers (white variety) were purchased from local markets and were identified at Landmark University Teaching and Research farm. The packaged soybean oil was purchased from a reputable shopping mall and labelled as commercial soybean oil (CSO). The *M. oleifera* (MOMAX3) seeds were harvested, identified, and transported to the laboratory for further processing.

2.2 Methods

2.2.1 Extraction of soybean and *Moringa oleifera* seeds oil

The method suggested by Iranloye et al. [11] was used to extract vegetable oils from soybean seeds and *M. oleifera* seeds. Two thousand grams of soybean seeds and 800 g of *M. oleifera* seeds were sorted separately, dried, and milled into powder and packaged in different zip lock bags. The milled seeds were weighed to obtain the formulations 100:0, 50:50, and 70:30 of soybean and *M. oleifera* and labelled as extracted soybean oil (ESO), soybean/*M. oleifera* seed oil mix (SMO) 50:50, and SMO 70:30, respectively. These were packaged in extraction bags and subjected to extraction using Soxhlet extraction method. *n*-Hexane was used as solvent and the extraction was carried out for 8 h at a temperature of 60°C. The oil was recovered by evaporating off the solvent using rotary evaporator.

2.2.2 Frying of potato chips

A batch (100 g) of thinly diced (3 mm) sweet potato chips were fried in 250 mL of vegetable oil blends for 3 min at 180 ± 5°C. The frying was carried out in replicates. After each frying period, the oil was cooled to 60 ± 5°C and filtered to remove debris. Some samples were collected for analysis and allowed to cool to room temperature. Another batch of potato chips was fried using the same oil. The oil samples from the first and second frying were collected, labelled, and analysed for chemical and physical parameters using the method described by Aniołowska and Kita [19].

2.2.3 Chemical test of the oil samples

2.2.3.1 Peroxide value

The peroxide value of all the oil samples was determined by using standard procedures as reported by Vaidya and Eun [20]. Five millilitres of all the vegetable oil samples were weighed and placed into a conical flask of 250 mL. An empty flask with no oil was also prepared. Thirty millilitres mixture of solvent acetic acid chloroform was added in to the flask and left for a minute, while swirling the flask occasionally and then 30 mL of distilled water was added. The mixture was then titrated with 0.1 N of sodium thiosulphate until brown colour was obtained and 0.5 mL of 1% starch solution was added and titration continued until the blue/grey colour disappeared. The mixture was vigorously shaken during titration to ensure all the iodine was liberated from the chloroform layer. The peroxide values were reported as milliequivalents of oxygen/kg of oil.

2.2.3.2 FFA determination

FFA composition of the oil sample was evaluated by using the method illustrated by Shimamoto et al. [21]. Oil (28 mL) was weighed and added into two 50 mL conical flask. Then, the sample was dissolved with 50 mL of 99% isopropanol and mixed completely. Finally, the sample was titrated against sodium hydroxide utilising phenolphthalein maker. The FFA values were conveyed as part of oleic basis.

2.2.3.3 Iodine value of the oil sample

The technique reported by Aladedunye and Przybylski [22] was used to determine the iodine value of the oil samples. Ten millilitres of oil were liquefied in iodine and halogen solvent. Sodium thiosulfate standard was used in titrating the liberated iodine, utilising a starch indicator; the iodine value was calculated using the formula:

$$\text{Iodine value} = (B–S) \times N \times 126.9/W \times 100,$$

where B = volume of titrant (mL) for blank, S = volume of titrant (mL) for sample, N = normality of sodium thiosulfate (mol/100 mL), 126.9 = molecular weight of iodine (g/mol), and W = sample mass (g).

2.2.4 Evaluation of the physical parameters of the oil samples

Viscosity of all the samples were determined using NDJ-1B Rotary Viscometer (Yuchengtechus, China); the viscometer was switched on, the spindle (60 rpm) was inserted in 100 mL of oil sample, confirmation key was pressed to check if the settings were confirmed, after which the run key was pressed. The readings were taken in mm^2/s using the method suggested by Firestone [23].

The smoke point of the oil was determined as by Shah et al. [24]. Two hundred millilitres of oil were filled in a cup and was heated in a well-lighted container; the smoke point was recorded when it gave off a thin, continuous stream of bluish smoke.

The method reported by Ariponnammal [25] was used to determine the refractive index (RI). A dual prism was opened by means of screw head and little drops of oil were retained on the prism. The screw head was tightened in order to close the prism firmly. To equilibrate the sample temperature with that of the instrument (20 ± 2°C), the instrument was left to stand for a few minutes. Cleaning of the refractometer was done between readings by wiping off the oil with a soft cloth, then with cotton moistened with petroleum ether, and then left to dry.

The colour of the oil was determined by a 10-point comparative colour scale, using the method suggested by Adeyemo and Popoola [26]. The oil sample was set in the cuvette and the plate comparing to its major colour was slid into the opening on the wooden box. The plate was pivoted in its space and the box was viewed against white light. The disc was pivoted gradually until a shade that matches was reached. The number of the colour was recorded.

2.2.5 Statistical analysis

Duncan Multiple Range Test was set at 5% level of significance to test for any significant difference. The mean values of the results obtained from all the analyses conducted were calculated and separated by using MS Excel 2016.

3 Results and discussion

3.1 Chemical properties

The degree of peroxidation is shown in Table 1. The values of peroxide of unused oil were CSO (1.67 meq/kg), ESO (2.03 meq/kg), SMO 50:50 (0.93 meq/kg), and SMO 70:30 (1.5 meq/kg). The peroxide values of all the unused oil are considered to be good if they were below 2 meq as reported by Sulieman et al. [27]. There was significant difference ($p \leq 0.05$) in the peroxide value of CSO, SMO 50:50, and SMO 70:30. The CSO indicated the highest increase in peroxide value after the first stage of frying (3.73 meq/kg), while there was a decrease in peroxide value of SMO 50:50 (0.82 meq/kg) after the first frying, the peroxide value was lower than when it was at fresh condition (0.93 meq/kg). This is a good indicator of quality as oil turns out to be progressively steady when it carries lower levels of linoleic, linolenic acid, and more significant levels of oleic acid as revealed by Aladedunye and Przybylski [22]. The mixing of *M. oleifera* seed oil with soybean seed oil has reduced the level of polyunsaturated fatty acid (linolenic and linoleic acid) within the oil. Peroxide values after the second frying were CSO (3.73 meq/kg), ESO (5.61 meq/kg), SMO 50:50 (1.61 meq/kg), and SMO 70:30 (1.86 meq/kg). All the vegetable oil samples showed an increase in their peroxide value after the second frying and the highest value was recorded in ESO (5.61 meq/kg). There was significant difference ($p \leq 0.05$) in all the vegetable oils after the second frying.

The iodine values of the oil samples are shown in Table 2. The iodine values of fresh oil were CSO (85.16 mg/100 g), ESO (82.16 mg/100 g), SMO 50:50 (87.56 mg/100 g), and SMO 70:30 (80.43 mg/100 g). There was significant difference ($p \leq 0.05$) among all the oil samples. The iodine values after the first frying were CSO (71.88 mg/100 g), ESO (72.99 mg/100 g), SMO 50:50 (77.53 mg/100 g), and SMO 70:30 (72.64 mg/100 g). SMO 50:50 and SMO 70:30 showed the lowest decrease in iodine value. The decline in iodine value with time of frying could be attributed to the modifications in fatty acids occurring with time of frying [28]. The iodine values after the second frying were CSO (59.45 mg/100 g), ESO (64.71 mg/100 g), SMO 50:50 (70.04 mg/100 g), and SMO 70:30 (68.73 mg/100 g). It was also observed that there was a decline in iodine values of all the oils after the second frying. SMO 50:50 and SMO 70:30 had the most minimal rate of decrease in iodine value following the frying period, indicating that lesser oxidation of unsaturated fatty acid took place in the blended oil samples. At the end of the second frying, there was significant difference in iodine value ($p \leq 0.05$) in all the vegetable oil samples. The mixing of *M. oleifera* seed oil which contains high levels of oleic acid and cancer preventing agents compared to soybean oil efficiently reduced the oxidation rate in the mixed seed oil during frying procedure, as distinguished by moderately low decrease in the iodine value. Researchers have reported that a decline in

Table 1: Peroxide value of oil samples (meq/kg) before and after frying

Sample code	F0	F1	F2
CSO	1.67 ± 0.00^{a}	3.73 ± 0.00^{d}	3.73 ± 0.09^{c}
ESO	2.03 ± 0.08^{c}	3.18 ± 0.00^{c}	5.61 ± 0.00^{d}
SMO (50:50)	0.93 ± 0.16^{a}	0.82 ± 0.00^{a}	1.61 ± 0.00^{a}
SMO (70:30)	1.50 ± 0.03^{b}	1.81 ± 0.00^{b}	1.86 ± 0.00^{b}

Mean values with the same superscript are not significantly different along the same column ($p > 0.05$). ESO, extracted soybean oil; CSO, commercial soybean oil; SMO (50:50), soybean/*Moringa oleifera* seed oil; SMO (70:30), soybean/*Moringa oleifera* seed oil; F0, fresh oil; F1, first frying; F2, second frying.

Table 2: Iodine value of oil samples (mg/100 g) before and after frying

Sample code	F0	F1	F2
CSO	85.16 ± 0.04^{c}	72.99 ± 0.26^{c}	59.45 ± 1.64^{a}
ESO	82.16 ± 0.04^{b}	71.88 ± 0.00^{a}	64.71 ± 0.00^{b}
SMO (50:50)	87.56 ± 0.02^{d}	77.53 ± 0.30^{d}	70.04 ± 0.35^{d}
SMO (70:30)	80.43 ± 0.04^{a}	72.64 ± 0.00^{b}	68.73 ± 0.00^{c}

Mean values with the same superscript are not significantly different along the same column ($p > 0.05$). ESO, extracted soybean oil; CSO, commercial soybean oil; SMO (50:50), soybean/*Moringa oleifera* seed oil; SMO (70:30), soybean/*Moringa oleifera* seed oil; F0, fresh oil; F1, first frying; F2, second frying.

Table 3: Free fatty acid (%FFA) of oil samples before and after frying

List of samples	F0	F1	F2
CSO	0.97 ± 0.00^{a}	1.59 ± 0.03^{a}	1.95 ± 0.02^{b}
ESO	1.43 ± 0.04^{c}	1.47 ± 0.00^{b}	1.65 ± 0.00^{c}
SMO (50:50)	0.30 ± 0.00^{d}	0.32 ± 0.00^{d}	0.40 ± 0.00^{d}
SMO (70:30)	0.50 ± 0.00^{b}	0.60 ± 0.00^{c}	0.65 ± 0.00^{a}

Mean values with the same superscript are not significantly different along the column ($p > 0.05$). ESO, extracted soybean oil; CSO, commercial soybean oil; SMO (50:50), soybean/*Moringa oleifera* seed oil; SMO (70:30), soybean/*Moringa oleifera* seed oil; F0, fresh oil; F1, first frying; F2, second frying.

Table 4: Viscosity (mm^2/s) of oil samples before and after frying

List of samples	F0	F1	F2
CSO	1.81 ± 0.00^{a}	1.73 ± 0.01^{a}	2.13 ± 0.00^{a}
ESO	0.41 ± 0.00^{a}	0.45 ± 0.00^{a}	0.52 ± 0.00^{a}
SMO (50:50)	0.51 ± 0.00^{c}	0.50 ± 0.00^{c}	0.49 ± 0.00^{b}
SMO (70:30)	0.61 ± 0.00^{b}	0.54 ± 0.00^{b}	0.50 ± 0.00^{a}

Mean values with the same superscript are not significantly different along the column ($p > 0.05$). ESO, extracted soybean oil; CSO, commercial soybean oil; SMO (50:50), soybean/*Moringa oleifera* seed oil; SMO (70:30), soybean/*Moringa oleifera* seed oil; F0, fresh oil; F1, first frying; F2, second frying.

iodine value is a pointer of lipid oxidation and is steady with the reduction in paired bonds, as oil gets oxidised [29].

The values of FFA of the fresh vegetable oils are shown in Table 3. The FFA values were CSO (0.97%), ESO (1.43%), SMO 50:50 (0.30%), and SMO 70:30 (0.50%). The FFA of the SMO 50:50 and SMO 70:30 was the lowest, while the highest was found in ESO at fresh conditions. All the oil showed significant difference ($p \leq 0.05$) in FFA value. All the vegetable oils under study showed an increase in FFA value after the first frying. ESO and CSO showed the highest increase (1.47 and 1.59%), while SMO 50:50 and SMO 70:30 showed the least increase (0.32 and 0.4%). As reported by Debnath et al. [30], FFA rise was because of the division and double bonds oxidation which leads to carbonyl mixture formation, and also leads to the formation of low atomic mass fatty acid throughout frying. The FFAs after the second frying were CSO (1.95%), ESO (1.65%), SMO 50:50 (0.40%), and SMO 70:30 (0.65%). The SMO 50:50 and SMO 70:30 had the lowest FFA value following the frying session. This could be ascribed to the addition of *M. oleifera* seed oil, which is a monounsaturated oil. This result is in line with the reports by Sebastian et al. [31] which showed that the FFA levels in new oil samples differ from the one that has been utilised. The higher percentage of FFA in the CSO and ESO implies that deterioration reactions have set in the vegetable oil with frying time.

3.2 Physical properties

The viscosity values are shown in Table 4. CSO had the highest viscosity (1.8 mm^2/s) compared to other vegetable oil samples at fresh condition. There was significant difference ($p \leq 0.05$) in the viscosity of the mixed seed oil and CSO. Decrease in viscosity after the first frying was observed, and this report is in agreement with that by Ike [32] which reported that viscosity decreases with increase in temperature, while ESO showed an increase in viscosity. The viscosity after the second frying were CSO (2.13 mm^2/s), ESO (0.52 mm^2/s), SMO 50:50 (0.49 mm^2/s), and SMO 70:30 (0.50 mm^2/s). Following the second frying, SMO 50:50 was significantly different ($p \leq 0.05$). The CSO had the highest percentage increase in viscosity (2.13 mm^2/s). Das et al. [28] also reported that increment in thickness of frying oil is likely to occur because of the development of polymers which increased with high frying temperature and overall number of frying. These results indicate that the greater deteriorative impact of oxidation and polymerisation of oil is high within the CSO when compared to the other vegetable oil samples in this study. At the same time, oil samples produced from mixing soybean seeds with *M. oleifera* seeds have a lower polymerisation reaction during frying, due to high beneficial plant compositions of *M. oleifera* seed oil.

The smoke point values at fresh condition are shown in Table 5; the values were CSO (172.3°C), ESO (168.3°C), SMO 50:50 (172.3°C), and SMO 70:30 (160.7°C). The smoke point of oil samples after the first frying decreased, the values were CSO (167.7°C), ESO (169.3°C), SMO 50:50 (168.3°C), and SMO 70:30 (159.7°C). All the vegetable oils showed a decrease in smoke point after the first frying.

Table 5: Smoke point (°C) of oil samples before and after frying

List of samples	F0	F1	F2
CSO	172.3 ± 0.33^{c}	167.7 ± 0.33^{b}	167.0 ± 0.33^{b}
ESO	168.3 ± 0.33^{b}	169.3 ± 0.33^{c}	167.7 ± 0.33^{c}
SMO (50:50)	172.3 ± 2.03^{c}	168.3 ± 0.33^{c}	167.3 ± 0.33^{b}
SMO (70:30)	160.7 ± 0.33^{a}	159.7 ± 1.00^{a}	158.7 ± 0.33^{a}

Mean values with the same superscript are not significantly different along the column ($p > 0.05$). ESO, extracted soybean oil; CSO, commercial soybean oil; SMO (50:50), soybean/*Moringa oleifera* seed oil; SMO (70:30), soybean/*Moringa oleifera* seed oil; F0, fresh oil; F1, first frying; F2, second frying.

Decrease in smoke point is an indication that the oil is deteriorating with frying. SMO 50:50 showed the greatest resistance to decrease in smoke point. The smoke point of all the vegetable oils decreased after second frying, CSO (167.0°C), ESO (167.7°C), SMO 50:50 (167.3°C), and SMO 70:30 (158.7°C). Idun-Acquah et al. [33] reported that a decrease in smoke point marks the start of both flavour and nutritious mortification of vegetable oil. There was no significant difference in the values of CSO and SMO 50:50 after the second frying.

The RI values of the oil samples are shown in Table 6. All the oil samples had equivalent RI value which conforms to the maximum limits 1.466–1.470°C, specified by Egbebi [34]. The RI values after the first frying were CSO (1.46°C), ESO (1.47°C), SMO 50:50 (1.47°C), and SMO 70:30 (1.47°C). All the vegetable oil samples showed no changes in their RI value after the first frying. The RI values after the second frying were CSO (1.49°C), ESO (1.48°C), SMO 50:50 (1.47°C), and SMO 70:30 (1.4°C). ESO and CSO showed a slight increase in their RI value after the second frying, which is in line with the report by Godswill et al. [35] which reported an increase in RI value of vegetable oil during frying. Increase in RI value is also an indication of deteriorating quality of the vegetable oil. The SMO 50:50 and SMO 70:30 showed no changes in their RI value (1.47°C). This is a reflection of stability of the mixed seed oil with frying process. All the vegetable oil samples were not significantly different ($p \geq 0.05$) after the second frying.

The colour values of the oil samples are shown in Table 7. ESO and SMO 50:50 had the same colour value (yellow colour), CSO had a golden yellow colour, while SMO 70:30 was brownish in colour. The colour of the oil samples after the first frying process were CSO (6.63), ESO (2.13), SMO 50:50 (6.57), and SMO 70:30 (9.40), indicating that the yellow units showed only minor changes, while all the oil samples showed slight increase in colour value.

Table 6: Refractive index (°C) of oil samples before and after frying

Sample code	F0	F1	F2
CSO	1.47 ± 0.00^a	1.46 ± 0.00^a	1.49 ± 0.00^a
ESO	1.47 ± 0.00^a	1.47 ± 0.33^a	1.48 ± 0.00^a
SMO (50:50)	1.47 ± 0.00^a	1.47 ± 0.00^b	1.47 ± 0.00^a
SMO (70:30)	1.47 ± 0.00^a	1.47 ± 0.00^b	1.47 ± 0.00^a

Mean values with the same superscript are not significantly different along the row ($p > 0.05$). ESO, extracted soybean oil; CSO, commercial soybean oil; SMO (50:50), soybean/*Moringa oleifera* seed oil; SMO (70:30), soybean/*Moringa oleifera* seed oil; F0, fresh oil; F1, first frying; F2, second frying.

Table 7: Colour (10-point comparative scale) of oil samples before and after frying

List of samples	F0	F1	F2
CSO	2.0 ± 0.00^a	2.13 ± 0.01^a	2.38 ± 0.01^a
ESO	6.0 ± 0.00^c	6.63 ± 0.00^c	6.73 ± 0.00^c
SMO (50:50)	6.0 ± 0.00^b	6.57 ± 0.00^b	6.70 ± 0.00^b
SMO (70:30)	9.0 ± 0.00^d	9.40 ± 0.00^d	9.42 ± 0.00^b

Mean values with the same superscript are not significantly different along the column ($p > 0.05$). ESO, extracted soybean oil; CSO, commercial soybean oil; SMO (50:50), soybean/*Moringa oleifera* seed oil; SMO (70:30), soybean/*Moringa oleifera* seed oil; F0, fresh oil; F1, first frying; F2, second frying.

The colour values of oil samples after second frying were CSO (2.38), ESO (6.73), SMO 50:50 (6.63), and SMO 70:30 (9.42). All the oil samples showed slight increase in colour value, indicating that there is less formation of polymer [36]; however, there was significant difference before and after the oil was utilised for frying.

4 Conclusion

This study has shown that mixing of soybean seed oil with *M. oleifera* seed oil at ratios of 50:50 and 70:30 had effects on the physical and chemical properties of oil with a better frying quality than CSO. Therefore, mixing of soybean seed oil with *M. oleifera* seed oil has potentials to improve the nutritive value of the oil and hence better health benefit to the consumers. Based on the results from the study, oil (SMO 70:30) produced from mixing 30% *M. oleifera* with 70% soybean seeds is therefore recommended for better stability and frying quality.

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Data availability statement: The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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