

Reclamation of Used Edible Oil

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Abstract: The amount of used edible oil generated in Japan annually is presumed to be some hundred thousand tons. Half of it is rather easy to recover because it comes from food manufacturing industries, supermarkets, restaurants, and the like. Recovered oil of good quality is diverted for use as a fatty acid source or in the production of feed oil, paint, ink, fuel oil, soap, or other products, but the rest is burned or discarded. Stiff competition between the price of good-grade oil and the cost of refining low-grade oil is the principal reason for the insufficient reuse of recovered oil. The burning or discarding of large amounts of recovered oil in spite of a relatively low level of deterioration adversely affects the environment and promotes Japan's dependency on imports. In this study, safe and inexpensive methods for refining used edible oil (Gardner color 11) to non-food industry oil (Gardner color <7) with possibly a small amount of factory waste were investigated. Refined oil with Gardner color 6 was prepared by a process consisting of filtration on an adsorbent and barium hydroxide or sodium hydroxide refinement. Barium hydroxide-refined oil was further bleached by hydrogen peroxide to obtain heat-stable reclaimed oil of Gardner color 3.

Key words: used edible oil, alkali refinement, bleaching, hydrogen peroxide, reclamation

1 Introduction

Although the abolition ratio of edible oil depends on usage and where it is used, the amount of abolished oil in Japan seems to be vast; presumably, 20% of annual consumption of edible tallow + vegetable oil, 2.5 million tons (1), is abolished at present. But one half of the used oil is rarely recovered because of domestic use (2). In spite of enthusiastic efforts of some groups making soap from it, most used frying oil is discarded after it is solidified with a gelling agent or bottled or is discarded directly to soil or kitchen drains (3). Thus, complete recovery of used edible oil will be a difficult goal to achieve immediately. The rest of the used oil is generat-

ed from food manufacturing industries, restaurants, supermarkets, and other food-related businesses and recovered by renderers, oil collectors, and blenderers, then classified by appearance and other properties and reused after simple treatments or burned. In short, some used edible oil ends up as a fatty acid source, feed oil for animals, paint, ink, fuel oil, or soap or is burned/discarded (2,4). Insufficient reuse of recovered oil is primarily due to tough competition between the price of good-grade oil coming from fancy restaurants and other such sources and the cost of refining low-grade, poor-colored oil (Gardner color ≥ 11), as well as to the relationship between the demand and the supply of both oils. Another contributing factor is the low price of

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palm oil imported from Southeast Asia.

Deterioration of used edible oil is not serious when compared to that of oil derived from other uses (2,4), but large volumes of this oil are burned or discarded as described above. This is not only undesirable from the environmental point of view but also increases the import dependency of Japan, which cannot grow enough oil crops to meet its demand. As conjectured from an oil demand survey (1), the used edible oil consists mainly of expensive soybean oil and rapeseed oil, which is the Japanese favorite. The main fatty acids contained in these oils are oleic and linoleic acids, so reuse of inexpensive refined oil is of interest to all kinds of oil industries. When a realistic and immediate solution is required, it is reasonable that the refinement should be performed using existing facilities and inexpensive materials in order to achieve the lowest cost. In addition, special attention is essential with regard to the safety and volume of materials used because the used edible oil to be treated will amount to more than several thousand tons annually.

Some reports describing the refinement of used edible oil have been published. Usuki (5) added 5 wt% Zeolite/activated carbon, 2:1, into oil that had been used to fry fish with Lovibond color yellow/red 50.0/10.5, and stirred for 20 min at 110-120°C, then filtered it using filter paper. The refined oil thus obtained lost oxidation stability, but the color improved to Lovibond color yellow/red 19.0/2.0. This method is simple and feasible for anyone, but the amount of adsorbents used seems to be problematic when much used edible oil of Gardner color ≥ 11 has to be treated as described above; the used edible oil in question is too dark-colored to express the color as a Lovibond color. It should also be kept in mind that the yield of refined oil will decrease in inverse proportion to the amount of adsorbents used.

Yuki *et al.* (6) applied 5 wt% dried aluminum hydroxide gel and 2 wt% diatom earth to used frying oil and reduced free fatty acids successfully; the mechanism reportedly was not soap formation. The behavior of metal hydroxide hydrate in oil seems to be very interesting. But here again, the starting material, the used frying oil, had good Lovibond color, yellow/red < 10.0/1.2, and it is unknown whether this technique is applicable for reclamation to the recovered used oil in question.

Recently, an attempt was made at membrane process-

ing of used frying oil and crude soybean oil (7-9). Frying oil that had been used in a restaurant was permeated through a composite gas separation membrane to improve its color and viscosity to nearly those of fresh oil. However, the calculated permeation rate was rather low, 78 tons per 7000 working hours/year when a 100-m² membrane was employed (9). More recently, used frying oil was diluted twice with hexane and applied on the separation membrane to increase the permeation rate up to 9 to 14 times higher than before (10). The quality of the treated oil was comparable to that of the oil without hexane. After this treatment, the oil was subjected to refinement with 18.75 wt% silica gel and 1.875 wt% magnesium oxide. The refined oil thus obtained was of almost the same quality as fresh oil. However, still some time seems to be needed to take advantage of this technique because of the following issues to be solved. Refined oil is supposed to be of the same price or less expensive than fresh oil; thus, it may be difficult to bring out the economical advantage using a newly installed membrane apparatus. In addition, the disposal of a huge amount of used adsorbents and recycling of hexane remain problematic.

The purpose of this study was to investigate the reclamation of oil for non-food industry use (Gardner < 7, acid value(AV) ≤ 3 , water content $\leq 1\%$), such as paint, ink, soap, and etc. from used edible oil (Gardner color 11), which was recovered from food manufacturing industries, restaurants, and other sources. The reason for reclaiming oil, not fatty acids, from the recovered oil described above is that oil covers wider range of uses than those of fatty acids, and that oil has appropriate properties for paint, ink, and the like. Thus two refining methods, a barium hydroxide method employing neither solvent nor water, and a sodium hydroxide method using sodium hydroxide, methyl alcohol, and water, were applied to the recovered oil and compared with the conventional technique of filtering with silica gel. Then, subsidiary bleaching of the alkali-refined oil was carried out with hydrogen peroxide. The combination of refining and bleaching was investigated in detail.

2 Experimental

2.1 Materials

A typical lot of "B-grade recovered vegetable oil," Miyoshi Oil & Fat Co., Ltd. (recovered oil) was used as

the starting oil throughout this study. The properties of the recovered oil were as follows: AV 3.3, iodine value (IV) 113.5, water content 0.6%. Gas chromatographic analysis by a Shimadzu GC-14A gas chromatograph equipped with a 3.1-m glass column of 3.2-mm bore packed with Shimadzu Shinchrom E71 5%/Shimalite 80-100 showed following fatty acid composition: myristic acid 0.2%, palmitic acid 9.5%, palmitoleic acid 0.5%, stearic acid 3.2%, oleic acid 44.7%, linoleic acid 33.7%, α -linolenic acid (+ eicosanoic acid) 7.1%, eicosenoic acid 1.0%, others 0.1%. Chemicals used: barium hydroxide octahydrate (Yoneyama Chemical Industries, Tokyo), sodium hydroxide (Nacalai Tesque, Inc. Osaka), silica gel 60H (Merck, Darmstadt, Germany), 35% hydrogen peroxide and 99% methyl alcohol (Wako Pure Chemical Industries Ltd., Osaka), Radiolite (Showa Chemical Industry, Osaka), and activated clay (Galleon Earth V₂R, Mizusawa Chemical Industry, Tokyo). Barium hydroxide octahydrate was ground by mortar and pestle for use.

2·2 Barium Hydroxide Method

Five hundred grams of recovered oil were filtered on 2.0 wt% silica gel 60H in a Buchner funnel under 3.6 kPa (Fig. 1). The obtained filtered oil (filtrate S) was poured into a 1-L three-necked separable flask and heated to 70°C, then combined with 1.5 wt% ground barium hydroxide octahydrate and stirred at 300 rpm. After 20 min, the oil was filtered again on 2.0 wt% silica gel 60H in a Buchner funnel under 1 kPa to obtain alkali-refined oil SB.

For comparison, recovered oil was filtered through filter paper (filtrate P) and subjected to barium hydroxide

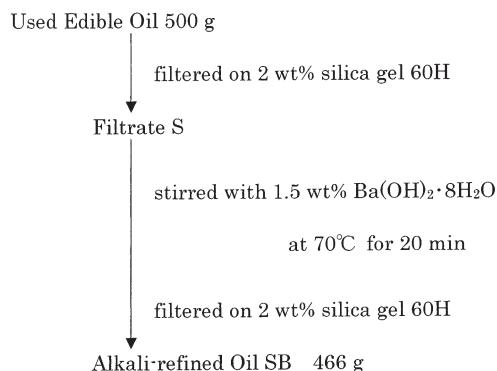


Fig. 1 Alkali-refinement of Used Edible Oil by Barium Hydroxide.

ide refinement including final filtration with 2.0 wt% silica gel 60H.

2·3 Sodium Hydroxide Method

Recovered oil, 150 g, was heated at 50°C in a 500-mL beaker, to which was added sodium hydroxide aqueous solution (0.8 g NaOH in 30 g H₂O, twice as much sodium hydroxide as required for neutralizing the free fatty acids in the recovered oil); it was then stirred vigorously for 30 min to make an emulsion (Fig. 2). Next, methyl alcohol (120 g) was added, and the mixture was stirred further at 50°C for 30 min. The contents were moved to a 1-L separatory funnel and allowed to stand at 50°C for 2 hr to obtain two layers. Activated clay (3.3 wt%) and Radiolite (0.2 wt%) were added to the oil layer (bottom layer) and stirred at 120°C for 30 min under 3 kPa, followed by removal of adsorbents by filtration to prepare alkali-refined oil N. Filtrate S was also subjected to sodium hydroxide refinement to obtain alkali-refined oil SN.

2·4 Hydrogen Peroxide Bleaching

Alkali-refined oil SB 200 g was poured into a 1-L four-necked flask and heated at 105-115°C. Then, 5% hydrogen peroxide was carefully added to avoid excess bubbling under stirring at 475 or 1000 rpm. After 1 hr of high agitation, the oil was heated to 130°C for 30

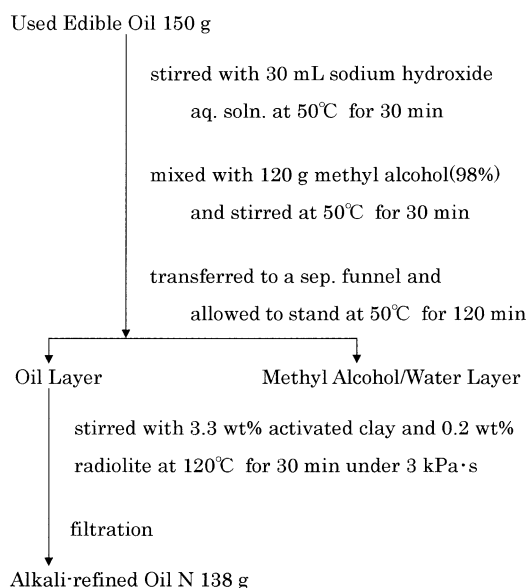


Fig. 2 Alkali-refinement of Used Edible Oil by Sodium Hydroxide and Methyl Alcohol.

min to dry. Dried oil was filtered on 2.0 wt% silica gel 60H to obtain reclaimed oil SBH.

In order to estimate effects of the first silica gel filtration and alkali refinements, filtrate P and alkali-refined oils PB, N, and SN were bleached by hydrogen peroxide as above to prepare reclaimed oils PH, PBH, NH, and SNH. The agitation speed was 1000 rpm, and 2.0 wt% silica gel 60H was used for final filtration.

2·5 Filtration on Silica Gel

Recovered oil was filtered with 2.0 wt% silica gel 60H under 3.6 kPa to get filtrate S, which was filtered again with fresh silica gel in the same manner to get filtrate S-2. Filtrates S-3, S-4, and S-5 were also prepared further. Hydrogen peroxide bleaching (1000 rpm) was applied to filtrate S and filtrate S-2 (reclaimed oil S-2H) as in 2·4 to estimate effects of silica gel as pretreatment.

Reclaimed oil SH obtained by hydrogen peroxide bleaching of filtrate S was refined with barium hydroxide powder (reclaimed oil SHB) to investigate the order of processing.

2·6 Spectrophotometric Analysis

Absorbance of oils was measured using a Shimadzu Bio Spec-1600 spectrophotometer in the range of 380 to 540 nm.

2·7 Heat Stability

Because the reclaimed oil had experienced hydrogen peroxide bleaching, deterioration of heat stability was expected. Thus, reclaimed oil SBH was heated at 200 °C for 30 min with commercial fresh soybean oil and salad oil as references.

2·8 Analyses of Properties

AV, IV, water content, and peroxide value (POV) were measured according to the standard methods for test and analysis of oil and fat, Japan Oil Chemists' Society. For POV determination, potentiometric titration was employed. Viscosity measurement was performed by Visconic ED, Tokimec, Tokyo. All the experiments and measurements were done in triplicate.

3 Results

The properties of the refined oils are shown in Table 1. The recovered oil was a turbid, dark-brown viscous

liquid but became a clear brown oil by the first filtration with silica gel 60H (filtrate S). The viscosity was a little high (61.9 mPa·s) when compared with fresh edible oils, which had viscosities of about 50 mPa·s. Silica gel after use was stained dark brown, while the improvement of oil color appeared relatively small. During barium hydroxide refinement, some bubbling was observed due to decomposition of the crystal water of barium hydroxide octahydrate, and many small fluffy lumps appeared from particles of the base. The oil that reacted with barium hydroxide bubbled up when filtered through silica gel, but the brown color of the filtrate S (Gardner color 9 +) was improved drastically to yellow (alkali-refined oil SB, Gardner color 6). The color of silica gel 60H used for the second filtration was dark yellow. Filtrate P, which was turbid and held water particles at the bottom of the container, had a darker color (Gardner color 11) and higher viscosity (65.9 mPa·s) than filtrate S.

In the sodium hydroxide method, recovered oil became creamy immediately after the addition of sodium hydroxide solution, but methyl alcohol addition created a two-phase liquid consisting of oil and methyl alcohol. After 10 min of agitation, the methyl alcohol suddenly turned brown. At the final stage, the alkali-refined oil N had Gardner color 7 – and viscosity 57.2 mPa·s.

When alkali-refined oil SB was bleached by hydrogen peroxide under agitation (1000 rpm), the color gradually improved, finally reaching Gardner color 3 (light yellow) and showing no hint of reddish color. As agitation at 475 rpm hardly improved the color of alkali-refined oil SB, it was obvious that agitation speed was the key factor in hydrogen peroxide bleaching. Filtration on silica gel 60H did not improve the color of the bleached oil, as the adsorbent used after bleaching stayed almost white. The Gardner colors of reclaimed oils PBH, PH, NH, and SNH were 6, 7, 6 +, and 6, respectively.

The iodine values of reclaimed oil SBH and alkali-refined oil N were the same as that of recovered oil, so it was clear that during the whole refinement no change had occurred in the number of double bonds of the fatty acids owing to polymerization and decomposition. Acid value and water content were decreased by alkali refinement and the use of an adsorbent. The odor of the recovered oil was improved with refinement and became acceptable for non-food industry oil. Yields of

Table 1 Properties and Yields of Alkali-Refined and Reclaimed Oils.

Properties	Used edible oil	Filtrate S	Alkali-refined oil SB	Reclaimed oil SBH	Alkali-refined oil N	Filtrate S-5
Color (Gardner)	11	9+	6	3 ¹ (5+ ²)	7 –	8 –
AV	3.3	—	—	1.6 ¹	0.5	—
IV	113.5	—	—	113.2 ¹	113.8	—
Water content (%)	0.6	—	—	0.1 ¹	—	—
Odor	fishy, burned	slightly fishy	bitter	oily ^{1,2}	oily	slightly rancid
Yield (%)	—	96.8	93.2	88.8 ^{1,2}	92.0	80.3

1: 1000rpm, 2: 475rpm

reclaimed oil were more than 88.8%, which was also acceptable.

Fatty acid compositions of reclaimed oil SBH and alkali-refined oil SB were analyzed by GC as follows respectively; myristic acid 0.1% / 0.1%, palmitic acid 10.9% / 11.0%, palmitoleic acid 0.6% / 0.6%, stearic acid 3.8% / 3.7%, oleic acid 44.3% / 44.7%, linoleic acid 33.0% / 32.7%, α -linolenic acid (+ eicosanoic acid) 5.8% / 5.8%, eicosenoic acid 0.8% / 0.9%, others 0.7% / 0.5%. From this result no big change was found in the composition during the refining processes.

The absorbance spectra shown in **Fig. 3** clearly indicate that silica gel filtration, alkali refinement, and hydrogen peroxide bleaching improved oil color remarkably. In particular, absorbance over 500 nm was

zero in reclaimed oil SBH, showing that no red color was present. On the other hand, it was shown that repeated filtration on silica gel 60H did not contribute much color improvement and that reddish materials were hard to remove using the adsorbent.

The heat stability, POV, and viscosity of reclaimed oil SBH are shown in **Table 2**. The reclaimed oil was not as heat-stable as fresh soybean oil and salad oil, the commercial references, but the stability seems to be acceptable for non-food industry use. Fresh edible oils may contain antioxidants to prevent color deterioration. Peroxide values and viscosities were higher than those of fresh edible oils. It is not known whether high viscosity limits the use of reclaimed oil.

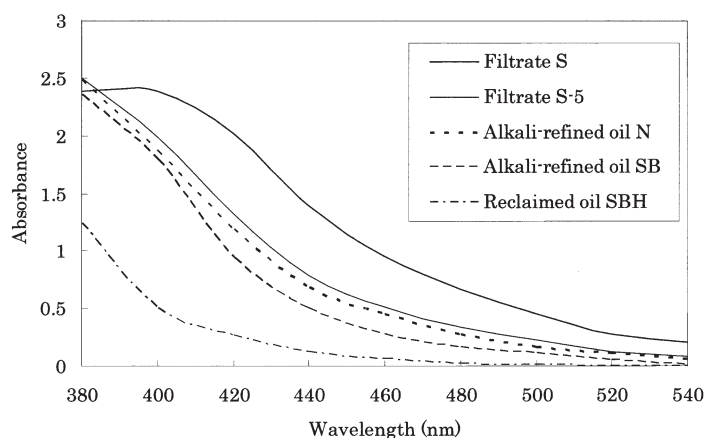


Fig. 3 Absorbance Spectra of Oils under Reclamation.

The first filtration of recovered oil on silica gel 60H was time-consuming (**Table 3**), but the subsequent speed of filtration increased remarkably, which was not expected from the slightly decreasing viscosity. Recoveries of filtered oil remained constant. Silica gel 60H used for the first filtration changed color to dark brown, but the oil color did not improve much. The adsorbent used after the second filtration became pale yellow, and improvement of oil color was even smaller. From recovered oil silica gel 60H, 10 wt% in total created a reddish oil of Gardner color 8 — with a slightly rancid smell. Thus, it was practically impossible to refine recovered oil with adsorbents such as silica gel 60H to oil of Gardner color < 7. The silica gel method was judged to be unsuitable for our purposes.

Reclaimed oils SH and S-2H, both of which were treated not by barium hydroxide refinement but rather by hydrogen peroxide bleaching, showed Gardner color 7. The result was far worse than that of reclaimed oil SBH. This means that silica gel filtration cannot replace barium hydroxide refinement and that refinement is essential for making the most of hydrogen peroxide bleaching. Reclaimed oil SHB, in which refining pro-

cesses were inverse of those of reclaimed oil SBH, was a highly viscous (150 mPa·s) and turbid oil with Gardner color 6. Therefore, it was found that barium hydroxide refinement can play a role as a pretreatment before hydrogen peroxide bleaching.

4 Discussion

As recovered oil is specified by a few items, many uncontrolled properties remain and many kinds of impurities may be present. The recovered oil used in this study has a clear history and was sampled from a typical lot collected. The major fatty acid constituents were oleic and linoleic acids, with a higher concentration of the former. It was conjectured that the recovered oil contained more rapeseed oil than soybean oil. Used edible oil rich in unsaturated fatty acids contains not only substances generated by heat deterioration and oxidation but also numerous complex substances produced by reactions with proteins and carbohydrates (11). Thin layer chromatographic analysis of recovered oil using hexane/diethyl ether/acetic acid as the developing solvent showed that most of the color substances

Table 2 Heat Stability of Reclaimed Oil SBH.

Amount of silica gel used (wt%)		Peroxide value (meq/kg)	Viscosity (mPa·s)	Color (Gardner) before heat resistance test	Color (Gardner) after heat resistance test
Reclaimed oil SBH	0	10	64.3	3	5
	2.0	8	62.9	3	5
Soybean oil	0	2	49.8	1	1
Salad oil	0	2	53.5	2	2

Table 3 Properties of Oils Filtered on Silica Gel 60H.

Number of filtration	0 (Used edible oil)	1 (Filtrate S)	2 (Filtrate S-2)	3 (Filtrate S-3)	4 (Filtrate S-4)	5 (Filtrate S-5)
Color (Gardner)	11	9 +	9	9 —	8	8 —
Viscosity (mPa·s)	67	61.9	59.9	59.9	59.4	59.8
Filtration velocity (g/min)	—	0.6	2.4	4.4	5.6	7.0
Recovery (%)	—	96.8	96.3	95.3	95.5	94.7

were very polar and stayed at the origin or developed near the origin. Accordingly, removing the substances by silica gel or activated clay is the direct solution for refinement. But more than 10 wt% of adsorbent would be needed to obtain oil of Gardner color < 7 , as shown in **Table 3**. Thus, refinement only by the use of an adsorbent is an impractical solution. In this paper, Gardner color was used exclusively instead of Lovibond color because of the convenience of comparison.

This study investigated simple and practical methods for producing reclaimed oil having properties that meet market needs using two kinds of alkali refinement followed by hydrogen peroxide bleaching. To our best knowledge, alkalis such as calcium hydroxide, magnesium hydroxide (3), and aluminum hydroxide (6) have not been applied for color improvement of the recovered oil but for reducing AV, where the equivalent amount of alkali is employed. Moreover, the use of barium hydroxide octahydrate was found out to be effective for the improvement for the first time. The amount of alkali used was 50-100% more than that equivalent to AV.

It is characteristic of the barium hydroxide method that no water was used in the process. Instead of barium hydroxide octahydrate, sodium hydroxide and calcium hydroxide can be employed in dry refinement. But pulverization of the former was impossible because of deliquescence, while grained sodium hydroxide did not have any affinity to recovered oil, resulting in no change occurring. The latter dispersed in recovered oil and showed a relatively good bleaching effect, but filtration speed was so low that an adequate investigation could not be carried out. Sodium hydroxide solution is frequently used for wastewater treatment in factories because of its safety.

Judged by all experiments performed on a laboratory scale, processing time at a factory seems to be shorter with the barium hydroxide method than with the sodium hydroxide method. Moreover, the latter method, although the amount of adsorbent used was only 3.5% in total, used methyl alcohol, which is a significant point in terms of fire law. Also, methyl alcohol has to be recycled for environmental and cost reasons, which consumes much time and space (reaction vessel + storage) also.

The amount of barium hydroxide octahydrate, 1.5 wt%, was calculated as follows: the moles of free fatty acids calculated from AV of recovered oil were $5.9 \times$

10^{-5} mol/g and the stoichiometric weight of barium hydroxide octahydrate for saponification was $5.9 \times 10^{-5}/2$ mol/g = 0.9×10^{-2} g/g. A 50% excess amount was selected.

When barium hydroxide was mixed in filtrate S, the reddish color of the oil decreased drastically. But the reaction product (fluffy lumps) showed a light color, and oil released from it by addition of excess hydrochloric acid was not especially dark in color. Therefore, it appeared that color substances lost their brown color through exposure to alkali, and the color of the whole oil appeared to be improved, while in silica gel filtration, color improvement obviously depended on removal of color substances.

Alkali refinement was sufficient to meet the initial target, but further improvement was desired in consideration of unknown factors of recovered oil. The color of alkali-refined oil SB (Gardner color 6) was improved to Gardner color 3 by hydrogen peroxide bleaching, especially owing to reduction of reddish color. Alkali-refined oil SN reached only Gardner color 6 through the same bleaching. Thus, barium hydroxide seems not only to reduce the level of color, as described above, but also to play some other role in color improvement. However, hydrogen peroxide bleaching is often carried out effectively under weak alkaline conditions, so the contribution of barium soap remaining in alkali-refined oil SB should not be overlooked when the difference between barium hydroxide and sodium hydroxide is discussed. Reclaimed oil SBH had a slightly higher viscosity than fresh edible oil and alkali-refined oil N.

The color improvement of alkali-refined oil PB by hydrogen peroxide bleaching was not great (Gardner color 6). Bleaching was not effective for filtrates S and S-2 (both Gardner color 7), which were not subjected to barium hydroxide refinement beforehand. This result implies that the effects of hydrogen peroxide were not fully realized in these samples. We suspect that oxygen generated from hydrogen peroxide was consumed by an unrelated reaction, such as a reaction with amines derived from deep-fried materials. Once the amines were modified by barium hydroxide, hydrogen peroxide could work effectively as a bleaching agent. In fact, amines as food extinction agents (11,12) and amino acids in natural rubber, which are antioxidants, are well known to quench oxygen very actively (13,14). As shown in the preparation of reclaimed oil SHB, hydrogen peroxide bleaching was not effective at all before

barium hydroxide refinement; however, barium hydroxide refinement was an effective pretreatment before hydrogen peroxide bleaching. Further investigation is required to clarify the mechanism of refinement.

In the process of preparing reclaimed oil SBH, three silica gel filtrations were performed. The bleaching effect of the first silica gel portion was large, but the second had less effect and the third almost none. Table 3 shows the same tendency. Thus, the color improvement after the first silica gel filtration was attributed mostly to alkali refinement and bleaching. But in the first filtration carbon and many of the viscous polar substances were removed, and alkali refinement and bleaching were performed successfully. Thus, it is a good idea to filter recovered oil on an adsorbent first.

When filtration is carried out after barium hydroxide refinement in a factory apparatus, a press-filter should be used to avoid bubbling due to the trace amount of barium soap in the oil. As yellow substances remaining in reclaimed oil SBH hardly adsorbed to silica gel 60H, they must have low-polarity chemical structures. It would be very difficult to refine the oil further by means of the polarity difference between the oil and the substances. Sodium hypochlorite could be used for bleaching instead of hydrogen peroxide, but the sodium chloride produced creates another abolition problem.

Concentrations of metal, barium or sodium in alkali-refined and reclaimed oils are not determined yet. Most of the metal should have been removed by filtrations with the adsorbent but in case where still unacceptable amount remains there are conventional ways to reduce it with acids.

Several routes for refinement investigated so far are summarized in Fig. 4, especially focusing on color development.

Based on the results of this study, the following method is proposed to refine used edible oil for non-food industry use:

1. Used edible oil is filtered on adsorbent to remove some highly polar colored substances.
2. Filtered oil is refined to oil with Gardner color 6 by an alkali such as barium hydroxide octahydrate or sodium hydroxide.
3. Oil refined with barium hydroxide octahydrate is bleached with hydrogen peroxide, dried, and filtered on adsorbent. Clear, heat-stable oil with Gardner color 3 is obtained.

According to our estimation on a scale of several thousand tons per year of reclamation, total cost for alkali refinement will amount to less than 20 yen/kg reclaimed oil. This cost will find feasibility of our method depending on the price of good-grade recovered

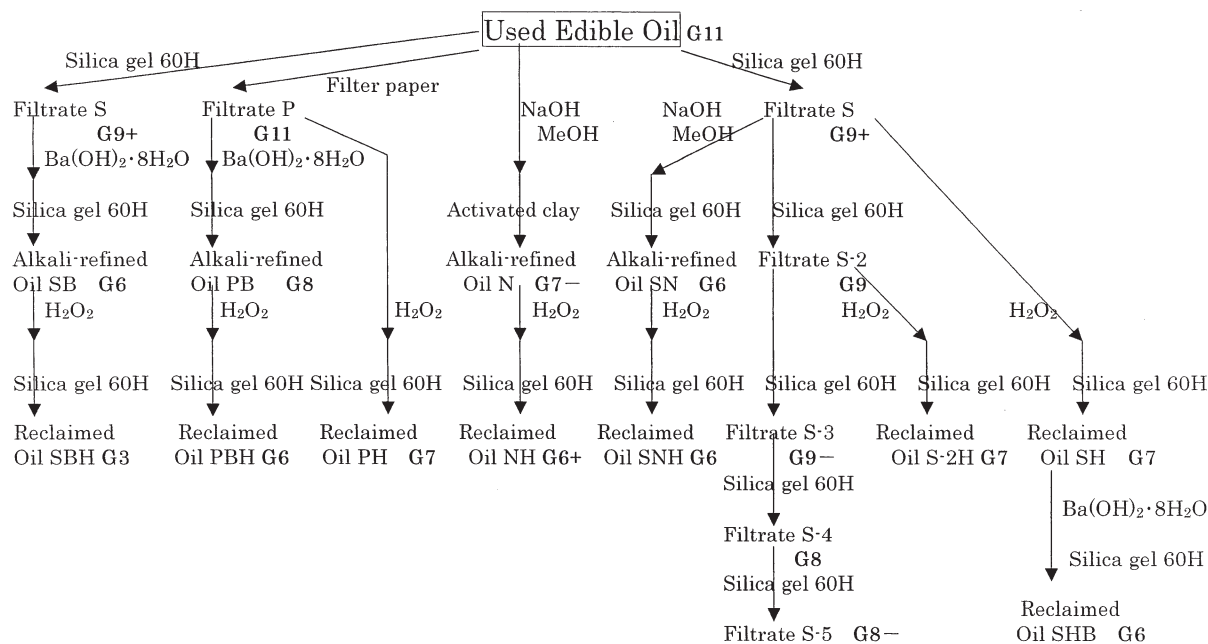


Fig. 4 Color Improvement of Used Edible Oil. G=Gardner color

oil described in the introduction.

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