



Evaluation of methods for reducing the ash content of waste frying oil processed to biofuel oil

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ABSTRACT

Waste frying oil (WFO) reclaimed from food processing and stripped from various impurities is considered a valuable feedstock for making biofuels. Specifically, to be used as bio-oil in industrial burners the ash content of WFO should not exceed maximum limits set for dust pollution from burners. Samples obtained from a WFO processing plant were used in a study to investigate efficient means of reducing ash to acceptable levels, i.e. <0.015%. Since the ash mainly exists as discrete particles dispersed in the oil, physical methods of separation such as filtration, extraction, settling and centrifugation were tested. Benchmark analysis of the current full scale process employing settling and 400, 200 µm filtration steps showed that end products after heating at 600 °C, contained 0.02–0.01% ash, regardless of high (0.5%) or low (0.02%) initial ash. Experimental filtration with 45 µm screen demonstrated that ash could be reduced 40–50% further. In aqueous extraction experiments ash reduction was dependent on both water:oil ratio and the temperature, in a manner showing interaction of the two factors. Extraction at a water ratio of 0.2 at 40 °C provided a consistent 60–70% reduction including the settling effect, and obtained with test volumes up to 1 l. High-speed centrifugation offered final ash levels as low as 0.012%. However, extensively purified WFO retained a particle fraction below 10 µm. The study points to possible improvements of steps in the current WFO line. Interestingly, any measures to reduce end product ash might be offset by burner temperatures above 800 °C due to the observation that approximate 50% of the ash being carbon based material combusted above this temperature.

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1. Introduction

1.1. Waste frying oil (WFO) as by-product

The annual generation of vast amounts of used deep-fat frying oil from fast food caterings, restaurants and food processing industry is posing a challenge for proper reuse. While some are paid for their WFO to be disposed off, others are charged a fee for the waste handling. In certain instances the WFO is mixed into pet food, make-up, livestock feed, or fertilizer, but still large volumes are dumped into sewers and landfills. Considering the benefit of energy conservation, companies and individuals can easily produce cheap biofuel from WFO [1,2], especially the used vegetable oils have been considered as a promising option. Several studies show the possibility of using WFO in the biofuel/biodiesel production [3–7].

Deep-fat frying is one of the most common methods for food preparation which improves the taste of food [8]. The same oil or fat is used several times, mainly for economic reasons. However, continuously using the same oil or fat for frying will cause various physical and chemical changes to the oil. Some physical changes observed in vegetable oil after frying are: increase in viscosity, increase in specific heat, change in surface tension, and change in color [9]. Oils are also subjected to three types of reactions during frying, mainly thermolytic, oxidative and hydrolytic [10,11]. The combined effect of these chemical reactions on the cooking oil is that many undesirable compounds are formed during repetitive heating and frying thereby increasing the polar content (FFA, ketones, aldehydes) [10–12].

1.2. Purification of WFO

WFO contains about 20% waste by volume owing to large solids (food, paper scraps, etc.), various metallic impurities especially alkali (earth) metals that can be added to cooking oils from foods or from cooking equipment used during frying, smaller-sized solids suspended within the oil, and water [13]. Dispersed solids and minerals contribute to the ash content in waste frying oil. In order to

Abbreviations: WFO, waste frying oil; FFA, free fatty acids; IV, iodine value (number); NEA, Norwegian Environmental Agency

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obtain a consistent yield of biofuel and avoid unpredicted chemical reactions caused by the impurities presented in WFO, the raw material requires a pretreatment that generally consists of several steps of heating, filtration, washing with hot water and settling [12,14].

Novel methods to purify the WFO have been reported, e.g. supercritical extraction of the oil with a non-polar supercritical fluid [12,14–16]. In a study by Boffito et al. [17], waste frying oil was first submitted to a rough filtration followed by drying under vacuum and vacuum filtration in order to remove water and solid deposits, respectively. Supple and co-workers [13] suggested running the WFO through a series of sieves ranging in aperture from 5 to 1 mm, which removed the unwanted solids, or alternatively, the oil could be reheated by steam injection into the tank followed by a second cycle of sedimentation and settling before the refined oil was stored.

Several patents on purification of WFO and cooking oils have been issued; by applying different activated filters [18] or adsorbents [19], steam stripping under reduced pressures [20] and agitating a WFO mixture with water and ozone [21].

1.3. Ash in WFO

For the refined WFO to be acceptable as a biofuel in oil burners, the ash content must be kept at a defined low level. The Norwegian Environment Agency (NEA) specifies the limits of emissions including dust, from burners 1–50 MW that are using liquid biofuels and vegetable oils [22]. To comply with the regulation, maximum ash content in WFO should not exceed 0.015% (E. Lundby, personal communication).

The objective of this study was to evaluate physical methods for reducing the ash content in the oil product from a local WFO-processing plant. The 12 m³ per batch process currently contains various refining steps like water separation, sedimentation holds and filtration (Fig. 1). The challenge of recycling WFO is to allow for the wide variation in raw material composition and still reach preset product specifications in the end product, in this respect the ash content. In this study a lab-scale examination of the behavior and nature of the ash in response to filtration, aqueous extraction and centrifugation was carried out. The results point to suggested revisions of the process to be validated at larger scale to provide a more robust low level of ash.

2. Materials and methods

2.1. Chemicals

Chemicals (essentially used in Section 2.7) were of analytical grade and obtained from common lab suppliers. Chloroform, Hanus-solution (cI₂Br = 0.1 mol/l), sodium thiosulfate-pentahydrate, and soluble starch were the products of MERCK KGaA, Darmstadt, Germany. Potassium iodide and mineral oil (M-5904) were the products of SIGMA-ALDRICH (St. Louis, MI, USA).

2.2. Oil samples

Waste frying oil samples (1–2 l) were collected from critical points of the process facility at *Bioproduksjon AS*, as indicated in Fig. 1: Raw material (1), after dewatering step (2), after first filtration 400 µm (3), after second filtration 200 µm (4), end product tank (5), and reject from the first filter (6). A set of samples represents the production at a given date.

2.3. Centrifugation

Centrifugation was carried out at 8 500 ×g for 30 min on samples (60 ml) of the raw material and end product, at room temperature (22 °C) in a Beckman JA-20 rotor. The resulting supernatant from each sample was taken to ash analysis.

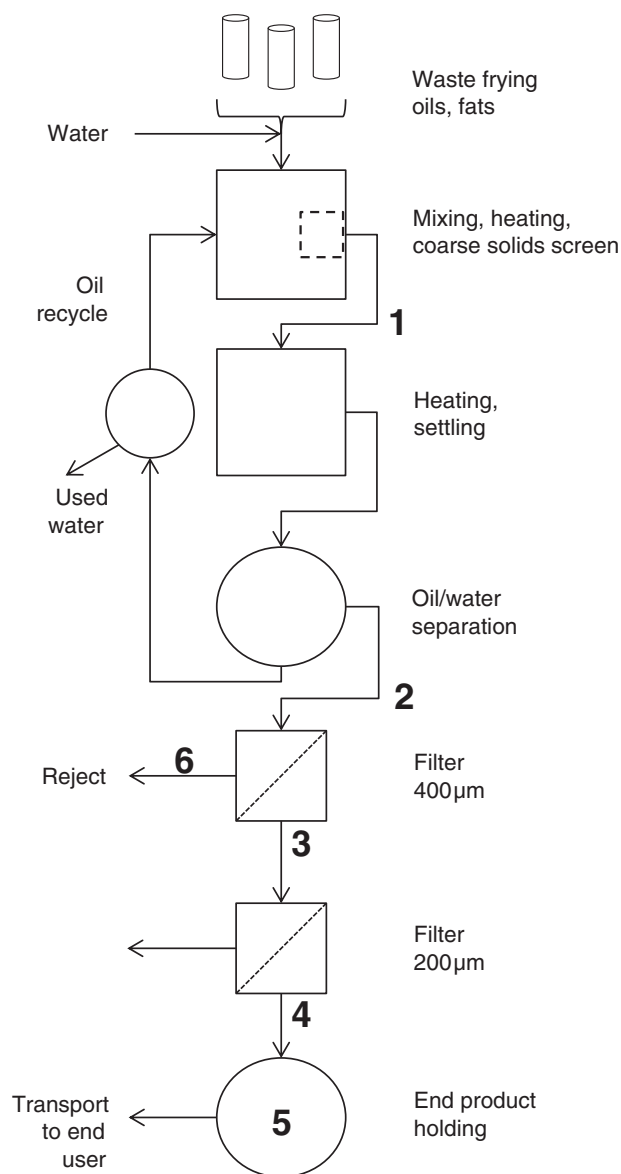


Fig. 1. The outline of a WFO to biofuel-oil production. Boldface numbers indicate the sampling points analyzed in this study, either taken from the process flow or holding tanks.

2.4. Filtration

For the filtration test was used an in-line filter holder with 50 mm polypropylene filters (Millipore™) with pore sizes 45 and 10 µm. In the setup, the oil was passed through the filter holder by a peristaltic pump (type 503U, Watson Marlow Ltd, Falmouth, UK) fitted with silicone tubing 6 mm i.d. The inlet side was equipped with a manometer and the positive pressure during filtration did not exceed 5 bars. Using this setup, the filtrated oil samples were tested for remaining ash content.

2.5. Aqueous extraction

The initial test for screening of extraction conditions was carried out as a two-level factorial design with center points. An oil sample (70 ml) was mixed with water by shaking for 1 min at different water:oil ratios (0.05–0.25) in a 100 ml conical separating funnel. The funnel was placed vertically on a stand in a heating cabinet and held at different temperatures (30, 40 and 50 °C) for 2.5–3 h until layers appeared visually well

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