Electrooxidation of Sesame Oil in Acid Electrolyte

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Abstract. The energy industry is based mainly on coal, crude oil, natural gas or nuclear energy. However, in recent years renewable energy sources have also become increasingly used. One of the devices that uses renewable energy sources is a fuel cell (FC). The fuel cell can be powered by hydrogen, methanol, hydrazine or other substrates. Commercial fuel cells use mainly hydrogen, methanol or hydrazine. Due to the fact that water is the only by-product, hydrogen is the considered to be the best fuel for fuel cells. Problems with hydrogen storage cause, however, that new fuels for FCs are very desirable. Vegetable oil seems to be such substance, application of which as fuel in FCs is possible. But in the first place, it is necessary to determine possibilities of electrooxidation of this fuel. The paper presents the research on sesame oil electrooxidation. The work shows results of electrooxidation of sesame oil emulsion on a smooth platinum electrode in acid electrolyte. The maximum stable current density reached in the tests was 5 mA cm^{-2}.

Keywords: Electrooxidation · Biofuel · Fuel cell · Environmental engineering · Renewable energy source

1 Introduction

In the past decades, alternative devices using renewable energy sources have been developing very fast. A fuel cell (FC) is one of these devices. The fuel cell is a type of a galvanic cell. However, whereas in a regular battery the energy is stored, in the FC the fuel and oxidant have to be supplied externally [1, 2]. In the FC the chemical energy of fuel is converted directly into electrical energy, without intermediate states [2–4]. FCs are characterized by high efficiency, silent operation and zero or low influence on the environment [2, 5].

The commercial fuel cells are powered mainly by hydrogen, methanol or hydrazine [6, 7]. Due to the fact that water is the only by-product, hydrogen is considered to be the best fuel for fuel cells [2, 5, 8]. Thus, FCs are most often powered by hydrogen. However, there is a problem with cheap storage and cheap production of this fuel [9–11]. Recently, more and more new renewable fuels have been researched and applied [12, 13]. One of these fuels can be vegetable oil, e.g. canola oil, which is often used as raw material to biodiesel fuel production [12, 14]. Recycled vegetable oil can be also used as fuel [15, 16]. The previous authors' research has shown a possibility of direct

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electricity production from canola or coconut oil [16–19]. The possibility of electrooxidation of sesame oil is shown in this paper.

Sesame oil is obtained from sesame seeds. This oil is mainly used in salad or cooking, also in cosmetics, soaps, paints and lubricants [20–22]. It can be used as a base substrate for production of biodiesel as well, e.g. by transesterification of sesame seed oil with methanol in the presence of NaOH as catalyst [23–25]. An internal combustion engine (diesel engine) fuelled with sesame biodiesel in terms of fuel efficiency, consumption and power has equal parameters compared to the one fuelled with mineral diesel. Moreover, it was noted that the environmental performance of biodiesel produced from sesame oil was superior to that of standard mineral diesel. Sesame oil can be blended with diesel fuel in different concentrations, e.g. B20%, B10% or B5%. It should be noted, that there is no noticeable change in engine power output even at 100% sesame biodiesel [26]. However, of importance is the question whether it is possible to use sesame oil for the direct production of electricity, bypassing the combustion process, e.g. in a FC. This paper presents the research on sesame oil electrooxidation on smooth platinum electrode in acid electrolyte, which allows for assessing the possibility of using sesame oil as fuel for FCs.

Current density (obtained in FCs) is the most important parameter that characterizes a FC and fuel for FCs [1, 2, 27, 28]. Theoretically, this parameter can be calculated from Butler-Volmer equation, but calculations often are not consistent with test results in real conditions [27, 28]. Therefore, the choice of fuel must be made by experimental methods. For this reason, this paper presents analysis of electrooxidation of sesame oil, which may contribute to design and building of a FC powered by this oil in the future.

2 Materials and Methods

Based on earlier studies a decision was made to add oil to the electrolyte. Due to hydrophobic properties of sesame oil it is difficult to mix it with water, therefore in order to add sesame oil to the electrolyte (aqueous solution of H_2SO_4) it is necessary to use a detergent [29]. As a detergent Syntanol DS-10 was used – it is a mixture of primary oxygen-ethylene-glycol ethers of fatty alcohol of C_{10}–C_{18} fraction [30]. This detergent is characterized mainly by high superficial activity [30, 31]. Moreover, Syntanol DS-10 is an environmental friendly detergent because it is fully degradable by bacteria [32].

First, an emulsion of sesame oil was prepared for measurements. The emulsion was obtained by mixing oil, detergent and water, in 1:1:2 proportions. A mechanical stirrer was for this purpose with speed of mixing set at 1200 rpm [33–35]. Emulsion stabilization time was 3 h.

Measurements were performed by the method of polarizing curves, using a smooth platinum electrode. The surface of working electrode (platinum electrode) was 6.28 cm^2. Platinum was chosen due to its excellent catalytic properties [27]. Saturated calomel electrode (SCE) was used as a reference electrode [36]. Measurements were carried out in a glass reactor, with acid electrolyte (H_2SO_4). The range of temperatures of measurements was 298–328K. The experimental set-up was equipped with AMEL potentiostat (System 5000), controlled by a computer with CorrWare software.

The scheme (Fig. 1) shows the scheme of the experimental set-up for electrooxidation of sesame oil emulsion (direct electricity production from sesame oil). The Fig. 2 shows the scheme of the reactor (glass vessel) applied for measurements.

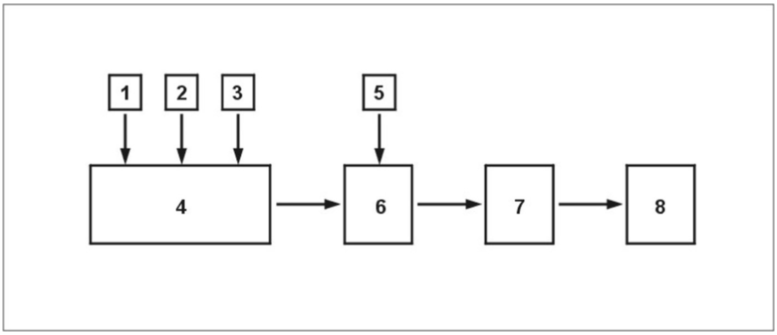

Fig. 1. Scheme of the research position: 1 – sesame oil, 2 – water, 3 – detergent, 4 – sesame oil emulsion preparation, 5 – electrolyte preparation, 6 – reactor (glass vessel), 7 – potentiostat, 8 – data analysis.

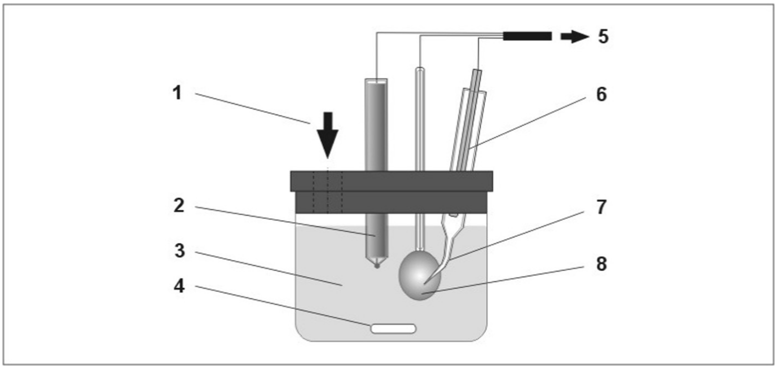

Fig. 2. Scheme of the reactor (glass vessel) for measurements of sesame oil emulsion electrooxidation: 1 – sesame oil emulsion, 2 – auxiliary electrode, 3 – electrolyte (aqueous solution of H_2SO_4) with sesame oil emulsion, 4 – stirrer bar, 5 – to potentiostat 6 – reference electrode, 7 – Haber-Luggin capillary, 8 – working (Pt) electrode.

First, before electrooxidation of sesame oil emulsion, measurements of electrooxidation of pure Syntanol DS-10 were carried out. Next, electrooxidation measurements of sesame oil emulsion were performed, for various concentrations of the oil (0.0025%, 0.0050%, 0.0100%, 0.0250%, and 0.0500% of working reactor volume) at temperatures ranging from 298–328K. The comparison of results from Syntanol DS-10 electrooxidation and sesame oil emulsion electrooxidation allowed for determining whether the electricity is generated from the electrooxidation of sesame oil or only from the detergent.

3 Results

The Fig. 3 shows the electrooxidation of emulsion at temperature 298K.

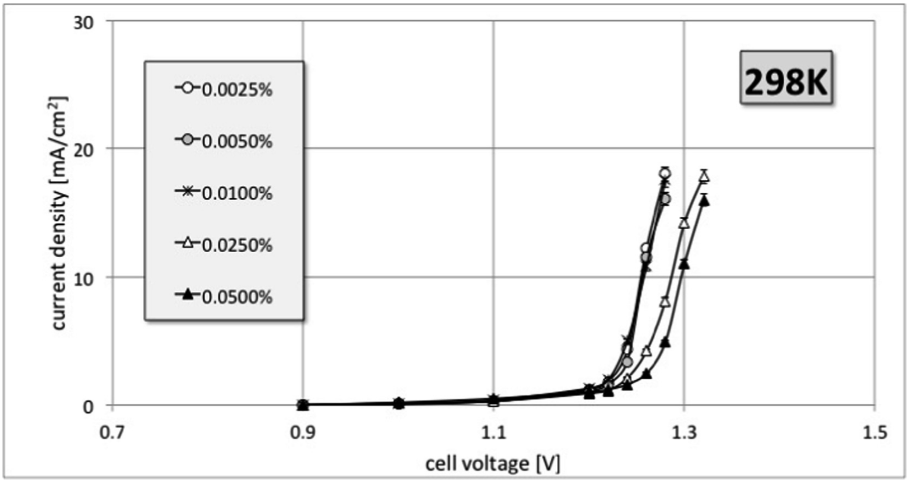

Fig. 3. Polarization curves of emulsion electrooxidation - 0.1n H_2SO_4, 298K – sesame oil concentration: 0.0025%–0.0500%

The Fig. 4 shows the electrooxidation of emulsion at temperature 308K.

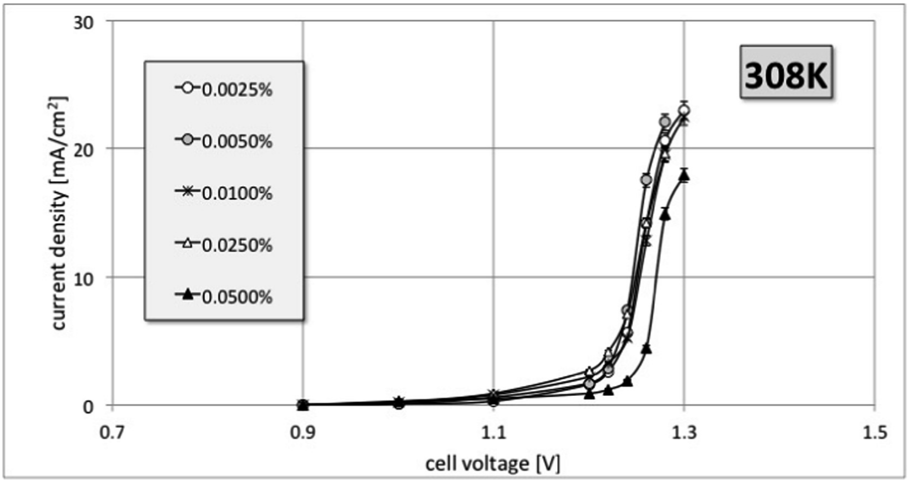

Fig. 4. Polarization curves of emulsion electrooxidation - 0.1n H_2SO_4, 308K – sesame oil concentration: 0.0025%–0.0500%

The Fig. 5 shows the electrooxidation of emulsion at temperature 318K.

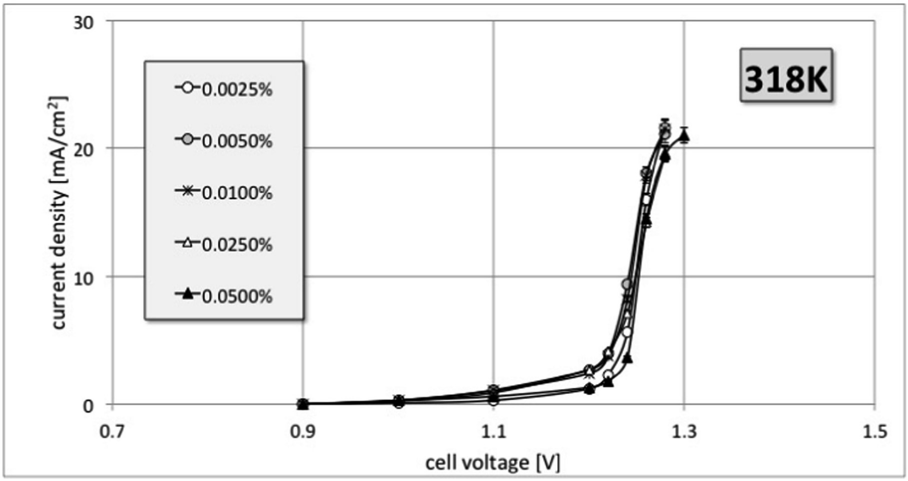

Fig. 5. Polarization curves of emulsion electrooxidation - 0.1n H_2SO_4, 318K – sesame oil concentration: 0.0025%–0.0500%

The Fig. 6 shows the electrooxidation of emulsion at temperature 328K.

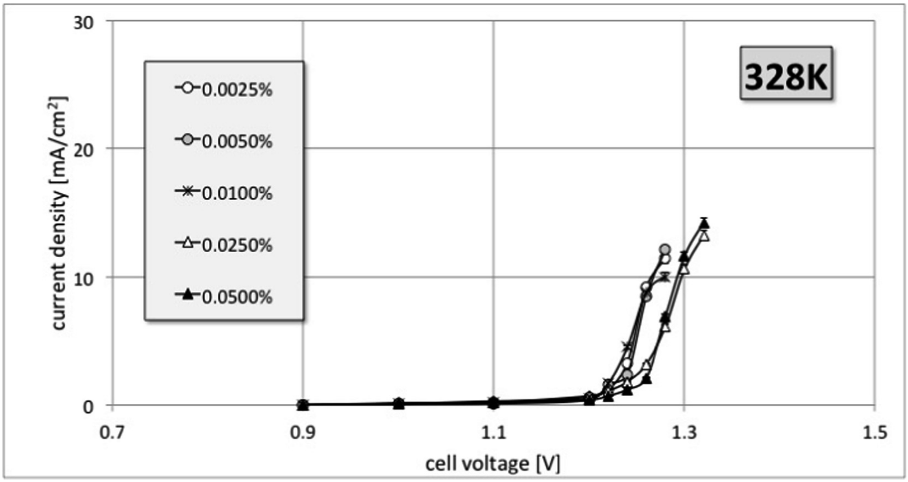

Fig. 6. Polarization curves of emulsion electrooxidation - 0.1n H_2SO_4, 328K – sesame oil concentration: 0.0025%–0.0500%

The potential of a working electrode was established in 20 min and was poorly reproducible. Real stationary potential was in the range of 0.51–1.14 V – this current-free potential depended on the concentration of sesame oil.

4 Conclusion

Despite obtaining low current density, the research data have shown that electrooxidation of sesame oil is the right direction of research. The electrooxidation of sesame oil emulsion occurred for all temperatures (298–328K) and for all tested concentrations of oil. The highest stable current density was obtained at the temperature 318K and it was equal to 5 mA cm^{-2}. The current density of about 1–3 mA cm^{-2} was obtained for all other analysed concentrations. Above the temperature 328K the current density begins to drop. Comparing the current density values above 328K for the Syntanol DS-10 electrooxidation and electrooxidation of sesame oil emulsions, it can be noted that in this temperature range electrooxidation of the detergent occurs in the first place, and only later electrooxidation of sesame oil. The presented results for sesame oil electrooxidation are close to data obtained during electrooxidation measurements of emulsions made of canola oil, waste canola oil or coconut oil [16–18]. Moreover, the data of sesame oil electrooxidation are also similar to electrooxidation of crude oil, diesel fuel or waste engine oil from agricultural machinery [33–35].

The possibility of electrooxidation of sesame oil emulsion (oil concentrations in the range 0.0025–0.0500%) on a smooth platinum electrode in acid electrolyte (0.1n H_2SO_4) in temperatures varying from 298 to 328K was shown in this paper. Thus, it can be stated that the electricity production from sesame oil without the process of combustion is feasible.

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