Sustainable Materials and Technologies 6 (2015) 1–5

Contents lists available at ScienceDirect

Sustainable Materials and Technologies

Turning pork processing waste into value-added chemicals for the food industry

Camila Dias Amorim [1], Aline Gomes Camilo [1], Clivaldo de Oliveira, Maria Eugênia Petenucci, Gustavo Graciano Fonseca *

Laboratory of Bioengineering, Faculty of Biological and Environmental Sciences, Federal University of Grande Dourados, Dourados, MS, Brazil

ARTICLE INFO

Article history:
Received 21 April 2015
Received in revised form 8 September 2015
Accepted 18 September 2015
Available online 30 September 2015

Keywords:
Fatty acids
Fractionation
Grease waste

ABSTRACT

Winterization is a method to modify the characteristics of oils and fats to provide added value by concentrating the unsaturated fatty acids. The purpose of this study is to characterize a residue from pork processing and evaluate two different fractionation methods via winterization. Furthermore, the fatty-acid composition and the chemical characterization were determined from the grease waste and the fractions obtained after fractionation. The untreated grease waste showed an acidity index of 0.57 mg KOH/g, a peroxide value of 10.74 mEq/kg, 56.45% unsaturated fatty acids and 43.55% saturated fatty acids, with the predominance of oleic, linoleic and palmitic acids. The experiment, which was performed in two cooling stages and stirred at 600 rpm, showed a decrease of 27.89% in the saturated fatty-acid content, which predominantly consisted of oleic, palmitic and stearic fatty acids. The winterization process improved the quality of the grease waste, reduced the peroxide value and concentrated the unsaturated fatty acids.

1. Introduction

Restaurants and households produce significant amounts of difficult-to-recycle wastes, waste cooking oils and waste fat, which can be valorized [1]. Thus, research on the recycling and valorization of these wastes is necessary. Modifying the physical structure of these grease wastes enables their valorization and increases their flexibility and applicability in the food industry [2,3]. Lipids have several food applications, mainly in baked goods, margarines, ice cream and chewing gums [4].

Changes in the lipid material can occur through the chemical modification of fatty acids (hydrogenation), reversal of the ester bond (hydrolysis), reorganization of fatty acids in the main chain of the triglyceride (interesterification) and separation of fatty acids (fractionation) [5]. Fractionation is a thermomechanical process to separate the triacylglycerol constituents of fats and oils. The resulting liquid (olein) and solid (stearin) fractions have different physical characteristics. Olein has a low melting point, and stearin has a high melting point [6]. The fractionation of oils, fats and fatty acid mixtures aims to obtain new products with broader applicability than the original ones. Olein and stearin are examples of these new products because olein can be used in the food industry in functional-food development [7,8], as an emollient in the cosmetic and soap industries, and in biodiesel production [9]. Stearin acts as a hydrogenated fat substitute in food formulation, and it is currently used in margarine production [10,11] and as a replacer for cocoa butter [12,13].

Winterization is a form of fractionation that involves the precipitation of fatty acids in crystals, which enables the fractions to be separated. Lipid crystallization is affected by many factors, particularly the method with which the lipids are cooled from their liquid state because, when oil is cooled, a solid phase separates, with the composition and amount mainly depending on the cooling rate and the initial and final temperatures [14].

Products with high lipid content, such as butter, margarine and vegetable creams, must have appropriate proportions of solid and liquid fractions to provide the desired texture and functionality (i.e., spreadability) in the products for consumers [15]. The rheological properties of lipid crystals from these products are also extremely important because many sensory attributes such as the spreadability, texture and mouthfeel depend on the mechanical strength of the crystal lattice [16].

The purpose of this study is to characterize an industrial residue and evaluate two different fractionation methods via winterization to improve the properties of the residue and add values and usabilities for other applications.

2. Materials and methods

2.1. Source of grease agro-industrial waste

The grease waste used in this study was obtained from an industrial pork-cooking process in a continuous cooking tunnel, which was heated

* Corresponding author at: Faculty of Biological and Environmental Sciences, Federal University of Grande Dourados, CEP 79.804-970, Dourados, MS, Brazil. Tel.: +55 67 3410 2211; fax: +55 67 3410 2190.
E-mail address: ggf@ufgd.edu.br (G.G. Fonseca).

[1] Both authors contributed equally to this work.

http://dx.doi.org/10.1016/j.susmat.2015.09.001

to 260 °C. Meat derived from pork belly, which contained approximately 50% fat, was frozen at −12 °C, sliced and arranged in the continuous cooking tunnel. In the process, the melted fat was removed and collected in tanks.

2.2. Collecting grease pork waste

A sample of 10 kg of grease waste was randomly collected from the storage tanks on different production days.

2.3. Fractionation of grease pork waste

The flowchart in Fig. 1 illustrates the steps to fractionate the grease pork waste via winterization. Table 1 describes the process parameters of winterization of grease waste from the cooking process.

Two experiments were performed. In Experiment A, a sample of grease waste was heated to 45 °C and rapidly cooled to 30 °C. Then, hexane was added at a proportion of 40% of the sample volume. The mixture was cooled to 5 °C for 1 h under vigorous stirring and subsequently cooled to 0 °C with a slow cooling rate of 2.5 °C/h under slow agitation. The fat crystals nucleated and appeared in the latter stages.

In Experiment B, a sample of grease waste was also heated to 45 °C but subsequently cooled to 30 °C at a rate of 15 °C/h, which was followed by the addition of 40% hexane in volume. Then the sample was cooled to 5 °C at a cooling rate of 5 °C/h and subsequently to 7 °C at a slow rate of 0.5 °C/h.

2.4. Chemical characterization

The samples of untreated grease waste, saturated and unsaturated fractions, which were obtained from the winterization process, were characterized based on their acidities, refractive indices and peroxide and iodine values according to the methodologies described by AOCS (1998) [17]. The moisture content was determined using the Karl Fischer method [17].

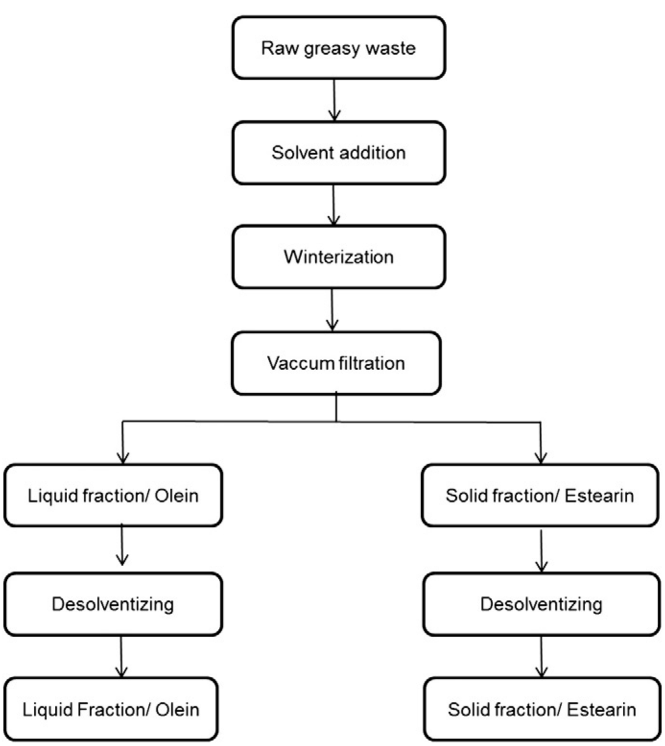

Fig. 1. Flowchart of the winterization process with a solvent.

Table 1
Operating conditions of the winterization process with a solvent.

Condition	Experiment A		Experiment B		
	Stage 1	Stage 2	Stage 1	Stage 2	Stage3
Initial temperature (°C)	30	5	45	30	15
Cooling rate (°C/h)	25	2.5	15	5	0.5
Stirring (rpm)	600	100	300	100	100
Final temperature (°C)	5	0	30	15	7

2.5. Determination of the fatty-acid composition

The fatty-acid composition was determined by preparing methyl esters according to a methodology described elsewhere [18]. The fatty acid methyl esters (FAME) were identified using gas chromatography coupled to mass spectrometry, GC-MS model Agilent 7890A, which was equipped with a 30 m × 0.25 mm × 0. 25 μm HP-5 MS capillary column, and helium was used as the carrier gas in a 1:10 split ratio. The analyses were performed from 180 °C to 300 °C at a heating rate of 10 °C/min. The temperatures of the detector and injector were set at 325 °C and 300 °C, respectively. All determinations were performed in duplicate.

The FAME were identified by comparing the retention time of the constituents of the sample with a mixture of 19 fatty acid methyl ester standards (Sigma-Aldrich) and by comparing with the mass spectra of the NIST MS Search 2.0 library, which is included in the chromatograph's software. Quantification was performed using the area normalization method.

2.6. Statistical analysis

The results were subjected to variance analysis (ANOVA) at 5% significance and by means of Tukey's test using the Statistica 5.0 software (Statsoft, USA, 1995).

3. Results and discussion

3.1. Characterization of the raw material

Table 2 shows the acidity index, refractive index, peroxide and iodine values and moisture content of the untreated grease waste from the industrial pork-cooking process, which was used as the raw material.

The untreated grease waste showed an acidity index of 0.575 mg NaOH/g, which was lower than the reported values for crude oil from carp (*Cyprinus carpio*) viscera (0.957 mg NaOH/g) [19] and shad fish oil (4.63 mg NaOH/g) [20]. The peroxide value (10.744 ± 1.180 mEq/kg) was higher than the values of golden mullet fish oil (3.15 mEq/kg) [20], crude oil from carp viscera (3.38 mEq/kg) [19] and flaxseed oil (6.96 mEq/kg) [21]. Nevertheless, the peroxide value of the grease waste slightly exceeded the established limit of 10 mEq/kg by Codex Alimentarius Commission (1999) [22], which indicates that the sample was unsuitable for consumption.

The iodine value was 82.21 cg/g, which is higher than the previously reported value [20] for shad fish oil (19.7 cg/g) and lower than the value

Table 2
Characterization of the grease waste from the industrial pork-cooking process.

Parameter	Content
AI (mg/g)	0.575 ± 0.150
PV (mEq/kg)	10.744 ± 1.180
II (cg/g)	82.212 ± 0.673
RI at 40 °C	1.471 ± 0.001
Moisture (%)	0.354 ± 0.030