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Mariia TARADAICHENKO, Fedor GLADKII

e-mail: m.taradaichenko@gmail.com

[1] **Department of Heat and Mass Transfer, Faculty of Process and Environmental Engineering, Lodz University of Technology, Lodz, Poland**

[2] **Department of Technology of Fats and Fermentation Products, Faculty of Technology of Organic Substances, National Technical University "Kharkov Polytechnical Institute", Kharkov, Ukraine**

Application of electromagnetic treatment for degumming process in high phosphorus content of sunflower oil

Introduction

Degumming process is the first stage of vegetable oil refining. The main target of this process is to remove phospholipids from the oil before further storage or processing. Degumming is an indispensable process in vegetable oil production. The presence of phospholipids in oil significantly affects technological properties of oil. During oil refining processes where water solutions are used phospholipids stabilize water-in-oil emulsion resulting in a limited separation of phases [*Andersen,1962*]. Phospholipids reduce catalyst activity during biodiesel production, i.e. the transesterification of vegetable oils. [*Fan et al., 2010*]. Degumming process is required before direct application of vegetable oil as a biofuel, because presence of phospholipids leads to a soot formationin the combustion chamber of the engine [*Zufarov et al.*, 2009]. Consequently, the upper limit of phosphorus content in degummed oil is 79 ppm for oil produced for human consumption [*State Standard of Ukraine, 4492:2005*] and 12 ppm for oil used as a biofuel [*Standard* DIN V 51605, 2010].

The traditional method of phospholipids recovery from the oil is the water degumming which based on amphiphilic properties of phospholipid molecules. In the presence of water in the oil, phospholipids coagulate and become oil-insoluble, which allows them to be removed from the oil by separation process. To obtain oil with a low final content of phospholipids (in the range from 30 to 5 ppm), many different techniques of chemical degumming such as acid degumming, TOP degumming, superdegumming and soft degumming have been employed. The major demerits of these techniques are high consumption of water and chemicals, generation of polluting effluents and loss of phospholipids [*Jiang et al., 2011*]. Alternative methods such as enzymatic degumming [*Dijkstra, 2010*], electrolyte degumming [*Nasirullah, 2004*] or ultrafiltration using membranes [*Koris and Marki, 2006*] have been recently raising a great practical interest, however these methods are quite costly.

Phospholipids recovered by means of degumming process are commonly used for the lecithin production. The lecithin is a food-grade emulsifier widely applied in food processing and pharmaceutical industry. The potential of application in food production as well as market value of lecithin is directly depends on the concentration of phospholipids and a content of impurities in the lecithin.

A scheme of the technology that allows for a threefold increase of yield of high quality lecithin in a sunflower oil solvent extraction plant is shown in Fig. 1. Crude lecithin (oil to phospholipids ratio 60:40) is mixed with miscella (oil-in-hexane solution). Subsequently, the mixture is delivered to filtration in order to remove impurities. Then hexane is separated from oil by distillation. Thereby extracted oil with high phosphorus content can be obtained. Further degumming of oil results in enhanced yield of lecithin with higher concentration of phospholipids (oil to phospholipids ratio 40:60). In the literature there is no description of studies in the degumming process of sunflower oil with addition of phospholipids.

In this work an attempt was made to improve degumming process of oil with addition of phospholipids using an alternative method of degumming, i.e. degumming with electromagnetic (EM) treatment. This method make it possible to intensify phospholipids removal. The EM treatment is carried out in the activator depicted in the Fig. 2. Originally, the EM activator was designed for the waste water treatment and has never been applied before for the degumming process of vegetable oils.

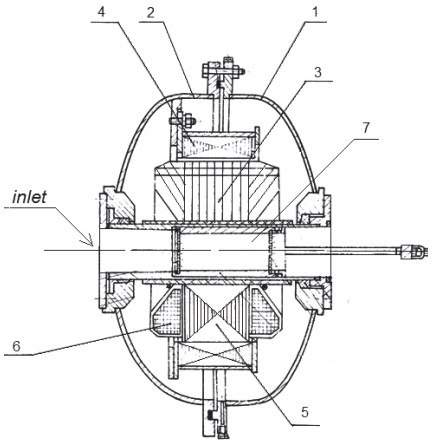

Fig. 1. Scheme of new technology for edible sunflower lecithin production

The activator is capable of working in the large scale and it can be easily added to the existing production line without replacement of any equipment.

There is a lack of publications available in the literature dealing with application of EM treatment in degumming process. Only works of *Kornena et al.* [*1963*]consider process of degumming with activation in spinning EM field. The stage of EM activation was carried out in two separate units: in mixer and in coagulator, which comprise elements generating EM field.

The first aim of this work is to study influence of phospholipids addition on the process duration and final phosphorous content in oil after water degumming. The second aim is to check effectiveness of degumming process with application of EM field for high phosphorous content sunflower oil and to prove that EM activator presented in this work can be applied for degumming process intensification.

Materials

Crude extracted sunflower oil and crude sunflower lecithin applied in the research were produced by *Doneck Sunflower Seeds Crush Plant*. Phosphorus content in oil and crude lecithin was 848 ppm and 17123 ppm resp.

The samples of sunflower oil with high phosphorous content were prepared in the following way: initially miscella with oil concentration of 25% (v/v) was prepared. In the next step crude lecithin was dissolved in the miscella (in the amount of 6.45 g phosphatide concentrate per every 100 g of oil) and then the mixture was filtered and the solvent was evaporated. The mixture was dried in an oven at 105°C till constant weight was achieved. The sunflower oil with the phosphorus content of 2000 ppm was obtained.

Methods

The standard water degumming process was conducted in the laboratory installation which consisted of a heater, water bath, beaker (expositor), stirrer ,water doser and thermometer. The sample of sunflower oil (200g) was placed in the 500 ml beaker which was heated on the water bath maintained at 75°C. Then 2,2 wt% of water was added to oil with phosphorous content 848 ppm and 5,0 wt% of water to oil with phosphorous content 2000 ppm (this quantities comes from phospholipids to water ratio 1:1 as phosphorous content in oil 848 ppm and 2000 ppm corresponds to phospholipids content 2,2 wt% and 5,0 wt% resp. in recalculation to stearoleolecithin).The mixture was stirred by agitator at 39 rpm for 15 minutes unless otherwise stated. After phospholipids exposition mixture was centrifuged at 3000 rpm for 15 minutes. The degummed oil was removed by decantation.

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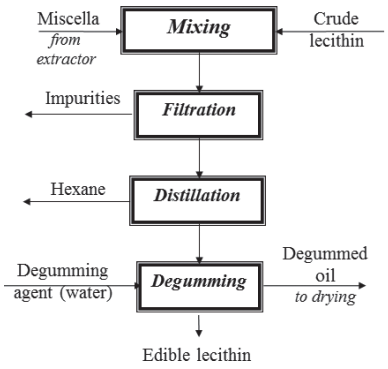

Fig. 2. Construction of B100-K09 electromagnetic activator: *1,2* – caps, *3* – inductor, *4* – stator, *5* – pole, *6* – coil, *7* – reaction vessel

To carry out process of degumming with EM treatment the procedure of standard water degumming was supplemented with stage of oil treatment in the activator which generates spinning EM field. The EM field is generated by the inductor 3 which consists of the stator 4 assembled from the steel sheets. Poles 5 and coils 6 are attached to the stator (Fig. 2). The activator can be used in both industrial and laboratory scale processes (for latter case the device is provided with a reaction vessel 7) [*EM activator B100-K09*]. When required amount of water was added to the oil, water and oil mixture was transferred from the beaker to the reaction vessel of EM activator. The reaction vessel filled with oil and water mixture was placed in the working zone of the activator for 1-2 seconds. The magnetic induction in the working zone of activator was 0.13T. In the next step the treated oil was moved to the beaker-expositor and further procedure was carried out as in the standard degumming process.

Every test in water degumming as well as degumming with EM treatment was performed twice.

Phosphorus content in the oil after degumming was determined by the colorimetric method [*State Standard of Ukraine* 7082:2009].

Results and discussion

Experimental tests in degumming were carried out for three cases:

A. standard water degumming of oil without addition of phospholipids (natural phosphorus content 848 ± 11 ppm);
B. standard water degumming of oil with high phosphorus content (2000 ± 16 ppm);
C. water degumming with EM treatment of oil with high phosphorus content (2000 ± 16 ppm).

The final phosphorus content (P-content) in the degummed oil was determined for different times of oil and water mixture exposition. Results of the tests are given in Tab. 1.

Tab. 1. Results of the experiment

Test no.	Case study	Initial P-content in crude oil, ppm	Exposition time, min	Final P-content in degummed oil, ppm
1	A	848 ± 11	15	498 ± 9
2			30	80 ± 7
3	B	2000 ± 16	15	1250 ± 15
4			50	86 ± 7
5			70	83 ± 6
6	C	2000 ± 16	9	24±2

Values of phosphorous content are the mean ± standard deviation of at least 2 determinations.

Tests 1 and 3 were carried out for the exposition time of 15 minutes according to the methodology of sunflower oil water degumming process [*Vengerova, 1963; Zufarov et al., 2009*]. Results of the tests showed that 15 minutes of exposition was not enough to achieve desirable final phosphorous content for both oil samples with low and high phosphorous content. In further experiments the exposition was conducted until visible formation of phospholipids precipitate will occur [*Niewiadomski, 1972*]. For oil with initial phosphorous content 848 ± 11 ppm the precipitation of phospholipids was found after 30 minutes of exposition and final phosphorous content of degummed oil was 80 ± 7 ppm. For oil with high phosphorous content 50 minutes of exposition was needed for precipitation of phospholipids. In this case final phosphorous content in degummed oil was 86 ± 7 ppm. Further increasing of exposition time to 70 min. has led to any significant enhancement of phospholipids removal. Taking into account accuracy of colorimetric method applied in this work for phosphorous content determination one can make a conclusion that final phosphorous content obtained in both cases A (test 2) and B (tests 4,5) are comparable and very close to required 79 ppm.

In order to improve phospholipids recovery for oil with high phosphorus content degumming with EM treatment was applied (case C). After contact time 9 minutes phospholipids coagulation occurred and phosphorus content in the degummed oil reached 24 ppm. Similar values of the phosphorus content could be achieved till now using only high-cost processes such as acid degumming [*Mag and Reid, 1980*] or enzymatic degumming [*Dahlke, 1998*] to name a few. It should be mentioned also that a consistence of the lecithin recovered by degumming with EM treatment differed greatly from that obtained by standard water degumming. The lecithin obtained due to EM treatment had more smooth and flowing consistence.

Enhancement of the phospholipid removal as well as quality of the lecithin due to influence of EM treatment can be explained by increase of phospholipid molecules polarity in the EM field. However, wider use of degumming method with application of EM field requires extensive investigation of the phenomena which occur during the process.

Conclusions

The water degumming process of oil with addition of phospholipids was investigated in this work. An alternative method of degumming, i.e. the degumming with EM treatment was applied for oil with high initial phosphorous content.

It was proven that addition of phospholipids to oil leads to increasing duration time of the standard water degumming process, however final phosphorous content in degummed oil is comparable for both oil samples with low and high initial phosphorous content.

Degumming process with application of EM field found to be suitable for degumming of sunflower oil with high phosphorous content in terms of contact time required for phospholipids exposition and quality of lecithin obtained. Furthermore, degumming with EM treatment can be applied in the production of degummed oil with a low final phosphorous content in the range from 20 to 30 ppm.

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