Product Soap from Waste Cooking Oil

Weixin Li, Rui Guan, Xiaoyue Yuan, Haiyang Wang, Shuqi Zheng, Lu Liu, Xiangyun Chen*

College of Light Industry and Textiles, Inner Mongolia University of Technology, Hohhot, China
lzg05006@163.com

Abstract. Waste cooking oil (WCO) is a good candidate as a material to make soap. It is typically cheaper than other oils. In this study, we have investigated the operation of produced soap from waste cooking oil. Phosphoric acid-hydration was provided for WCO degumming. The operating temperatures is 60 °C, phosphoric acid concentration is 2% and 4% content of moisture is the optimum technology of degumming. The most favorable decoloring agent is activated clay, WCO and activated clay ratio of 100:5 at 70 °C with 30 min treated time. The optimal technology of saponification is that the mass ratio of NaOH and WCO is 0.3:1, saponification temperature is 100 °C and the concentration of NaOH is 30%.

1. Introduction
WCO generated by-restaurants, fast food outlets, and food processing industries every day and everywhere around the world. The abandoned WCO caused water pollution and land pollution and difficult to be degraded. Statistically, by 2017, annual WCO production is around 4 million tones in China. At present, it is a wise idea that we can reuse the WCO to save the energy and prevent environment from being polluted. WCO could be recycled to be a potential alternative raw material for many areas. It is mainly applied in production of biodiesel, chemical raw materials, feed and demeshing agent of concrete product. WCO is one of the low-cost raw materials for making soap.

Producing biodiesel is the most common research direction for the utilization of WCO. MdEhsan and Edgar M. Sánchez Fabare et al.[1,2] had production of biodiesel using alkaline based catalysts from waste cooking oil, Mega NurSasongko [3] studied the percentage effect of WCO mixture in biodiesel fuel on droplets combustion characteristics. WCO also can be available for biomass production. M. S. Alvarez Serafini et al.[4] had studied the synthesis of fatty acid methyl esters using crude olive pomace oil as raw material. Waste cooking oils was used as feedstock for lipase and lipid-rich biomass production by Marlene Lopes et al.[5]. M.s. Alvarez Serafini et al.[4] produced the fatty acid methyl esters from an olive oil industry waste. WCO preprocessing is another research aspect, Bio-removal of phenanthrene, 9-fluorenone and anthracene-9, 10-dione by laccase from Aspergillusniger in waste cooking oils was studied by Chong Teng et al.[6].

Xiang-nan Zhu et al.[7] studied a renewable soap collector from waste oil was prepared by alkaline hydrolysis, and was subsequently applied to the flotation test of fluorite.

In this work, WCO was used as raw material to making soap which was filtered, degumming and decolorized before. Processing of soap making was investigated in this paper by single factor and orthogonal experiments, then the optimum process parameters were determined.
2. Experimental

The raw material of WCO was obtained from the canteen in Inner Mongolia, China. The sample was filtered three times by filter cloths, the solid particles were filtered from the solution. The WCO was heated to 100°C to remove the moisture in it. Phosphoric acid–hydration method was used for degumming, the curve of process was shown in Figure 1. Base on physical absorption mechanism, active clay were conducted to decolorize. Saponification reaction was acted by heterogeneous reaction heating by water bath, the reaction is oil in alkaline conditions of hydrolysis reactions. Saponification process is shown in Figure 2.

3. Results and discussion

3.1. Degumming of phosphoric acid–hydration method

According to the process of Figure 1, water in degumming oil was removed by centrifugal at 3000 rpm for 5 minutes. The liquid sample is divided into two layers. The upper is the oil layer while the below is the water and coagulation layer. There is few solids precipitation attached to the wall of the tube, the reason is some free metal ions in the oil combine with acid radicals. Figure 3 shows the experimental phenomena.

The mine composition of the colloid in WCO is phospholipid. There are two forms of the phospholipid, hydrated phospholipids (HP) and non-hydrated phospholipids (NHP). NHP will be converted into HP by phosphoric acid. HP condensate formation after water swelling, then the phospholipid is removed.

The degumming loss rate can be calculated on the basis of the weight variation of the WCO. That can be expressed by Eq. 1.

$$C = \frac{W_0 - W_1}{W_0} \times 100\%$$

Where C is degumming loss rate, $W_0$ is the weight of WCO degumming before; $W_1$ is the weight of WCO degumming after. The value of C is 53.52%.
3.2. Decoloration of the WCO

The activated clay was added slowly into WCO and stirring constantly. Keep the set constant temperature for the set time, centrifugal separation with 3000 r/min, RCF=9.9×100g for 5 minutes. The absorbance can be determined directly by spectrophotometer in λ_max=436nm.

Methods Orthogonal experiment was used to determine the optimal absorbancy with the mass fraction of activated clay, decoloring temperature and decoloring time as markers. Orthogonal factors were shown in Table 1.

Decolourization ratio can be calculated on the basis of the absorbancy. That can be expressed by Eq. 2.

\[ D = \frac{A_0 - A}{A_0} \]  
\[ (2) \]

Where D is decolourization ratio, \( A_0 \) is the absorbancy of WCO decoloring before, the value of \( A_0 \) is 0.744; A is the absorbancy of WCO decoloring after.

| NO. | Factors | Decoloring temperature /℃ | Decoloring time /min | Activated clay mass fraction/% | A   | D /%    |
|-----|---------|-----------------------------|----------------------|-------------------------------|-----|---------|
| 1   |         | 60                          | 15                   | 3                             | 0.107 | 85.618  |
| 2   |         | 60                          | 30                   | 4                             | 0.116 | 84.409  |
| 3   |         | 60                          | 45                   | 5                             | 0.146 | 80.376  |
| 4   |         | 70                          | 15                   | 4                             | 0.114 | 84.677  |
| 5   |         | 70                          | 30                   | 5                             | 0.105 | 85.887  |
| 6   |         | 70                          | 45                   | 3                             | 0.143 | 80.780  |
| 7   |         | 80                          | 15                   | 5                             | 0.171 | 77.016  |
| 8   |         | 80                          | 30                   | 3                             | 0.122 | 83.602  |
| 9   |         | 80                          | 45                   | 4                             | 0.113 | 84.812  |

We can see from Table 1, the experimental parameter of NO.5 get the high decolourization ratio value. That is warming up the sample to 70℃ and keep 30 min. NO.7, 6 and 3 get the low value of decolourization ratio. One of the reason could be the high temperature and the long holding time makes the WCO oxidized and produce the new pigment, another reason is that the low mass fraction of activated clay make the pigment residue. NO.5 is the optimal experimental parameter for WCO decoloring process.

3.3. Saponification process

Heterogeneous reaction method was acted for Saponification process. The method can realize saponification reaction in one-step and get the soap base. The products of this reaction is emulsus saponifiables, which can easy to be salted out, molded and dried though at low reaction rate and long reaction time.

Methods Orthogonal experiment was used to determine the optimal saponification rate and pH range with the mass ratio of NaOH and WCO, saponification temperature and NaOH concentration as markers. Orthogonal factors were shown in Table 2.

Saponification ratio can be calculated on the basis of the concentrate of the residue NaOH. That can be expressed by Eq. 3.

\[ S = \frac{C_0 - C_1}{C_0} \times 100\% \]  
\[ (3) \]

Where S is the saponification ratio, \( C_0 \) is the concentrate of NaOH; \( C_1 \) is the concentrate of the residue NaOH. Saponification time is fixed at 30 minutes for this experiment.

It can be seen from Table 2 that No.5 experiment get the highest saponification ratio value, No.8 can be set because of the higher saponification ratio value. From the soap quality perspective, there are some bubbles in No.5 soap production for the too high saponification rate. NO.8 is the optimal parameters.
Table 2. Orthogonal factors of saponification process

| NO. | Temperature /℃ | NaOH:WCO | Concentration of NaOH /% | pH range | S /% |
|-----|-----------------|-----------|--------------------------|----------|------|
| 1   | 80              | 0.3:1     | 30                       | 7-8      | 70.83|
| 2   | 80              | 0.4:1     | 40                       | 8-9      | 76.34|
| 3   | 80              | 0.5:1     | 50                       | 8-9      | 84.36|
| 4   | 90              | 0.3:1     | 40                       | 7-8      | 74.61|
| 5   | 90              | 0.4:1     | 50                       | 7-8      | 90.54|
| 6   | 90              | 0.5:1     | 30                       | 7-8      | 87.41|
| 7   | 100             | 0.3:1     | 50                       | 8-9      | 81.27|
| 8   | 100             | 0.4:1     | 30                       | 8-9      | 89.78|
| 9   | 100             | 0.5:1     | 40                       | 9-10     | 79.12|

4. Conclusions
In this research, the process experimental of degumming, decoloration and saponification of WCO were determined by orthogonal experimental method, the experimental conditions were optimized. Our results showed the following:

1) Phospholipids micelle in WCO will affect the combine stability of oil and NaOH. Phosphoric acid–hydration method can remove HP and NHP in the WCO. The value of degumming loss rate is 53.52%.

2) The sample color is tan after filtered and decoloration. Decolorizing with activated clay. The most suitable technological parameters is that processing for 30 minutes at 70℃. The mass ratio of WCO and activated clay is 100:5.

3) Methods Orthogonal experiment was used to determine the optimum saponification technology. The mass ratio of NaOH and WCO is 0.3:1, saponification temperature is 100℃ and the concentration of NaOH is 30%.

Acknowledgments
This work was financially supported by undergraduate innovation program of Inner Mongolia (201810128010).

References
[1] Md Ehsan, Md Tofajjal Hossain Chowdhury. Production of Biodiesel Using Alkaline Based Catalysts From Waste Cooking Oil: A Case Study[A]. Procedia Engineering[C]. 2015,105: 638-645.
[2] Edgar M. Sánchez Faba, Gabriel O. Ferrero et,al. Alternative Raw Materials to Produce Biodiesel through Alkaline Heterogeneous Catalysis [J]. Catalysis. 2019,690 (9): 1-14.
[3] Mega Nur Sasongko. Droplet Combustion Characteristic of Biodiesel Produced from Waste Cooking Oil[A]. International Conference on Mechanical Engineering Research and Application.2019.
[4] M. S. Alvarez Serafini, G. M. Tonetto. Production of Fatty Acid Methyl Esters from an Olive Industry Waste [J]. Brazilian Journal of Chemical Engineering Grain and Oil.2019, 36 (1): 285-297.
[5] Marlene Lopes, Silvia M. Miranda et al. Waste Cooking Oils as Feedstock for Lipase and Lipid-Rich Biomass Production [J]. European Journal Lipid Science and Technology. 2019 (121): 1-9.
[6] Chong Teng , Shimin Wu et al. Bio-removal of Phenanthrene, 9-fluorenone and Anthracene-9,10-dione by Laccase from Aspergillus Niger in Waste Cooking Oils[J]. Food Control.2019,105:219-225.
[7] Xiang-nan Zhu*, Xian-jun Lyu et al.Clean utilization of waste oil: Soap collectors prepared by alkaline hydrolysis for fluorite flotation[J].Journal of Cleaner Production.2019(240):1-6.