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Optimum conditions for producing oil-base with certain melting point through transesterification

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ABSTRACT

The study found that, through ester exchange, palm oil and corn oil can produce the oil-base of margarine which has rich content of unsaturated fatty acids and produce no extra trans fatty acid. Such oil-base of margarine produced by palm oil and corn oil is beneficial for health. If the melting point of the oil-base is controlled at around 37, it can be well absorbed by humans. Therefore, the research considered four parameters (matching ratio of oil, temperature of reaction, time of reaction and dosage of catalyst) and designed five levels (different combination of the four parameters). Through orthogonal experiments, the qualified value of each four parameter when the melting point of the oil-base is 37 can be obtained, which is considered to be the best conditions of reaction.

Keywords: *oil base, margarine, fatty acids, palm oil, orthogonal experiments, corn oil.*

1. INTRODUCTION

Generally, the cream can be divided into two categories, natural cream and margarine. The natural cream is rare in quantities and expensive with a high fat content. Nonetheless, compared to natural cream, the margarine has high nutrition which can be controlled, better flavoring and low in price. Plus, its qualified flexibility and workability are necessary in food production. Therefore, margarine is well recognized and considered to be the substitute of the natural cream [1]. In 1980s, with China's reform and opening-up, western and eastern food culture was combined. In result, western food, especially the bread, received a great deal of gratifying attention and margarine industry in china obtained flowering of developments [2].

In margarine, the oil phase generally takes up 80 percent of the entire phases. In early days, the margarine took the material of animal oil and fat as the material, such as lard and butter, and was produced through mixing, emulsification and cooling. Such method was gradually eliminated due to unstable melting point of oil-base and rich content of cholesterol [3]. The current methods to produce margarine utilize hydrogenation of vegetable oil reducing the unsaturation to meet the requirements of melting point and hardness of production. However, the hydrogenation strictly relies on metal catalyst such as Ni and Cu. Although hydrogenation decreases the contents of cholesterol, it also reduces some beneficial unsaturated fatty acids such as linoleic and linolenic acid and produces trans fatty acids which is harmful for health. Those disadvantages to some extent limit hydrogenation in the production of margarine [4-5]. Furthermore, the negative sides of the trans fatty acids produced by hydrogenation process have been demonstrated to be harmful to human's health. In 1990, the Dutch scientist, Rondld Mensink, indicated that feeding of trans fatty acids could possibly increase the content of LDL (Low Density Lipoprotein) in serum which was illustrated to be counter-health and naturally decrease the content of HDL (High Density Lipoprotein) which was healthy. In 1994, America's association of shortening and edible fat published the similar view. Latter Scientist, Joseph Jared, of America's Nutrition Research Centre trans fatty acids could possibly lead to cardiovascular disease due to its negative influence to health. Plus, FAO (Food and Agriculture Organization) and WHO (World Health Organization) frequently reported the harmfulness of feeding trans fatty acids. Consequently, in 1950s, Feuge successfully utilized hydrogenated bean oil and olive oil through random transesterification in place of hydrogenation to produce plastic fat. Chobanov utilized lard, butter and sun-flower seed oil to produce margarine oil-base through transesterification and analyzed the regulations of components and changes of glycerides. The oil-base produced by trasesterification demands common basic catalyst such as NaOH and create no extra trans fatty acids [6-8]. On contrast to hydrogenation, margarine oil-based fabricated through trasesterification obtained wild concentrations due to its advantages which can be concluded as simple manufacture, no production of extra trans fatty acids, better flavoring [9-10].

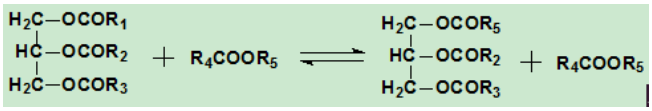
2. EXPERIMENTAL SECTION

The vitamin E (tocotrienols, 600-1000mg/Kg), carotenoid (500-700mg/Kg) and linoleic (10%) are particularly rich in olive oil which is beneficial for health. The research analyzing comprehensively the effect of olive oil to different races proved that the olive oil met the requirements of health. The corn oil has high contents of vitamin E and unsaturated fatty acids which takes

up 80 percent in which linoleic and oleic acid are main parts. In particular, linoleic takes up 50 percent of the whole fat. It is well known that linoleic as an essential fatty acid cannot be made by the human body but must be supplied by food or drugs. It can sufficiently reduce the contents of cholesterol and blood pressure in human body while relax stiffness of blood vessels and improve the functions of muscle and cardiovascular system, which is necessary for prevention and amelioration of arteriosclerosis lowering the heart attack ratios. It can also relive the inflammation of the prostate gland and ease the dermatitis.

In the experiment, the melting point of the olive oil is 47 with the acid value of 0.24mg KOH. The corn oil is liquid with the acid value of 0.24mg KOH. The catalyst is caustic alcohol.

There are three kinds of ester exchange reaction: alcoholysis, acidolysis and ester-ester [11]. The research choose two kinds of vegetable oil using ester-ester exchange to obtain the oil-base in which the melting point is 37. Accordingly, the conditions with the melting point of 37 of the oil base are the mission. The ester-ester eaction equation is shown as follows according to the material selected.



The analysis of optimum conditions producing the oil base with the melting point of 37□ was made using orthogonal design methods to select the representative experiments and avoid repeated tests. Plus, the orthogonal experiments cover sufficient situations for obtaining an overall awareness. Thus, its simplicity, efficiency and high quality are essential guarantee of the experiment [12-13].

In the experiment, the ester exchange reaction conditions contain four parameters: matching ratio of oil (mass ratio, olive oil/ corn oil) temperature of reaction, time of reaction and dosage of catalyst. Five levels are designed to consider the combination of the four parameters with a range of value. According to the four parameters and five levels designed, the orthogonal table is determined as L_{25} (5^6) in which only four parameters are considers. L represents the orthogonal table; 25 means the experimental numbers; 6 means the numbers of parameters but only 4 principal one are considered; 5 means the levels. In terms of the orthogonal table shown as table 1, the optimum conditions producing the oil-base with the melting point of 37□ can be found through 25 tests.

experimental procedure, olive oil and corn oil are mixed with certain mass ratio. Then the mixture is put on the magnetic stirring apparatus with a vacuum to guarantee a vacuum degree of 0.008MPa. During the mixing process, the temperature is kept (95), stirring for 1 hour is required to eliminating water. Then add the catalyst and keep stirring until the termination of the reaction; drip a few drops of acids to make the mixture neutral; heat the thin salt water with the concentration of 5% to 90□ and heat the oil mixture to 100□; spray heated t water into hot oil mixture and stir to purge the oil. Then, the mixture is allowed to separate into layers and wastewater of the bottom layer is drop out. After 3 times of purge and then dewatering, the esterification oil as the oil-base is obtained. After the suspension of the oil-base until entire solidification, the melting point is tested [14].The experimental apparatus is shown as figure 1.

Table 1. Orthogonal Design.

Factor / Level	mass ratio of oil(A)	Reaction temperature/ (B)	Reaction duration /min(C)	Catalyst dosage /g(ωt%)(D)
1	2:1	80	30	0.1
2	3:1	90	45	0.15
3	3.5:1	100	60	0.2
4	4:1	110	75	0.25
5	6:1	120	90	0.3

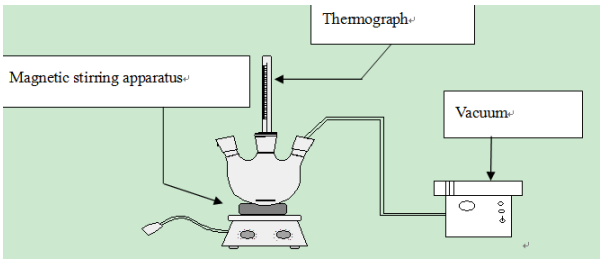


Figure 1. Experimental apparatus.

3. RESULTS SECTION

According to the orthogonal design, the results of 25 tests are shown in table 2. In the table, number 1 corresponds to 4 parameters under level 1, the melting point of the outcome is 42.6. Number 2 corresponds to parameter A under level 1 and parameter B, C, D under level 2 and the melting point of the outcome is 42.4. Other groups are in follows.

Table 2. Results of data processing.

Factor	A	B	C	D
K1	190.5	192.6	196.2	195.5
K2	201.7	198.7	192.2	199.0
K3	200.5	185.2	185.6	198.9
K4	177.2	183.2	180.2	190.2
K5	174.0	184.2	189.7	169.3
k1	38.1	38.5	39.2	39.1
k2	40.3	39.7	38.4	39.8
k3	40.1	37.0	37.1	39.8
k4	35.4	36.6	36.0	38.0
k5	34.8	36.8	37.9	33.9
R	5.5	3.1	3.2	5.9

The data of table 2 is processed to obtain the a melting point of 37 using orthogonal methods, shown in table 3. The values of maximum difference represented by R demonstrate the accuracy of the data.

K1: Sum of the melting point under level 1of corresponding factor
K2: Sum of the melting point under level 2 of corresponding factor
K3: Sum of the melting point under level 3 of corresponding factor
K4: Sum of the melting point under level 4 of corresponding factor
K5: Sum of the melting point under level 5 of corresponding factor
k_n: Average value of corresponding K_n (n=1,2,3,4,5)
R: Difference between largest and smallest value of k

A diagram can be obtained from table 3 shown as figure 2. Axis X represents melting point while axis Y represents level. Draw a horizontal line from the point 37 at axis Y. Then points of intersection from the horizontal line and broken line are obtained and their corresponding values of axis X represent the optimum reaction conditions. From the diagram, the mass ratio of oil lies between level 3 and level 4; the reaction temperature lies near level 4; the reaction duration time lies between level 3 and level 4; the dosage of catalyst lies between level 4 and level 5. Therefore,

according to table 1 and linear relations, the optimum reaction conditions are obtained: the mass ration of oil is 3.8:1 (olive oil/corn oil); the reaction temperature is supposed to be 100, the reaction duration time is 60min and the dosage of catalyst is 0.26% (the dosage corresponding to the mass of oil).

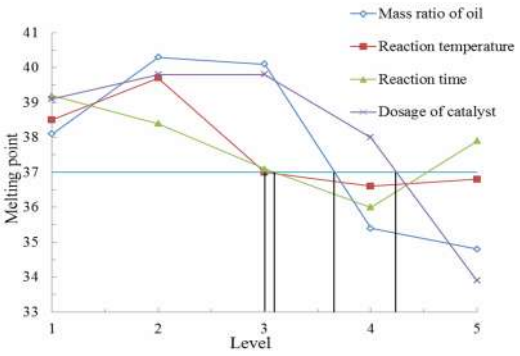


Figure 2. Relations between factors and melting point of oil-base.

Table 3. Test Results.

Factor Number	A	B	C	D	Melting point/℃
1	1	1	1	1	42.6
2	1	2	2	2	42.4
3	1	3	3	3	41.7
4	1	4	4	4	31.2
5	1	5	5	5	32.6
6	2	1	2	3	42.3
7	2	2	3	4	40.5
8	2	3	4	5	34.2
9	2	4	5	1	42.3
10	2	5	1	2	42.4
11	3	1	3	5	34.2
12	3	2	4	1	42.2
13	3	3	5	2	41.5
14	3	4	1	3	42.5
15	3	5	2	4	40.1
16	4	1	4	2	38.3
17	4	2	5	3	38.1
18	4	3	1	4	33.2
19	4	4	2	5	32.8
20	4	5	3	1	34.8
21	5	1	5	4	35.2
22	5	2	1	5	35.5
23	5	3	2	1	34.6
24	5	4	3	2	34.4
25	5	5	4	3	34.3

4. CONCLUSIONS

Using olive oil with the melting point of 47 and liquid corn oil as the material to produce margarine oil-base with a melting potin of 37 through tranesterification reaction, the optimum conditions are: the mass ration of oil is 3.8:1 (olive oil/ corn oil); the reaction temperature is supposed to be 100, the reaction duration time is 60min and the dosage of catalyst is 0.26% (the dosage corresponding to the mass of oil). According to such requirements, the melting point of margarine oil-base obtained is 37, adjust to the temperature of human body. Plus, the oil-base produce no extra trans fatty acids and have high value of unsaturated fatty acids, beneficial for human's health.

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